Report 7: Thermal comfort & overheating

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

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Executive Summary

The main aim of the 2011 Energy Follow-Up-Survey (EFUS) is to collect new data on patterns of household and dwelling energy use. This data is valuable for a number of policy reasons, including updating the evidence base underpinning current household modelling assumptions, e.g. as used in the UK Standard Assessment Procedure (SAP) and the BRE Domestic Energy Model (BREDEM). This report presents analysis of the data collected as part of the household interview thermal comfort and overheating. It presents the results as reported by the householder together with the information obtained from the monitored household temperatures data collected as part of the EFUS 2011. Analysis is based on the interview sample and temperature logger sub-sample, both weighted to the national level using their specific weighting factors. The results presented in this report are therefore representative of the English housing stock, with a population of 21.9 million households.

The main findings of the analysis are:

Thermal Comfort

- The majority of households (94%) report being comfortably warm in their living room during the winter months.
- 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).
- Bivariate comparisons suggest that factors determining whether a household will feel comfortably warm in their living room during the winter months are likely to be the dwelling characteristics of dwelling type and age, heating system type and fuel, and insulation levels along with the household characteristics of tenure, age of occupant, household income, under-occupancy status and fuel poverty status.
- 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 room temperatures throughout the winter period compared to those reporting that they are able to keep comfortably warm.

Overheating

- Overall, 20% of households report at least one room is overheating during the summer months.
- Over 40% of the households having difficulty in keeping at least one room cool report that 'insufficient shade' is 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 overheating every day during the summer months (June to August).

- 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 and age, whether the dwelling is in a rural or urban location, SAP rating, region, along with the household characteristics of tenure, whether children are present, household size and under-occupancy status.
- 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.
- There is some correlation between the temperature thresholds and definitions used in the SAP overheating algorithm and reported problems with overheating.

Table of Contents

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. Analysis is based on the interview sample weighted to the national level, using a weighting factor specific to the interview sample. The results presented in this report are therefore representative of the English housing stock, with a population of 21.9 million households.

In this 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. It is anticipated that these results will be used to inform energy efficiency policy and to inform and update the assumptions used in the BRE Domestic Energy Model (BREDEM) and the UK Standard Assessment Procedure (SAP) as required. These methodologies are extensively used to predict annual energy consumption in dwellings. CO_2 emissions can be deduced directly from energy use, and the prediction of housing-related CO_2 emissions through to 2050 will continue to rely heavily on the SAP and BREDEM methodologies. BREDEM and SAP model the energy consumption associated with the use of air-conditioning. SAP also has an overheating calculation based on the region, orientation, overshading, the thermal mass of the building ventilation type and window area plus occupant determined factors such as the presence of blinds, curtains or shutters.

The SAP/BREDEM development teams are particularly interested in the following questions relevant to thermal comfort:

- What temperatures are those reporting under-heating achieving?
- What proportion of households experience overheating?
- What temperatures are those that are reporting overheating experiencing?

Households were asked specific questions relating to under-heating and overheating in the EFUS survey. The questions provided a broad understanding of these issues from the householders' perspective. It should be remembered that 'thermal comfort' is a relative concept – householders were asked to report on whether they were 'comfortably warm' or 'comfortably cool', their perception of which is a very personal experience.

This report presents the results of the interview survey component of the EFUS 2011, alongside the results from the temperature monitoring. The results from the interview survey are those that are reported by the householders, whereas the temperature survey results are from directly monitored data.

A key component of this analysis process has been the linkage of the EFUS data to key dwelling and household descriptor variables collected in the interview and physical survey components of the 2010 English Housing Survey (EHS). In this report, and the majority of the companion reports in this EFUS series, simple bivariate comparisons between the variable under consideration and individual descriptor variables have been performed in order to provide preliminary results and identify bivariate trends. It should be recognised, however, that subsequent investigations using more sophisticated statistical analysis may assist in the interpretation of results.

2 Methodology

A summary of the methodology of particular relevance to this report is provided below. Additional details, including the full interview questionnaire, can be found in the EFUS 2011 Methodology report.

The results presented in this report have been produced using data collected from the 'Overheating and Cooling' section of the EFUS Interview survey[1] and using data collected from temperature loggers installed in a sub-sample of 823 households drawn from the original 2616 households in which an interview survey was completed.

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). When weighted, this resulted in a population of 21.9 million households.

In the interview survey, all householders were first asked whether, during a typical winter (December to February), they were *normally* able to keep comfortably warm in their living room. Those households reporting that their living room was not 'comfortably warm' were asked to provide a reason for this, from the following list of categories:

- It costs too much to keep your heating on.
- It is not possible to heat the room to a comfortable standard.
- Both of the above.
- Neither.

The remainder of the questions were related to overheating and cooling in summer. Households were asked if they experienced difficulty keeping particular rooms (main living room, main bedroom, and other bedrooms) in their dwelling cool between June and August in a typical summer. Householders also had an opportunity to specify if there were other rooms in the dwelling that were overheating. Those experiencing difficulty in more than one room were asked to provide reasons for this from a set of responses. Again, there was an opportunity to provide an alternative response; these verbatim responses were coded and are provided below. They were also asked about the frequency of overheating in the particular room(s).

Of the 2,616 households interviewed, 943 households also received temperature loggers of which 823 sets were adequate for analysis. Up to three temperature loggers were placed in the bedroom, hallway and living room of these households. Further details of the temperature logger installation and retrieval process, the survey methodology (including the questionnaire) can be found in the EFUS 2011 Methodology report and EFUS 2011 Mean Household Temperatures report.

