



Report 1: Summary of findings

Prepared by BRE on behalf of the
Department of Energy and Climate Change

December 2013

BRE report number 289605



Department
of Energy &
Climate Change

bre

The EFUS has been undertaken by BRE on behalf of the Department of Energy and Climate Change (DECC).

Report editors and lead authors: Jack Hulme, Adele Beaumont and Claire Summers.

Project directed by: John Riley and Jack Hulme.

Data manager: Mike Kay.

Supporting authors and analysts: Mike Kay, Busola Siyanbola, Tad Nowak, Peter Iles, Andrew Gemmell, John Hart, John Henderson, Afi Adjei, Lorna Hamilton, Caroline Buchanan, Helen Garrett, Charlotte Turner, Sharon Monahan, Janet Utley, Sara Coward, Vicky Yan & Matt Custard.

Additional thanks to the wider team of reviewers and contributors at BRE, DECC and elsewhere, including GfK NOP Social Research, Gemini Data Loggers, Consumer Futures, G4S, Eon, British Gas, and for the input of the Project Steering Group and Peer Reviewers.

Table of Contents

1	Introduction	1
2	Background to the survey	3
3	Summary of key survey findings.....	4
3.1	Mean household temperatures	4
3.2	Metered energy consumption.....	6
3.3	Main heating systems	7
3.4	Secondary heating systems	10
3.5	Conservatories.....	12
3.6	Thermal comfort and overheating.....	13
3.7	Lighting.....	15
3.8	Domestic appliances, cooking and cooling equipment.....	16
3.9	Household underspend	18
4	Future analysis.....	20

1 Introduction

The main aim of the 2011 Energy Follow-Up Survey (EFUS) was to collect new data on domestic energy use, in order to update the current modelling assumptions about how energy is used in the home, and to inform energy efficiency policy. The 2011 EFUS consisted of a follow-up interview survey of a sub-set of households first visited as part of the 2010/2011 English Housing Survey (EHS). Additionally, sub-samples of these households were selected to have temperature loggers and electricity consumption monitors installed. A further stage of the EFUS was the compilation of gas and electricity consumption data from meter readings.

This report summarises the key findings from the primary analysis of the survey data. The full results of this analysis are contained in an accompanying series of detailed reports. These reports should be considered as the beginning of the process of data analysis, and a mechanism of placing some of the most important findings into the public domain in a timely manner. The survey provides a wealth of data that is suitable for re-analysis for several years in the future. The dataset is being released publicly and it is expected that it will be a rich resource for energy efficiency research for many years to come.

The principal objectives of the analysis to date are to inform energy efficiency policy, and provide data to update the assumptions in the key energy modelling methodologies in use in the UK: the BRE Domestic Energy Model (BREDEM) and its derivative the UK Standard Assessment Procedure (SAP). BREDEM and SAP are widely used to predict the annual energy consumption in dwellings, and housing-related CO₂ emissions.

The BREDEM and SAP development teams at BRE were integrated into the process of survey and experimental design, and subsequent analysis of the data. They acted as key reviewers for all reports, and provided guidance on key outcomes.

A number of key questions of interest to the SAP and BREDEM development teams have been informed by the initial analysis. Among the most important are:

- How many hours are households heating their homes for on weekdays, and at weekends during the winter? How do these heating hours compare to those typically used as inputs into modelling?
- How many rooms are unheated in winter? What rooms are unheated?
- How are secondary heating systems being used?
- What average 24hr temperatures are found in homes? How do these compare to those typically calculated by the models?
- What temperatures are being achieved during periods of heating? How do these compare to those typically used as inputs into the models?
- How are conservatories being used? Are they being heated?
- How much lighting is found in homes, and how is it being used?

- What electrical appliances are found in homes, and how are they being used?
- What can evidence of underspending by households (i.e. spending below that predicted by modelling) tell us about how energy use may change following energy efficiency improvements?

2 Background to the survey

The requirement for the 2011 EFUS was first highlighted by BRE in 2007 and 2008. BRE proposed to members of the Department of Environment and Rural Affairs (DEFRA) that a new and detailed survey was required to reflect changing patterns in home energy use and to update the evidence base underpinning modelling and policy. Developments in technology would also allow for the collection of detailed monitored data on home temperatures and electricity consumption for the first time.

The Energy Follow-Up Survey is so called because it revisits dwellings and households first visited as part of the English Housing Survey (EHS). By revisiting EHS properties, the data from the earlier survey (for example on the household type, or physical characteristics of the dwelling) can be combined with the data from the EFUS. This provides a much richer data source for analysis.

The EFUS consisted of an interview survey and several subsets

- a) Interview Survey (2,616 homes): The EFUS 2011 interview survey was undertaken by interviewers from GfK NOP between December 2010 and April 2011. A total of 2,616 interviews were completed, drawn from a sample of addresses provided from the first three quarters of the 2010/11 English Housing Survey (EHS). These data were then weighted to account for survey non-response and to allow estimates at the national level to be produced.
- b) Temperature monitoring survey (a sub-sample of 823 homes): During the interview survey, householders were invited to take part in a temperature monitoring study. This required the placement of up to three temperature monitors in three rooms of the home, which would record room temperatures every twenty minutes for around one year.
- c) Meter readings (a sub-sample of 1,345 homes): To provide information on how much electricity and gas was actually being used, meter readings were also taken as part of the EFUS, and matched with original readings taken as part of the EHS. These readings provide data on annual gas and electricity consumption.
- d) Electricity profiling (a sub-sample of 79 homes): Finally, a small number of properties had electricity profiling equipment installed to examine patterns of lighting, appliance and electrical cooking use. This equipment collected data at rapid intervals on how much electricity was being used in the home.