[1] See the EFUS 2011 Methodology Report. The results in this report relate to responses given to questions q77 through to q81. Analysis of questions q82 and q83 regarding the use of electrical cooling equipment is presented in the EFUS 2011 Domestic Appliances, Cooking and Cooling Equipment report.

2.1 Data quality

The raw outputs from the interview survey were generally complete and considered good quality. The confidence intervals around the statistics derived from the EFUS Interview Survey have been calculated using a design factor of 1.1. The confidence intervals around the statistics derived from the EFUS Temperature logger sub-sample have been calculated using a design factor of 1.2. Please refer to the EFUS 2011 Methodology report for further details.

For all outputs, results which are based on an un-weighted sample size of fewer than 30 have been highlighted with an asterisk (*) and should be treated as insufficiently robust for further analysis or reporting.

2.2 Weighting factors

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. See the EFUS 2011 Methodology report for further details of the weighting process.

3 Findings

3.1 Winter comfort

3.1.1 Ability to keep comfortably warm

The majority of households (94%) report that they are comfortably warm in their living room during the winter months (December to February) (Table 1). However, 6% of households (representing over 1.3 million households) do not share this experience.

Table 1: Ability to keep comfortably warm in living room during the winter

[q77] During a typical winter (December to February), can you normally keep comfortably warm in your living room?	*Sample size*	Number of households (000s)	Percentage of households (%)	95% C.I. (%)
Yes	*2,436*	20,461	93.5	(92.4,94.5)
No	*174*	1,370	6.3	(5.2,7.3)
Don't know	*6*	*61	*0.3	(0.1,0.5)
Total	*2,616*	21,893	100.0	(100,100)

Base: All households in the EFUS interview sample (n=2616).

**Sample responses are very small and subject to large sampling errors*

Over half (54%) of the group who were not comfortably warm (approximately 750,000 households), give the reason for this as 'because it is not possible to heat the room to a comfortable standard' (Table 2). Approximately 28% of households who reported they were unable to keep comfortably warm (400,000 households), give 'cost' as the sole reason.

Table 2: Reasons for not being warm in the living room

[q78] (If 'no' to q77) Is this because…..	*Sample size*	Number of households (000s)	Percentage of households (%)
It costs too much to keep your heating on	*48*	389	28.4
Because it is not possible to heat the room to a comfortable standard	*92*	742	54.2
Both of the above	*23*	*135	*9.9
Neither	*11*	*103	*7.5
Total	*174*	1,370	100.0

Base: All households in the EFUS interview sample who report no being comfortably warm in the living room (n=174).

**Sample responses are very small and subject to large sampling errors*

Analysis using the English Housing Survey (EHS) identifies differences in the dwelling and household characteristics of those able to keep comfortably warm in the living room and those experiencing difficulty. Table 3 shows the proportions across the different categories in various dwelling type groups in which the householders respond that they cannot keep comfortably warm in their living room in the winter. The 95% confidence intervals of the percentages show the significance of the differences across categories. Detailed descriptions of the variables used or derived from the EHS and EFUS data can be found in the Glossary.

Table 3: Percentage of various dwelling type groups responding 'No' to question 'During a typical winter (December to February), can you normally keep comfortably warm in your living room?

Dwelling characteristic	Characteristic category	Sample size of group	% of group that response is 'No' to question	95% C.I.
Dwelling type	End terrace	274	5	(2.5, 8.4)
	Mid terrace	476	7	(4.5, 9.6)
	Semi detached	715	5	(3.4, 7)
	Detached	419	2	(0.7, 3.7)
	Bungalow	243	5	(2.2, 8.4)
	Flat	483	12	(8.6, 14.9)
House or flat	house or bungalow	2127	5	(4, 6.1)
	flat	483	12	(8.6, 14.9)
Age of dwelling	Pre 1919	487	8	(5.6, 11)
	1919-1944	422	4	(2.3, 6.7)
	1945-1964	600	8	(5.3, 10)
	1965-1974	402	6	(3.4, 8.4)
	1975-1980	183	6	(2.1, 9.6)
	1981-1990	219	7	(3.1, 10.4)
	Post 1990	297	3	(0.9, 5.1)
Useable floor area	< 50 m^2	311	11	(7.2, 14.8)
	50 to 69 m^2	652	9	(6.5, 11.4)
	70 to 89 m^2	744	5	(3.4, 6.9)
	90 to 109 m^2	342	7	(3.8, 9.6)
	110 to 139 m^2	261	2	(0.3, 4.4)
	≤140 m^2	300	2	(0.5, 4.4)
Region - EHS order	North East	168	5	(1.2, 8.4)
	North West	419	9	(6.3, 12.5)
	Yorkshire and the Humber	342	6	(2.9, 8.2)
	East Midlands	216	4	(1.3, 7.2)
	West Midlands	236	7	(3.3, 10.4)
	East	308	5	(2.3, 7.6)
	London	268	8	(4.2, 11.2)
	South East	374	6	(3, 8.2)
Is dwelling in an urban or rural location?	Urban	2351	7	(5.5, 7.7)
	Rural	259	3	(1, 5.9)
Central Heating or Non-CH system in dwelling	Central Heating system	2351	6	(4.6, 6.6)
	Non-Central Heating system	259	12	(8, 16.9)
Main fuel (3 categories)	Mains gas	2168	6	(4.6, 6.8)
	Electricity	246	13	(8.4, 17.7)
	Other (bottled/bulk gas,solid,oil,community scheme	196	4	(0.9, 6.9)
Are the walls of the dwelling insulated?	Insulated	1121	4	(3.1, 5.8)
	Not insulated	1489	7	(6, 8.9)
Is loft is well insulated (200+mm)	<50mm	177	8	(3.5, 12.2)
	50-149mm	1035	6	(4.3, 7.4)
	150+ mm	1082	5	(3.3, 6.1)
Is dwelling fully double glazed?	Yes	1999	6	(4.6, 6.9)
	No	611	8	(5.4, 10.1)