The EFUS data have been scaled up to represent the national population (and to correct for non-response) using weighting factors. The results presented in this report are therefore representative of the English housing stock, with a population of 21.9 million households.

3 Summary of key survey findings

The EFUS has provided a wealth of new information about how energy is being used in English homes. A number of key results are of direct relevance to developers of domestic energy models and energy efficiency policy. Detailed results are presented in the full reports which accompany this summary, and which provide comprehensive information on each of the areas of energy use examined. Presented below are summaries of the key findings for modelling and policy from each report, alongside a summary of each report itself.

3.1 Mean household temperatures

Key findings and implications:

A number of questions relating to average internal temperatures (i.e. the average temperatures in a dwelling over a 24hr period) are of importance for the development of energy models. Average internal temperatures are key quantities in calculations of the energy requirement of homes, and it is valuable to compare the averages calculated by the models to the average temperatures observed by the EFUS. Key findings of relevance to energy modelling are:

- § *The difference between the zone 1 (living room) and zone 2 (other areas) mean temperatures typically calculated by these models is larger than the difference observed from the monitoring. The EFUS suggests differences of approximately 0.6°C, whereas the difference calculated for a typical semi-detached house in SAP is approximately 1.3°C in the heating season. The models may need to be recalibrated in light of these findings.*
- § *The difference between weekday/weekend mean temperatures currently calculated in SAP is not observed in the monitored data. This supports the results of analysis of main heating patterns (see section 3.3 below) in which householders reported no change in the number of hours that their heating was on between weekdays and weekends.*

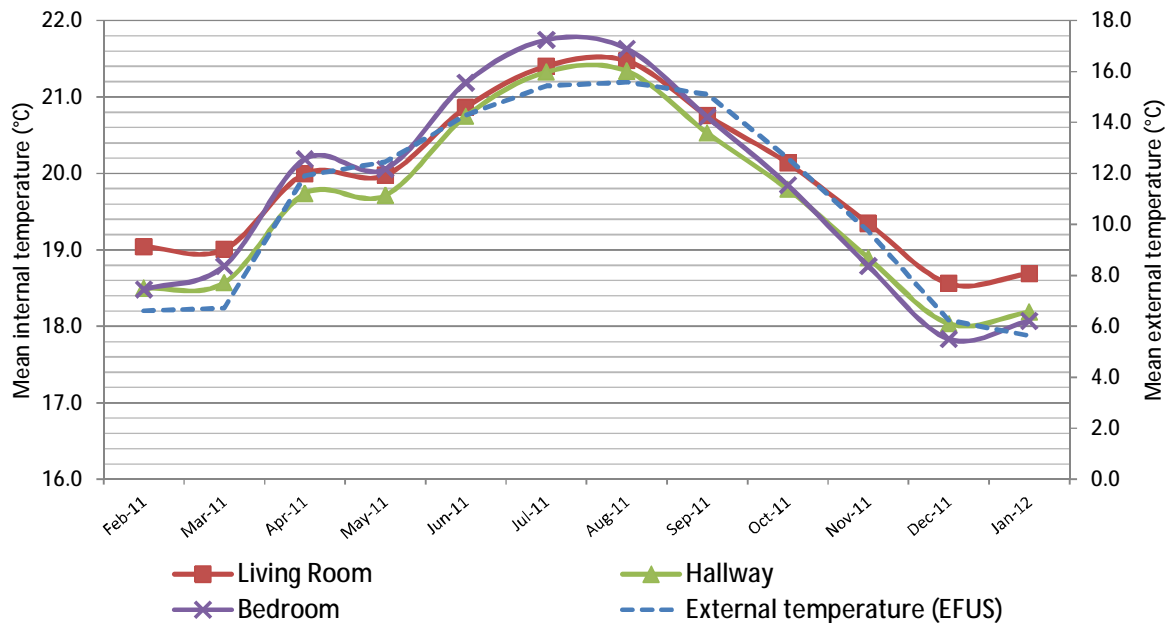
Summary of report

Mean household temperatures have been produced using data collected during February 2011 to January 2012 inclusive. These give a dataset of monthly mean temperatures in the three rooms monitored (living room, main bedroom and hallway). Data from individual rooms have also been combined to produce proxies for the BREDEM zone 2 (mean of the hallway and bedroom) and the whole dwelling (mean of all three rooms).

The mean monthly room temperatures recorded are shown in Figure 1 below. During the heating season (October to April) these are 19.3°C for the living room, 18.8°C for the hallway and 18.9°C for the bedroom, from which heating season mean temperatures of 18.8°C for zone 2 and 19.0°C for the dwelling have been derived. There are no statistically significant differences between weekday and weekend monthly mean temperatures in the living room, bedroom, zone 2 or the dwelling as a whole. The differences between the zone 1 (living room) and zone 2 temperatures are less than those typically calculated through SAP. The EFUS suggests differences of approximately 0.6°C,

whereas the difference calculated for a typical semi-detached house in SAP is approximately 1.3°C in the heating season.