How many insulation measures does the dwelling have?	All 3 insulation measures	397	3	(1, 4.5)
	2 insulation measures	749	4	(2.7, 5.9)
	1 insulation measure	831	7	(5.3, 9.2)
	No insulation measures	317	6	(3.3, 9.1)
Energy efficiency (SAP09) rating	less than 30	83	6	(0.6, 12.2)
	30 to 50	595	7	(4.7, 9.2)
	51 to 70	1688	6	(5, 7.5)
	more than 70	244	4	(1.6, 7.3)

Base: All households in the EFUS interview sample (n=2616), excluding 6 cases for "don't know".

It can be seen that households living in detached dwellings are significantly less 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.

Table 4 shows the proportions across the different categories in various household type groups in which the householders respond that they cannot keep comfortably warm in their living room in the winter.

Table 4: Percentage of various household type groups responding 'No' to question 'During a typical winter (December to February), can you normally keep comfortably warm in your living room?'

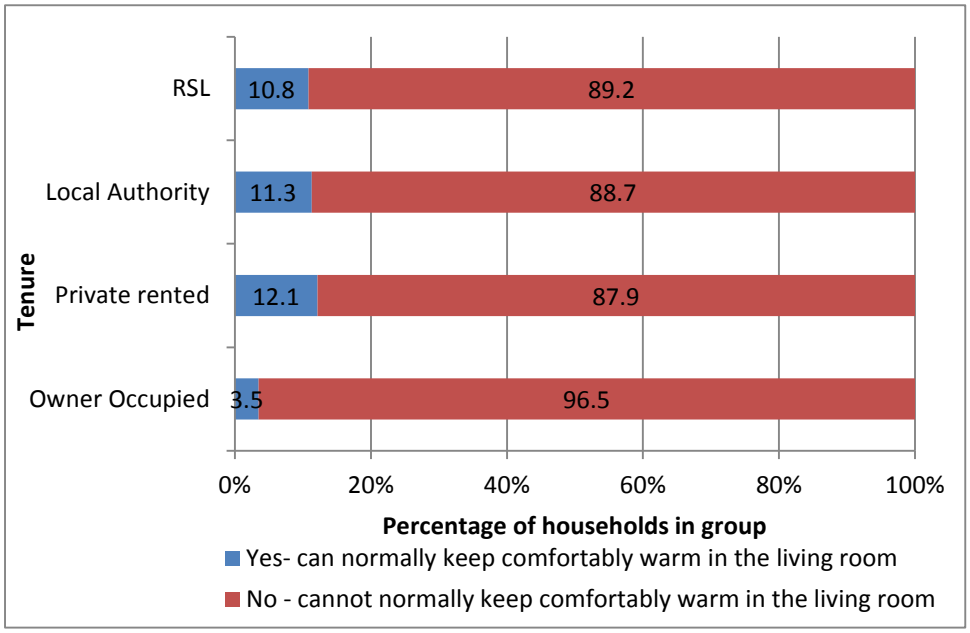
Household characteristic	**Characteristic category**	Sample size of group	% of group that response is 'No' to question	95% C.I.
Tenure	Owner Occupied	1484	3	(2.5, 4.5)
	Private rented	384	12	(8.5, 15.7)
	Local Authority	405	11	(7.9, 14.7)
	RSL	337	11	(7.2, 14.5)
Household size	1	731	7	(4.6, 8.6)
	2	905	5	(3.7, 7)
	3	424	9	(5.8, 11.7)
	4	365	5	(2.7, 7.8)
	5 or more	185	6	(2.2, 9.7)
Pensioner Present	At least one person of pensionable age	939	3	(1.5, 3.8)
	No persons of pensionable age	1671	8	(6.7, 9.6)

Children Present?	At least one child	806	7	(5, 8.8)
	No children	1804	6	(4.8, 7.2)
Age of HRP	16 - 34	394	11	(7.2, 13.9)
	35 - 44	477	7	(4.5, 9.5)
	45 - 54	523	9	(6.2, 11.6)
	55 - 64	493	3	(1.6, 5)
	65 - 74	425	3	(1.5, 5.2)
	75 or more	298	3	(0.7, 4.9)
Employment status of HRP and partner combined	1 or more work full time	1265	6	(4.3, 7.2)
	1 or more work part time	229	5	(2, 8.2)
	none working, one or more retired	771	3	(1.6, 4.2)
	none working and none retired	345	18	(13.7, 22.6)
Annual gross income of the HRP and partner weighted quintiles	1st quintile (lowest)	608	11	(8.2, 13.6)
	2nd quintile	577	8	(5.4, 10.2)
	3rd quintile	499	5	(3.3, 7.7)
	4th quintile	470	4	(2.3, 6.3)
	5th quintile (highest)	456	3	(1.3, 4.7)
Is anyone in the household at home during the day on a weekday?	No	1012	7	(4.9, 8.2)
	Yes	1598	6	(4.8, 7.4)
Underoccupying?	Not under-occupying	1800	8	(6.3, 9)
	Under-occupying	810	4	(2.1, 4.9)
Fuel Poverty Low Income High Cost indicator (LIHC)	Not in fuel poverty - LIHC	2345	5	(4.5, 6.5)
	In fuel poverty - LIHC	265	13	(8.9, 18)

Base: All households in the EFUS interview sample (n=2616) excluding 6 cases for “don’t know”.

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 (Figure 1). 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). The finding that households with older occupants report that that they are more likely to feel comfortably warm than households with younger occupants correlates with the higher mean household temperatures reported for older households in the EFUS 2011 Mean Household Temperatures and the higher mean achieved temperatures for older households reported in the EFUS Main Heating Systems report. A multivariate analysis may help provide an explanation for these higher temperatures as to whether it is down to higher thermostat settings or the use of secondary heat sources. It is also interesting to note that results presented in the EFUS Secondary Heating Systems report show that households with a pensioner present are more likely to use supplementary heating than households without a pensioner.

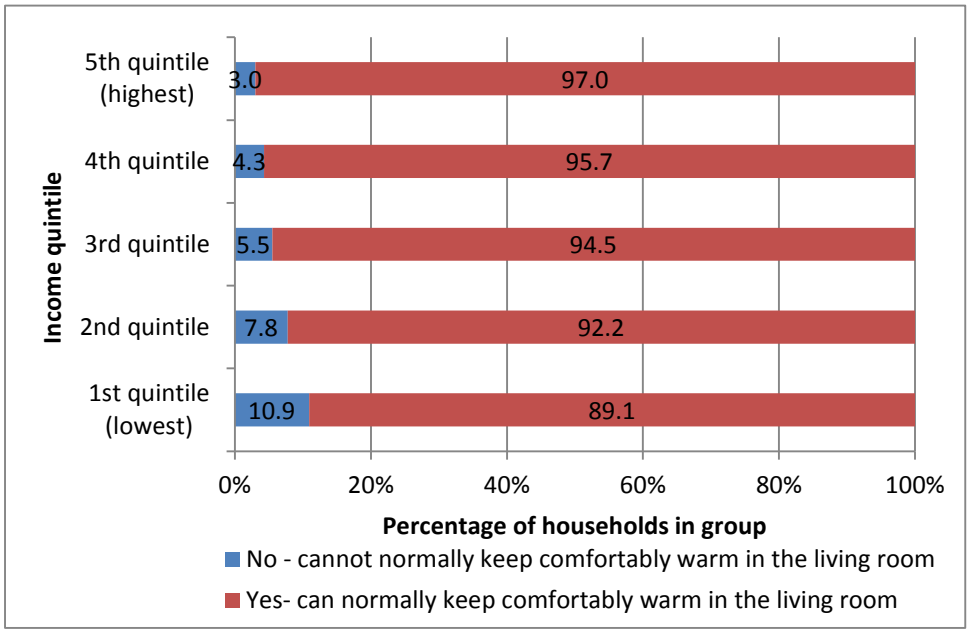
Figure 1: Percentage of tenure group reporting ability to keep comfortably warm in the living room in winter



Base: All households in the EFUS interview sample (n=2616).

The EFUS data confirms that affordability is likely to be a factor in whether a household feels that they can heat their living room to a comfortable standard. Households with incomes in the top two deciles of incomes are significantly less likely to report that they cannot keep comfortably warm in their living room during winter compared to households with incomes in the lowest quintile (Figure 2).

Figure 2: Percentage of income quintile group reporting ability to keep comfortably warm in the living room in winter



Base: All households in the EFUS interview sample (n=2616).

Households that are calculated to be in fuel poverty are significantly more likely to report that they cannot keep comfortably warm in their living room during winter compared to households not in fuel poverty, as are households in which the occupants are neither working nor retired (i.e. likely to be unemployed or long-term sick/disabled).

No significant difference in the likelihood of households reporting that they cannot normally keep warm in winter was seen between households of differing household size or between households with or without children present.

3.1.2 Mean living room temperatures in households reporting an inability to keep warm

Table 5 shows the mean living room temperatures in January 2012, February 2011 and December 2011, for those households that report that they are unable to keep their living room comfortably warm and those that report that they can keep it comfortably warm. There is no significant difference (at the 95% confidence level) in the temperatures for either group, nor in the temperatures across the different months within each group.

Table 5: Mean living room temperatures in January, February and December

During the cold winter weather, can you normally keep comfortably warm in your living room?	Sample size	Mean temperature in living room in January 2012 (°C)		Mean temperature in living room in February 2011 (°C)		Mean temperature in living room in December 2011 (°C)	
		Mean	95% C.I.	Mean	95% C.I.	Mean	95% C.I.
Yes	773	18.7	(18.4, 18.8)	19.0	(18.8, 19.2)	18.5	(18.3, 18.7)
No	48	18.5	(17.5, 19.4)	18.4	(17.3, 19.4)	18.5	(17.5, 19.4)

Base: All households in EFUS temperature sub-sample (n=823) excluding 2 cases reporting 'unknown' for q77.

3.2 Summer comfort

3.2.1 Overheating areas of the dwelling

SAP calculations consider the impact of overheating by assessing a number of factors including the region, orientation and overshading, the thermal mass of the building, and occupant determined factors such as blinds, curtains or shutters, ventilation type and window area. During the interview, householders were asked about overheating in three rooms; the main living room, the main bedroom and other bedrooms. They also had the opportunity to provide information about other rooms in the house that were considered too hot.