Figure 1: Monthly mean room temperatures (left y-axis) and external temperature (right y-axis) recorded during EFUS 2011



Base: All households in EFUS 2011 temperature sub-sample (n=823)

The variation in average heating season temperatures for different dwelling and household characteristics has also been investigated. Dwellings that are fully double glazed, those with someone in during the day during a weekday, and those in which the occupants are not under-occupying show both living room and zone 2 mean heating season temperatures that are significantly *higher* than their alternative category.

Other significant differences that can be seen include dwellings built pre-1919 having *lower* mean heating season temperatures in both zones than dwellings built between 1945 and 1990; dwellings with a floor area <50m² having *higher* mean heating season temperatures in both zones than the largest dwellings with floor areas >140m²; owner-occupied dwellings having *lower* living room and zone 2 mean heating season temperatures than local authority or RSL dwellings and dwellings in which the Household Reference Person¹ (HRP) is older than 75 years having *higher* living room and zone 2 mean heating season temperatures than dwellings with the HRP aged between 45-64 years.

Some groups of dwellings have significant differences in the mean heating season temperatures in one or other of the zones but not both. For example, flats are seen to have *higher* living room mean heating season temperatures than detached or semi-detached dwellings but no difference is seen between dwelling types for zone 2 mean heating season temperatures.

¹ This is the highest income earner in the household.

For some groups there are no significant (or very small) differences in mean heating season temperatures: these are centrally heated versus non-centrally heated dwellings, dwellings using different fuels for their main heating; cavity insulated walls versus non-insulated walls, households with differing levels of loft insulation, households of differing sizes, households with and without children present, households in all income quintiles and households classified as being in fuel poverty under the Low Income High Costs (LIHC) indicator.

3.2 Metered energy consumption

Key findings and implications:

The collection of metered energy consumption allows SAP and BREDEM modelled results to be compared to actual consumption. This provides the base data (at the stock level) for comparison with SAP and BREDEM, and has been used throughout the reporting alongside other data from the interview and temperature monitoring. An overview of consumption patterns in the stock has also been produced, which includes an annex examining high energy users.

Key findings of relevance to energy modelling and policy from this overview include:

- § The median annual mains gas consumption determined using the EFUS meter reading data is approximately 14,000 kWh, with a median value of approximately 3,700 kWh for electricity.*
- § The analysis provides evidence of links between total gas consumption and floor area, and between electricity consumption and number of occupants and floor area. These results may be able to be used to refine the existing algorithms used in modelling.*
- § There is some evidence of lower median gas consumption in dwellings with insulation installed, although the only statistically significant difference is between the most insulated and least insulated dwellings in the stock.*

Summary of report

Annual consumptions have been produced using gas and electricity meter readings collected as part of the EHS and EFUS. The median annual mains gas consumption determined using the EFUS meter reading data is around 14,000 kWh, with a median value of around 3,700 kWh for electricity².

Significant differences are found in the median consumption levels for different categories of dwelling and household types. Gas use appears closely associated with dwelling floor area and type as well as household size, with detached houses having a median gas consumption more than twice that found in flats. Electricity use appears to be more strongly affected by the number of people in

² The data used to produce these estimates have been adjusted using degree days to represent the core period of meter reading data collection (the period November 2010 to November 2011). They have not, however, been weather corrected to a standardised temperature profile. It should be noted that the core period includes the very cold period in December 2010, which acts to raise consumption of the EFUS data when compared to other estimates which do not include this month.

the household, with the data showing a median consumption of around 2,400 kWh for single people, compared with a figure of around 6,000 kWh where there are at least 5 people in the household.

Households living in dwellings built between 1919 and 1944 show a significantly higher median gas consumption than those from other periods with a median of 17,100 kWh per year. These households also have a higher median electricity consumption than households living in dwellings built between 1965 and 1980.

There is no statistically significant difference in the median gas consumption of households living in rural or urban areas. However, median electricity consumption is significantly higher in households in rural areas compared to urban areas, related to the large number of dwellings without a gas supply in these areas.

There is some evidence of lower median gas consumption with increasing levels of different insulation measures, although the only statistically significant difference can be seen between those households living in 'well insulated' dwellings who have both lower gas and electricity consumption than households living in 'poorly insulated' dwellings. Owner occupiers tend to consume more gas than households in all other tenures and more electricity than households in the private rented or local authority tenures. For both fuels, households in the private rented, local authority and RSL tenures show no significant differences in their median annual consumption rates.

Median gas consumption is lower for households in the lowest income quintile compared to households in all other income quintiles with around 7,500 kWh separating the median gas consumption in the highest and lowest income quintiles. The median electricity consumption increases as income increases; however the difference is only statistically significant between the first income quintile and the top three income quintiles. The trend of higher use of both gas and electricity and higher incomes is what might be expected when considering the larger size of dwelling that might typically be associated with high incomes and the ability to afford higher fuel bills and in fact, similar median values are found for all income groups when the consumption is normalised for floor area.

There are no significant differences in the median consumption values of either gas or electricity between households in which someone is in during the day and households in which no-one is in during the day. There is also no significant difference in the median consumption of either fuel for households in fuel poverty compared to those not in fuel poverty. However, in dwellings where the household is said to be under-occupying, the median gas consumption is significantly *higher* than where they are not under-occupying. This is likely to be because under-occupying households will tend to be found in large dwellings, with correspondingly high heating requirements.

3.3 Main heating systems

Key findings and implications:

Domestic energy use is dominated by energy used by the main heating systems in homes.

Understanding how these systems are used is of great importance to developers of energy models.