Table 6 shows the household responses to the question of whether, during a typical summer (June to August), they find it difficult to keep any of the mentioned rooms comfortably cool. The majority of households (80%) do not report any difficulty keeping rooms cool during the summer, however, some 20% of households reported that at least 1 room in their dwelling was too hot during the summer months. There were 9% of households who reported finding it difficult to keep the main living room comfortably cool and 11% of households experience this difficulty with the main bedroom. A slightly smaller proportion of households (8%) find it difficult to keep other bedrooms comfortably cool. 'Other' rooms are also reported to be too hot by 4% of households and these rooms were predominantly specified as conservatories, kitchens and bathrooms.

Table 6: Difficulty in keeping rooms cool during a typical summer

During a typical summer (June to August), do you find it difficult to keep any of these rooms comfortably cool?		*Sample size*	Number of households (000s)	Percentage of households (%)	95% C.I. (%)
Main living room	No	2376	19,987	91.3	(90.1,92.5)
	Yes	240	1,907	8.7	(7.5,9.9)
Main bedroom	No	2321	19,500	89.1	(87.7,90.4)
	Yes	295	2,394	10.9	(9.6,12.3)
Other bedrooms	No	2412	20,194	92.2	(91.1,93.4)
	Yes	204	1,700	7.8	(6.6,8.9)
Other rooms (mainly conservatories, bathrooms and kitchens)	No	2524	21,132	96.5	(95.7,97.3)
	Yes	92	762	3.5	(2.7,4.3)
None of the above	No	539	4,456	20.4	(18.7,22)
	Yes	2077	17,438	79.6	(78.0,81.3)

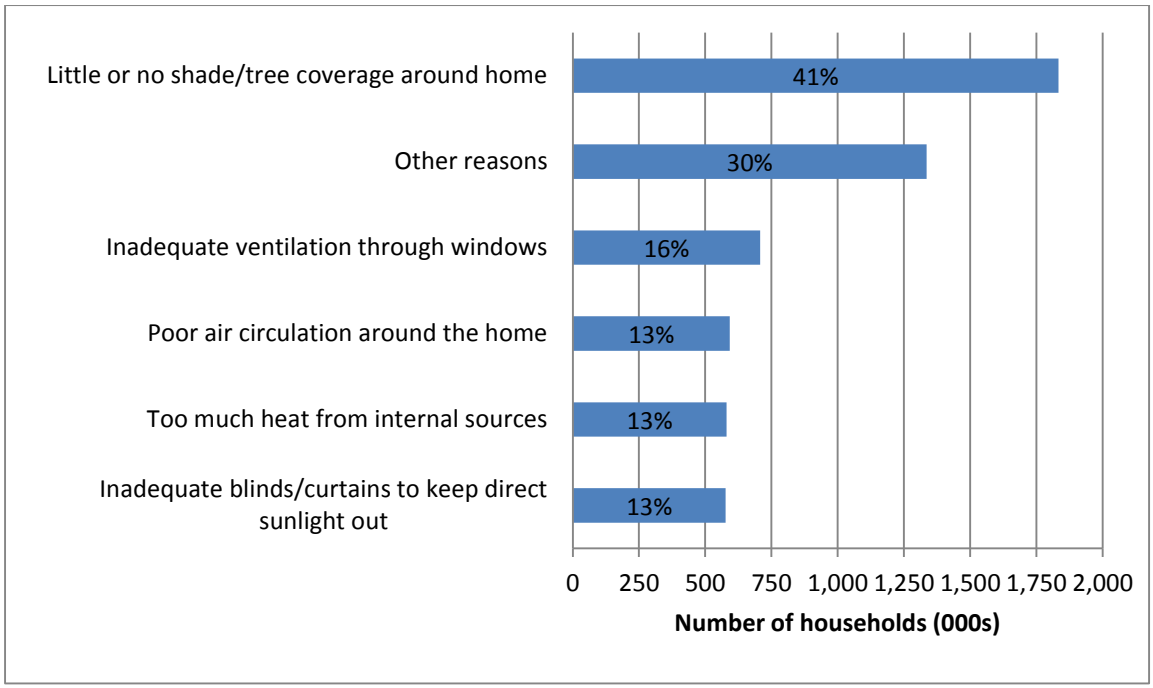
Base: All households in the EFUS interview sample (n=2616).

**Sample responses are very small and subject to large sampling errors*

3.2.2 Reasons for overheating

The 20% of households that reported difficulty in keeping at least one room cool during the summer months were asked to provide a reason for this, from a set list of options. Householders were able to provide multiple responses. The percentages of households reporting the various reasons are shown in Figure 3.

Figure 3: Householders' reasons for their overheating dwellings



Base: All households in the EFUS interview sample reporting problems with overheating (householders are able to give multiple reasons) (n=539).

Approximately 41% of the households having difficulty in keeping at least one room cool reported that 'insufficient shade' was the main reason for overheating and approximately 30% of householders report other reasons. The other reasons households report include:

- Amount of glass in the building.
- Building retains heat.
- Heat from neighbouring dwelling/other parts of the building.
- Heating controlled by social landlord.
- Level of insulation.
- Inadequate ventilation.
- Location of room.
- Location of heating system.
- Poor condition of windows.
- Position of building.
- Type of building.
- Type of room.
- Closed windows due to noise, wind or for security.

By far the most common 'other reason' relates to the orientation of the dwelling. Householders report problems with 'sunlight' or noted the orientation of their dwelling as the cause of the problem in specific rooms. High and low levels of insulations are also blamed for overheating rooms by a number of households providing other reasons for their overheating dwellings. Many households also report that they experienced overheating rooms because they had to keep their windows closed to reduce noise or to keep their dwelling secure.

3.2.3 Frequency of overheating

The households experiencing difficulty keeping at least one room cool during the summer months were asked how often the rooms were 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 overheating every day during the summer months (Table 7).

Table 7: Frequency of overheating

In a typical summer (June to August) how often do this/these rooms get uncomfortably hot?	*Sample size*	Number of households (000s)	Percentage of households (%)	95% C.I. (%)
Every day	128	995	22.3	(18.5,26.2)
5 or 6 days a week	49	371	8.3	(5.8,10.9)
1 to 4 days a week	207	1,754	39.4	(34.8,43.9)
Less than once a week	124	1,077	24.2	(20.2,28.2)
Don't know	31	255	5.7	(3.6,7.9)
Total	539	4,455	100.0	(100,100)

Base: All households in the EFUS interview sample reporting problems with overheating (n=539).

3.2.4 Overheating by dwelling and household characteristics

Table 8 shows the variation in the percentage of households in various dwelling types reporting a problem with overheating in at least one room during the summer. The 95% confidence intervals of the percentages show the significance of the differences across categories. Detailed descriptions of the variables used or derived from the EHS and EFUS data can be found in the Glossary.

It can be seen from the table and Figure 4 that households living in bungalows are less likely to report a problem with overheating compared to households in other dwelling types.

Households living in pre-1919 dwellings are also less likely to report a problem compared to households living in dwellings built 1975-1980 and post 1990. Households living in the largest dwellings (>140 m^2) are less likely to report a problem with overheating than households living in medium sized dwelling (70-89m^2). Additionally, household livings in rural areas are less likely to report a problem than households living in urban areas. SAP considers region a factor in determining whether a dwelling is at risk of overheating and there are some notable difference between whether households report overheating in their homes and their region. Households in London are more likely to report problems with overheating compared to households from the North East and the South West.

There are no significant differences in the percentages of households reporting a problem with overheating for any of the insulation measures groups. However, households living in dwellings with a SAP rating > 70 are more likely to report a problem with overheating compared to households living in dwellings with lower SAP ratings.

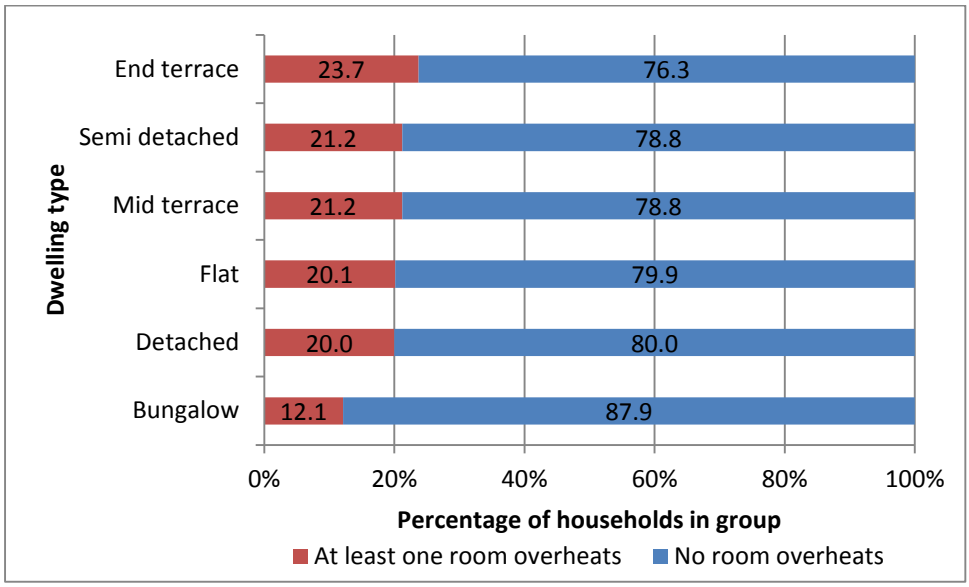
Table 8: Variation by dwelling characteristics in the percentage of households that report a problem with overheating in at least 1 room during summer

Dwelling characteristic	Characteristic category	Sample size of group	% of group that report problem with overheating in at least 1 room	95% C.I.
Dwelling type	End terrace	274	24	(18.2, 29.3)
	Mid terrace	478	21	(17.2, 25.2)
	Semi detached	715	21	(17.9, 24.5)
	Detached	419	20	(15.8, 24.2)
	Bungalow	244	12	(7.6, 16.6)
	Flat	486	20	(16.2, 24.1)
House or flat	house or bungalow	2130	20	(18.5, 22.3)
	flat	486	20	(16.2, 24.1)
Age of dwelling	Pre 1919	488	15	(11.6, 18.6)
	1919-1944	423	21	(16.5, 25)
	1945-1964	600	19	(15.8, 22.7)
	1965-1974	404	21	(16.7, 25.4)
	1975-1980	185	26	(19.4, 33.4)
	1981-1990	219	24	(17.3, 29.7)
	Post 1990	297	25	(19.5, 30.3)
Useable floor area	< 50 m^2	313	21	(16, 26)
	50 to 69 m^2	654	20	(16.3, 22.9)
	70 to 89 m^2	744	24	(20.4, 27.1)
	90 to 109 m^2	344	17	(13.1, 21.9)
	110 to 139 m^2m	261	22	(16.7, 27.8)
	>=140 m^2	300	15	(10.7, 19.7)