This analysis examines the heating patterns of households, and the temperatures achieved when the main heating system is on (as opposed to the 24hr average temperatures described under section 3.1 above), providing new data to act as inputs into energy models. Key findings of relevance to energy modelling and policy are:

- § The 9 hours of heating on weekdays, currently used in SAP, is supported by the analysis of the both the EFUS interview and temperature data for centrally heated dwellings. Non-centrally heated households, however, may be heating for significantly longer than this (10 to 15 hours).*
- § The EFUS interview and temperature data suggest that the total number of hours heating are approximately the same on weekends as they are on weekdays. Currently, SAP implements a heating pattern of 9 hours for weekdays and 16 hours for weekends in the living room for all heating system types. These assumptions may need to be reviewed in light of these results.*
- § The results from EFUS interview and temperature data suggest that main heating is typically used over a 6-7 month period. This is shorter than the 8 month heating season currently used in SAP.*
- § Currently, SAP 2009 implements a demand temperature of 21°C in zone 1 and 18-21°C in zone 2. The results from the EFUS suggest mean achieved temperatures of 20.2°C in zone 1 (living room) and 19.1°C in the zone 2 proxy (mean of hallway and bedroom) – i.e. the zone 1 temperature in SAP is 0.8°C higher than the average living room achieved temperature from the EFUS temperature data. The zone 2 temperatures are within the expected range.*
- § Interesting patterns are seen in the temperatures achieved by different types of households. There is a clear pattern of higher achieved temperatures in older households (approximately 22°C for those aged over 75). Similarly, higher achieved temperatures are seen in dwellings with insulation present (20-21°C) than in those with no insulation (19°C).*
- § The temperature data show that for those households heating twice a day, the first period of heating is typically for a short interval, and the time that the heating is on for in many households may not be sufficient to bring the room temperatures to the thermostat set-point temperature. In general, most models (including SAP and BREDEM) assume that temperatures demanded by households are reached in all periods of heating. The fact that many households are not achieving these temperatures may be resulting in an overestimate of energy consumption by these models.*

Summary of report

The EFUS collected detailed information on the type and use of main heating systems. Data was obtained on the months that heating took place, and the times that heating was used on different days of the week. Table 1 provides a summary of the use patterns of the main heating system reported by households.

Households that are in during the day on weekdays report heating their homes for a longer period of time (median 9.4 hours per day) than households that are not in during the day on weekdays (median 8 hours per day). This difference is lower than the typically assumed standards in many energy modelling applications which attempt to account for household occupancy.

Households report that they heat their homes regularly for a period of 6 to 7 months (the EFUS temperature data suggests a similar length). This is 1-2 months shorter than currently assumed in SAP.

Table 1: Summary of the key findings reported by households with respect to the heating patterns used

Type of main heating system	Regularity of heating	Number of heating periods		Boost heating (asked of households with CH controlled by timer to give regular heating) (12.2m households; n=1399)			Daily heating hours
				Use boost heating at least once per week?	Yes	No	
Centrally Heated 19.7m households (90%)	Regular heating 14.7m households (75%) (n=1715)	0 heating periods	*1% (n=20)	Use boost heating at least once per week?	Yes	7.5m households (61%) n=850	95% C.I. of median daily heating hours 8.4-8.8 (Householder responses) 8.8-9.5 (Temperature data derived)
		1 heating periods	21% (n=395)				
		2 heating periods	69% (n=1158)		No	3.2m households (26%) n=378	
		3+ heating periods	8% (n=142)				
(n=2356)	Non-regular heating 5m households (25%) (n=641)	Heating periods	N/A	Use boost heating?	N/A	N/A	95% C.I. of median daily heating hours
		N/A			N/A	N/A	4.0-5.1 (Householder responses) 9.8-11.3 (Temperature data derived)
Non-Centrally heated 2.2m households (10%)	Regular heating 1.3m households (60%) (n=158)	0 heating periods	*8% (n=15)	Use boost heating?	N/A	N/A	95% C.I. of median daily heating hours 10.7-15.3 (Householder responses) 9.1-16.5 (Temperature data derived)
		1 heating periods	81% (n=128)				
		2 heating periods	*9% (n=14)		N/A	N/A	
		3+ heating periods	*1% (n=1)				
(n=260)	Non-regular heating 0.9m households (40%) (n=102)	Heating periods	N/A	Use boost heating?	N/A	N/A	95% C.I. of median daily heating hours
		N/A			N/A	N/A	2.3-4.6 (Householder responses) 15.6-23.4 (Temperature data derived)

Base: All dwellings in EFUS 2011 Interview Survey representing 21.9 million households in England (n=2616)

Mean achieved temperatures (i.e. those temperatures achieved at the end of the longest period of heating within the dwelling) in the living room (zone 1) fall within the range of 19.7-20.4, with the mean being 20.2°C, and the mean temperature achieved for the (hallway and bedroom) zone 2 within the range of 18.7-19.4, with the mean being 19.1°C. The zone 1 temperature used in SAP is approximately 0.8°C higher than the mean living room achieved temperature derived from the EFUS temperature data. Higher achieved temperatures are observed in the living room in the homes of older households (approximately 22°C in those households with an HRP aged over 75, compared to 20-21°C for those younger than 75) and in dwellings with insulation present (20-21°C for those with at least one insulation measure, compared to 19°C for those with none).