GOR	North East	168	15	(9.1, 21)
	North West	419	20	(15.6, 23.9)
	Yorkshire and the Humber	342	20	(15.1, 24.4)
	East Midlands	216	20	(14, 25.6)
	West Midlands	237	21	(15.2, 26.6)
	East	311	22	(16.9, 27.1)
	London	268	27	(21.1, 32.8)
	South East	375	20	(15.2, 24)
	South West	280	15	(10.6, 19.9)
Is dwelling in an urban or rural location?	Urban	2356	21	(19.3, 22.9)
	Rural	260	14	(9.1, 18.3)
Central Heating or Non-CH system in dwelling	Central Heating system	2356	20	(18.9, 22.6)
	Non-Central Heating system	260	20	(13.6, 24.3)
Main fuel (3 categories)	Mains gas	2173	21	(11.6, 23.3)
	Electricity	247	19	(19.7, 25)
	Other (bottled/bulk gas,solid,oil,communal)	196	17	(16.9, 21.3)
Are the walls of the dwelling insulated?	Insulated	1122	22	(13.6, 26.6)
	Not insulated	1494	19	(19.7, 25.3)
Loft insulation 3 bands	<50mm	177	20	(16.9, 22.1)
	50-149mm	1038	22	(19.5, 23.4)
	150+ mm	1083	19	(13.9, 20.5)
Is dwelling fully double glazed?	Yes	2005	21	(14.7, 23.2)
	No	611	17	(13.9, 23.4)
How many insulation measures does the dwelling have?	All 3 insulation measures	397	19	(14.7, 23.2)
	2 insulation measures	751	23	(19.7, 26.3)
	1 insulation measure	833	21	(18, 24.1)
	No insulation measures	317	19	(13.9, 23.4)
Energy efficiency (SAP09) rating	less than 30	83	15	(6.3, 23.1)
	30 to 50	597	18	(14.5, 21.3)
	51 to 70	1691	20	(18.3, 22.6)
	more than 70	245	29	(22.9, 35.4)

Base: All households in the EFUS interview sample (n=2616).

Figure 4: Percentage of households reporting overheating rooms by dwelling type



Base: All households in the EFUS interview sample (n=2616).

Table 9 shows the variation in the percentage of households of differing types reporting a problem with overheating in at least one room during the summer. The 95% confidence intervals of the percentages show the significance of the differences across categories. As in the previous section, detailed descriptions of the variables used or derived from the EHS and EFUS data can be found in the Glossary. A greater proportion of households in Registered Social Landlord (RSL) dwellings (27%) experience overheating during the summer (Figure 5) compared to households in the owner occupied sector (19%). Households with children are also more likely to report a problem with overheating compared to households without children, as are households that are not under-occupying compared to those that are. Single person households are less likely to report a problem with overheating compared to households with 3 or 4 persons as are households with at least one pensioner present, compared to households without pensioners.

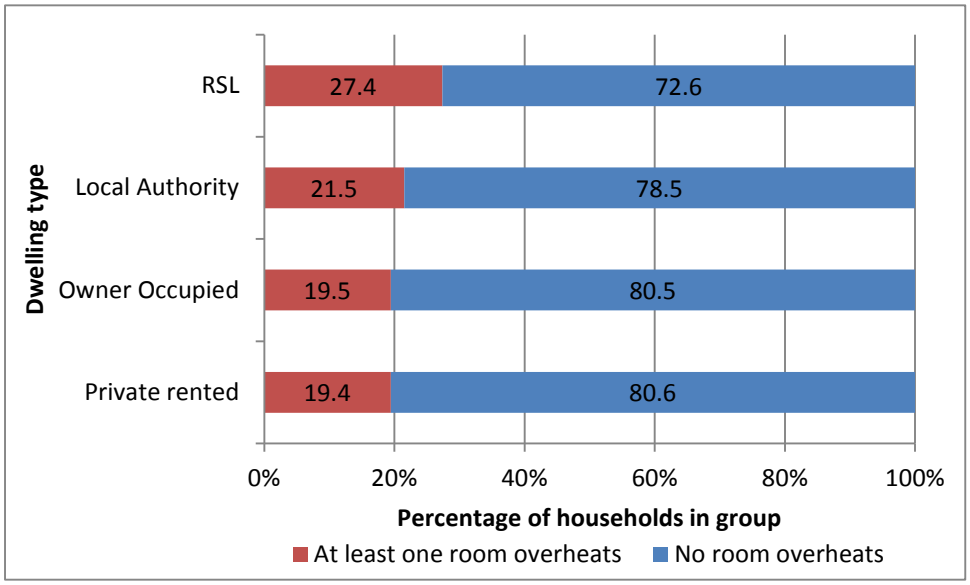
Table 9: Variation by household characteristics in the percentage of households that report a problem with overheating in at least 1 room during summer

		Sample size of group	% of group that report problem with overheating in at least 1 room	95% C.I.
Tenure	Owner Occupied	1486	19	(17.3, 21.7)
	Private rented	385	19	(15.1, 23.8)
	Local Authority	405	21	(17.1, 25.9)
	RSL	340	27	(22.2, 32.6)
Household size	1	734	15	(12.1, 17.7)
	2	907	20	(17.2, 23)
	3	424	27	(21.9, 31.2)
	4	365	24	(19, 28.6)
	5 or more	186	22	(15, 28)