Around 65% of households (14.3 million households) have one or more rooms that are not heated by the main heating system. Conservatories, separate WCs, bedrooms, hallways and kitchens are more likely not to be heated by the main heating system than living rooms, dining rooms, studies and bathrooms. The only significant difference in the likelihood of a certain household characteristic group having one or more rooms not heated by the main heating system is seen for fuel poverty status; households that are calculated to be fuel poor are more likely to have one or more rooms not heated by the main heating system than those households that are not fuel poor.

3.4 Secondary heating systems

Key findings and implications:

Secondary heating systems are those that provide space heating which is in addition to that provided by the main heating. This can be as heating in rooms where the main heating is not present or not used (referred to in this analysis as alternative heating); or as 'top-up' heating in rooms where the main heating is used (referred to in this analysis as supplementary heating). Prior to the EFUS, little was known about the use of these systems. This analysis examines how these systems are used in homes, providing valuable new data in these areas to the SAP and BREDEM development teams for the development of new algorithms relating to these systems. Key findings of relevance to energy modelling and policy are:

- § *Alternative heating (which provides heat instead of the main heating system in one or more rooms) is used by approximately 26% of all households with rooms not heated by the main heating system (17% of all households). These systems are typically electric and commonly found in kitchens, bathrooms, bedrooms and conservatories. On average, these systems are reported as being used for 17.5 hours per week.*
- § *Supplementary heating (which provides heat alongside the main heating system in one or more rooms) is used by approximately 48% of all households. These are likely to be either electric or gas systems, and found in living rooms. On average, these systems are reported as being used for 8 hours per week.*
- § *Currently SAP and BREDEM modelling simply assigns a proportion of total energy use to secondary heating systems. New SAP and BREDEM algorithms could potentially be developed using these data, to more appropriately model the use of different types of heating systems.*

Summary of report

Two types of secondary heating are considered by the analysis:

- a) Alternative heating - defined as heating that is used *instead* of the main heating in a room. This could either be where the main heating is turned off or does not extend into this room.
- b) Supplementary heating - defined as heating that is used in *conjunction* with the main heating in a room.

Approximately 65% of all households have one or more rooms not heated by the main heating system. Of these, 26% (17% of all households) use alternative heating to heat these rooms. Alternative heating is typically used in one room per household, and the predominant type of alternative heater used is electric (74% of households with alternative heating). Households using storage radiators as their main heating are most likely to use an alternative heater.

Close to half of all households (48%) indicate that they have supplementary heating in one or more rooms. Approximately 79% of households using supplementary heating use it in only one room per dwelling, with a further 17% using it in two rooms per dwelling. Of households with supplementary heating, 83% use it in living rooms and 12% in bedrooms. Supplementary heating is rarely used in other room types. Typically supplementary heaters are either electric (46%) or mains gas (41%).

On average, households use alternative heating for 17.5 hours per week (median) during their heating season. Supplementary heating is typically used for a shorter period of 8 hours per week (median).

Almost half (47%) of all households using supplementary heating indicate that they use their heaters *'to provide extra heat when the heating system is on'*, about a quarter (26%) state that it is used *'to provide heat when the heating system is not on'*, 18% say that it is used for both these reasons.

No heating is provided from the main or alternative heating system (including main heating turned off) in one or more rooms in 48% of all households. The majority of these households (60%) report less than a fifth of all rooms in the dwelling are unheated. Typically, circulation spaces, WCs and 'other' rooms (which include rooms such as utilities etc.) are much more likely to be unheated than other types of rooms. Approximately 23% of households with at least one bedroom have one or more bedrooms that are not heated by the main or alternative heating system. The most common responses from households to the question of why they do not heat specific rooms were that the room is warm enough already (41% of households), the room does not have a heater (36% of households) or that the room does not need a heater as the room is not used (33% of households). Only 5.2% of households reported that they do not heat a room due to expense.

3.5 Conservatories

Key findings and implications:

Conservatories are increasingly common additions to homes in England. In general, however, no additional energy losses are assigned to homes with conservatories under standard energy modelling assumptions (as it is presumed that they are thermally separated from the dwelling, and unheated). The EFUS collected data on thermal separation (the presence and use of a door) and heating in conservatories. Key findings of relevance to energy modelling and policy are:

- 91% of conservatories have a separating door, which is typically kept shut in winter (83% of those with doors).
- Around 77% of conservatories have a heating system present. In the winter, approximately 56% of conservatories with heating are heated daily. Conservatories are typically reported to be heated to the same or cooler temperature than the rest of the house.
- These results demonstrate that a significant proportion of conservatories are heated, with potentially important implications for domestic energy modelling methodologies. Under the SAP methodology, a conservatory is currently ignored (i.e. no energy use is assigned) if it is 'thermally separated'. While 91% of conservatories studied by the EFUS have a separating door (and it is likely that most of these may be included in the definition of 'thermally separated'), the EFUS results indicate that the majority of these conservatories will actually be heated. The thermal separation may, therefore, be irrelevant in many cases.
- In light of these results consideration should be given to amending SAP to assign energy usage to conservatories whether or not thermal separation exists. Any changes to SAP should also note that most households report heating the conservatory to the same or a lower temperature than the rest of the dwelling.
- There are further potential implications for Building Regulations. Under current Building Regulations guidance, conservatories are exempt from energy efficiency requirements given certain conditions, one being that the heating system is not extended into the conservatory. This does not cover the case of conservatories in which portable heaters are used, which this report indicates is about half of heated conservatories. Consideration should therefore be given to including conservatories under Building Regulations under other circumstances, perhaps where there are gas or electric points that portable heating may be connected to.

Summary of report:

Conservatories are found in approximately 18% of households in England. Most conservatories (95%) open on to the living room, kitchen or dining room.

Around 77% of conservatories have heating. Just over half of those with heating (55%) are connected to the central heating system, and 42% have storage or direct acting electric heaters. In

winter, 56% of conservatories with heating are heated every day. Most occupants report that they heat the conservatory to the same (45%), or a lower (39%) temperature than the house.

In approximately 91% of dwellings with conservatories there is a separating door. Most households with a conservatory with a separating door (83%) keep it shut in winter. This is mainly to keep heat in the room, and also for security. Of the small proportion (17%) of households who report the door is kept open, it is reported to be mainly for convenience.

In summer 81% of households report that they keep the door to the conservatory open for a period of time. This is reported to be mainly for convenience and to let heat into the adjoining room, and also to make the room feel more spacious.

3.6 Thermal comfort and overheating

Key findings and implications:

The reported ability to keep a home warm in the winter, and cool in the summer was also collected in the EFUS. Households were asked questions relating to their ability to keep warm, designed to provide a broad understanding of these issues from the householders' perspective.

A number of findings with policy implications have been found. These include:

- *6% of households report that they are not able to keep their living room comfortably warm in the winter. Those in fuel poverty, those with low levels of insulation, and low income groups are more likely to report that they could not keep this room warm. Pensioner households are less likely to report problems keeping this room warm.*
- *20% of households report that one or more rooms cannot be kept comfortably cool in the summer. Those living in modern dwellings, those in urban areas, and those in the highest SAP rating bands are among the groups most likely to report a problem keeping one or more rooms cool.*
- *Households that report a problem with overheating have living room and bedroom mean (24hr) temperatures that are significantly higher than households that do not report a problem with overheating. This temperature difference is of the order of 0.5°C to 1.5°C during periods of hot weather.*

Summary of report

The analysis of the data collected during the EFUS household interview and temperature monitoring sub-sample is used to provide an overview of winter and summer comfort levels in England.

The majority of households (94%) report being comfortably warm in their living room during the winter months; however, around 6% of households do not. Although this is a relatively small group within the population, it is of interest to policy makers to analyse the characteristics of this group. Half (54%) of the households who report that they are unable to stay comfortably warm in their

living rooms during the winter do not believe it is possible to 'heat the room to a comfortable standard'(i.e. 3% of all households).

Those households reporting that they are unable to keep comfortably warm in their living room during the winter months do not have statistically significantly different recorded mean living room temperatures throughout the winter period compared to those reporting that they are able to keep comfortably warm.

Bivariate comparisons suggest that households living in detached dwellings are significantly more likely to report that they cannot normally keep warm in winter compared to households living in mid-terraced dwellings. Additionally, households living in flats are significantly more likely to report that they cannot normally keep warm in winter compared to households living in any type of house. Households living in dwellings built post 1990 are less likely to report that they cannot normally keep comfortably warm compared to households living in dwellings built pre-1919 or 1945-1964. Households with non-central heating systems and households using electricity as the main fuel are also significantly more likely to report that they cannot normally keep warm in winter compared to their counterpart groups. Households in dwellings that have un-insulated walls are more likely to report that they cannot normally keep warm in winter compared to households in dwellings with insulated walls and further to this, households in dwellings that are well insulated with three insulation measures are less likely to report that they cannot normally keep warm in winter compared to than households living in dwellings with one insulation measure.

No significant difference in the likelihood of households reporting that they cannot normally keep warm in winter was seen between households living in different regions, nor between those in urban or rural areas, nor for households living in dwellings with differing loft insulation levels, with or without double glazing, or with differing SAP ratings.

Owner occupiers are significantly less likely to report that they cannot keep comfortably warm in their living room during winter compared to any other tenure. Households with at least one pensioner and households who are under-occupying are also significantly less likely to report that they cannot keep comfortably warm in their living room during winter compared to their counterpart groups. Households in which the Household Reference Person (HRP) is older than 55 years are significantly less likely to report that they cannot keep comfortably warm in their living room during winter compared to households with a younger HRP (aged 16-34 and 45-54 years).

Overall, 20% of households report at least one room cannot be kept comfortably cool during a typical summer. Over 40% of the households having difficulty in keeping at least one room cool report that 'insufficient shade' was the main reason for overheating. Just over 39% of these households report that parts of the dwelling are overheating for one to four days per week. For 22% of households, at least one room in their home is reported to be overheating every day in a typical summer. Households reporting problems with overheating show higher mean room temperatures in the summer months, and on the hottest day of the year, than those that do not. This temperature difference is of the order of 0.5°C to 1.5°C during periods of hot weather.

Bivariate comparisons suggest that factors determining whether a household will find it difficult to keep at least one room in their dwelling comfortably cool in summer are likely to be

- the dwelling characteristics of
 - dwelling type (those in bungalows are less likely than other dwelling types to report problems with overheating) and dwelling age (those in pre-1919 properties are less likely to report overheating problems than those in post-1990 properties),
 - whether the dwelling is in a rural or urban location (households in urban locations are more likely to report overheating problems),
 - region (those in London are more likely to report overheating than those in the North East, or in the South West) and
 - SAP rating (those with a SAP rating > 70 are more likely to report problems with overheating than those in dwellings with a SAP <70) ,
- along with the household characteristics of
 - tenure (RSL tenures are more likely to report problems with overheating),
 - whether children are present (households containing children are more likely to report problems with overheating),
 - household size (larger households are more likely to report problems with overheating) and
 - under-occupancy status (under-occupying households are more likely to report problems with overheating).

3.7 Lighting

Key findings and implications:

The EFUS interview contained questions on the type and use of lighting in the kitchen, living room and bedroom. These data can be used by the SAP and BREDEM teams for the development and refinement of algorithms for lighting energy use. Key findings from the analysis of lighting data of relevance to energy modelling and policy are:

- *The living room and kitchen typically contain more lightbulbs (a median of 5 and 4 respectively) than the bedroom (a median of 2).*
- *In the living room and main bedroom approximately 40% of light bulbs are tungsten and 30% low energy compact fluorescents (CFLs). In the kitchen however, halogen bulbs (50%) and fluorescent strip lighting (15%) are the dominant type of lighting.*
- *Lighting is reported to be used for about 2 to 3 times as long in winter as summer (5-8 hours per day in the winter compared to 2-3 hours per day in the summer).*
- *Lights are reported to be left on overnight in approximately 17% of households.*

- *Approximately 62% of households reported using outside lights (powered by the main electricity supply).*

Summary of report

Information was collected in the EFUS 2011 Interview Survey about the number of sets of lights, the number of bulbs per set, the types of bulbs in each set and the length of time each set is used, in three of the main rooms of the house (living room, main bedroom and kitchen), as well as lights left on overnight and outside lights powered from the household electricity supply.

In the living room and main bedroom approximately 40% of light bulbs are tungsten (traditional light bulbs – not of a low-energy type), and 30% low energy compact fluorescents (CFLs). In the kitchen however, halogen bulbs (50%) and fluorescent strip lighting (15%) are the dominant type of lighting. Lighting is reported to be used for about 2 to 3 times as long in winter as summer (5-8 hours per day in the winter compared to 2-3 hours per day in the summer).

Lights are reported to be left on in one or more rooms overnight by 17% of households. Of these households, 92% leave a light on in just one room and a further 7% in two rooms. These rooms are typically the hallway/landing, bathroom with a WC or the second bedroom. For the households that leave lights on in either of the hall/landings overnight, just under 60% of them use low energy CFLs. This may reflect the fact that households value the energy savings these bulbs provide for this type of usage. However, just over 20% of households leaving lights on in hallways overnight use tungsten bulbs.

Approximately 62% of households have outside lights powered by their mains electricity supply. Of these, almost half (47%) have one bulb and a further 37% have two or three bulbs. The most commonly-used type of bulb in outside lights was described as tungsten. This may indicate a preference for instant, brighter light for this purpose. Manual switching is the most usual form of control with more than 60% of lights being switched manually.

3.8 Domestic appliances, cooking and cooling equipment

Key findings and implications:

The EFUS examined the use and type of a number of key kitchen appliances, cooking equipment, televisions and cooling equipment. These data can be used by the SAP and BREDEM teams for the development and refinement of algorithms for appliance energy use. A number of policy implications are also apparent. Key findings from the analysis of the appliance data of relevance to energy modelling and policy are:

- *Some appliances are almost universally owned. These include washing machines, fridges, freezers, ovens and hobs.*
- *The average (median) number of washing loads per week is 4, and drying loads is 3 in the winter.*

- *Electricity is the dominant fuel used for ovens, whereas gas is the dominant fuel used for hobs.*
- *The average(median) number of televisions owned is 2, with the most used television reported to be used for around 5-6 hours per day.*
- *Air conditioning units are very rare (used by <3% of households), but approximately 43% of households use portable fans to keep their homes cool.*
- *Considerable scope has been identified for the replacement of older appliances in the stock which may represent a significant potential for energy saving. In particular, the survey suggests that there are over 2 million each of washing machines, tumble dryers, standalone fridges and standalone freezers that are over 10 years old.*

Summary of report

The EFUS 2011 has revealed detailed information on patterns of ownership and use of key domestic appliances, including cooking and cooling equipment, which is of use for the development of energy efficiency policy and refinement of energy modelling methodologies such as SAP and BREDEM.

Almost all households own a washing machine (97%), a fridge (99%), a freezer (93%), a television (98%), an oven (95%) and a hob (93%). Other appliances are less universally owned. Almost 80% of households own a grill, 80% a microwave, 62% a tumble dryer, and 41% a dishwasher. The EFUS has identified differences in patterns of ownership and use among different household groups. Owner occupiers are more likely to own washing machines and tumble dryers compared to the other tenures. Single person households, households without any children, households in which the HRP is 75 years old or more, households in which none of the occupants is working, households with incomes in the lowest income quintile and households that are not under-occupying are all *less likely* than their counterpart groups to own a washing machine or tumble dryer. There are no apparent differences in fridge ownership across the different household groups suggesting that this appliance is considered a necessity. Freezer ownership and dishwasher ownership across the different household groups is more variable with similar differences in the patterns of ownership as those seen for the laundry appliances. There is a particularly strong relationship between dishwasher ownership and income.

The median number of washing loads per week is 4 and the median number of drying loads per week is 3 in the winter. Approximately 59% of households report typically running their washing machine at 40°C; 27% report typically washing at 30°C, and 8% report typically using temperatures hotter than 40°C. As to be expected, there is a pattern of more frequent washing machine use among large households, particularly those with children. The median number of loads per week also increases as household income increases. However, households with at least one pensioner present, and households that are considered to be under-occupying, use their washing machines less than their counterpart groups.

Electricity is the dominant fuel used in ovens (almost 70% of households with ovens have electric ovens and just under 30% have gas ovens). For hobs, the prevalence of fuels is reversed with gas

being the dominant fuel (38% of households have electric hobs, whereas 61% have gas hobs). Households use their hobs and microwaves more frequently than their ovens or grills.

The number of televisions in homes ranged from 0 to 9, with a mean number of 2.3 televisions per household. Owner occupiers typically have more televisions than any of the other tenures. Additionally, the mean number of televisions in a household increases as household size increases. Households in the lowest income quintiles have fewer televisions on average than households in any of the four high income quintiles. Households with children present, and households where no pensioners are present, also report owning more televisions compared to their counterpart groups.

The main (most used) television in the home is likely to be a flat screen type. Owner occupied households are *more likely* to have a flat screen television than a standard CRT type as the most used television compared to households in the social rented sector, whereas households in the lowest income quintile are *less likely* to have a flat screen model as the television used the most compared to households with higher incomes. Additionally, single person households are *also less likely* to have a flat screen television as the most used television compared to larger households.

The television used most often in the house is reported to be used for approximately 5 to 6 hours per day. The average number of hours is greater for households that are in the social rented sector compared to owner occupiers or private renters, and higher for households with children, containing someone of pensionable age, where someone is in during the day and households that are not under-occupying.

43% of all households report using portable fans. Other fixed fans are reported to be in use by around 9% of households. Air conditioning use is very rare with less than 3% of households using fixed or portable air conditioning units during the summer months. Around 17% of households use portable fans on a daily basis during the summer months. Just under 40% of households with portable fans use them more than once per week but not every day, and a further 39% of households use them less than once a week.

Considerable scope has been identified for the replacement of older appliances in the stock which may represent a significant potential for energy saving. The survey suggests that over 2.1 million washing machines, and 2.6 million tumble dryers, are more than 10 years old. A large number of refrigeration appliances are more than 10 years old, including around 24% of standalone fridges and 24% of standalone freezers (equivalent to around 2.5 million of each of these types of appliance). Approximately 22% of ovens are over 10 years old (equivalent to around 4.5 million ovens).

3.9 Household Underspend

Key findings and implications:

Households are said to be “underspending” when their actual fuel expenditure is below their notional fuel expenditure requirement, which is calculated using the methodology used for fuel poverty statistics. The EFUS examined the level of household underspend under this definition (although it should be noted that the EFUS analysis presented in these reports may in itself challenge many of the

underlying assumptions in this methodology). A number of findings with policy implications were found:

- *Approximately 67% of households are underspending when compared to the fuel poverty methodology to some degree. Fuel poor households are more likely to be underspending than non-fuel poor households.*
- *Households that are underspending also have lower average and achieved temperatures, than those that are not.*
- *The level of underspend decreases as energy efficiency increases (i.e. at higher levels of energy efficiency households will, on average, meet or exceed the modelled requirement).*
- *The relationship between energy efficiency and underspend may have significant policy implications. In particular, it highlights that improvements made to poorly performing properties may simply reduce the level of underspend, rather than deliver reductions in consumption.*

Summary of report

The methodology used to produce estimates of fuel poverty in England defines a regime which is considered sufficient to provide adequate energy for heating and other uses in the home. This includes energy for heating, lighting, appliance use and cooking. A household is said to be underspending when its actual fuel expenditure is below that predicted by this theoretical regime.

Approximately 67% of all households are underspending to some degree. Around 35% of all households are underspending by more than 25% of the required fuel bill, and approximately 8% of all households are underspending by more than 50% of the required fuel bill.

Households that are underspending have lower mean internal temperatures, and lower achieved temperatures, than those that are not. Households exhibiting the highest levels of underspend also report heating for fewer hours per day than households that are not underspending.

Fuel poor households (using the Low Income High Costs definition) are more likely to be underspending than non-fuel poor households. Around 80% of those in fuel poverty are underspending, compared to 65% of households not in fuel poverty underspending.

There is no clear relationship between underspending and income. High income households are as likely to be underspending as low income households. Similarly, the likelihood of underspend is not directly influenced by other household factors including household type, age of household or employment status. However, a clear relationship exists with the energy efficiency of the property as defined by the SAP rating. Those households living in higher energy efficiency properties are less likely to be underspending than those in lower energy efficiency properties. Approximately 90% of those living in the least energy efficient properties (below a SAP rating of 30) are underspending (relative to the modelled requirement for those dwellings), compared to 47% underspending in the most energy efficient properties (SAP >70).

This relationship with energy efficiency is reflected in the fact that households in older properties are more likely to underspend, as are those without gas central heating systems, and in poorly insulated properties. This may have significant policy implications as improvements made to poorly performing properties may simply reduce the level of underspend, rather than deliver reductions in consumption.

4 Future analysis

These reports should be considered the beginning of the process of data analysis, and a mechanism of placing some of the most important findings into the public domain. This reporting is, however, necessarily limited by the desire to report on findings in a timely manner. Further analysis is expected in the future, using the publicly available data, by researchers from across the research community which will add greatly to these initial findings.

The EFUS has provided a wealth of new data on energy use in English households. The results from the survey provide essential new information to assist in the development of energy efficiency policies, and to enhance the energy models which underpin them.