Pensioner Present	At least one person of pensionable age	942	15	(12.2, 17.2)
	No persons of pensionable age	1674	23	(21, 25.4)
Children Present	At least one child	807	25	(21.6, 28.2)
	No children	1809	18	(16.4, 20.3)
Age of HRP	16 - 34	395	21	(16.4, 25.2)
	35 - 44	477	25	(20.4, 28.9)
	45 - 54	524	22	(18.2, 26)
	55 - 64	494	22	(18.1, 26.2)
	65 - 74	426	15	(10.9, 18.2)
	75 or more	300	14	(9.4, 18)
Employment status of HRP and partner combined	1 or more work full time	1267	22	(19.6, 24.6)
	1 or more work part time	229	17	(11.6, 22.3)
	none working, one or more retired	774	16	(13.4, 19.2)
	none working and none retired	346	24	(19.5, 29.4)
Annual gross income of the HRP and partner weighted quintiles	1st quintile (lowest)	611	19	(15.7, 22.5)
	2nd quintile	578	19	(15.6, 22.6)
	3rd quintile	499	18	(13.9, 21.2)
	4th quintile	471	23	(19.2, 27.7)
	5th quintile (highest)	457	23	(18.3, 26.8)
Whether at home anytime during the day, on a weekday	Out during the day	1012	21	(18.4, 23.9)
	In during the day	1604	20	(17.6, 21.9)
Under-occupying?	Not under-occupying	1806	22	(19.9, 24.1)
	Under-occupying	810	17	(14.1, 19.8)
Fuel Poverty Low Income High Cost indicator (LIHC)	Not in fuel poverty - LIHC	2351	21	(19, 22.6)
	In fuel poverty - LIHC	265	16	(11.1, 20.8)

Base: All households in the EFUS interview sample (n=2616).

Figure 5 : Percentage of households reporting overheating rooms by tenure



Base: All households in the EFUS interview sample (n=2616).

3.2.5 Room temperatures in dwellings reporting overheating

The EFUS temperature sub-sample of households allows us to investigate the actual temperatures achieved in dwellings where there is difficulty in keeping rooms cool in the summer. Our approach has been to examine the mean room temperatures across all days in the three summer months of June 2011, July 2011 and August 2011. This is consistent with the current method of examining overheating in SAP, but numerous other mechanisms of defining and identifying overheating are also used and could be investigated further with this data in the future (e.g. period of time above a set temperature etc.).

The SAP and BREDEM methodologies use a heat balance equation to determine the heating requirement for each month during the heating season. The procedure in SAP for assessing the propensity of a dwelling to have a high internal temperature in hot weather uses this same monthly heat balance equation, for the three summer months, June, July, August, but assuming zero heat input from the heating system. The equation is used to calculate an average 24 hour internal temperature for each of the three summer months. These are referred to as the 'threshold temperature' and qualitative descriptions of the likelihood of high internal temperature are stated in Table P2 in SAP, reproduced below in Table 10.

Table 10: Levels of threshold temperature corresponding to likelihood of high internal temperature during hot weather.

$T_{threshold}$	**Likelihood of high internal temperature during hot weather**
< 20.5°C	Not significant
≥ 20.5°C and < 22.0°C	Slight
≥ 22.0°C and < 23.5°C	Medium
≥ 23.5°C	High

The mean temperatures[2] recorded in the living room and main bedroom during the summer months are shown in Table 11 and it can be seen that for those households that report difficulty in keeping the living room cool the mean temperatures recorded are significantly higher in that room compared to those households that do not report any difficulty in keeping that room cool. The same conclusion can be drawn from the temperatures recorded in the main bedroom.

The average mean room temperature for those who report a problem is consistent with a level of 'medium' overheating risk on the existing SAP scale (Table 10), whereas households without a problem in this room have an average risk level of 'slight'.

[2] These are calculated as the mean of the three monthly mean room temperatures for June 2011, July 2011 and August 2011, which themselves are the mean of all recorded temperatures obtained during that month.

Table 11: Mean room temperatures during summer months for those households reporting a problem keeping the living room and main bedroom cool

During a typical summer (June to August) do you find it difficult to keep the room cool?	Living Room			Bedroom		
	Sample size	Mean	95% C.I.	Sample size	Mean	95% C.I.
Yes	82	22.3	(21.8,22.7)	93	22.3	(21.8,22.6)
No	741	21.1	(20.9,21.2)	730	21.4	(21.2,21.5)
Total	823	21.2	(21.1,21.3)	823	21.5	(21.4,21.6)

Base: All households in the EFUS temperature subsample (n=823).

The EFUS temperature subsample has also been used to investigate the mean room temperatures on the hottest days of 2011. Analysis reported on in the 'Mean Household Temperatures' report showed that a period of extreme hot conditions occurred across most of the country on the 26-27 June 2011 and that the temperatures recorded in dwellings during this hot spell were significantly higher than the summer average, with a mean difference of about 3°C. Looking at the recorded mean room temperatures for dwellings on those hottest days for households that report a problem overheating and those that don't, it can be seen from Table 12 and Table 13 that households who report problems with overheating have both living room and bedroom temperatures that are statistically significantly higher than households that do not report a problem with overheating, and this temperature difference is of the order of 0.5°C to 1.5°C.

Table 12: Mean room temperatures in the living room on hottest day

During a typical summer (June to August), do you find it difficult to keep the main living room cool?	Sample size	Mean external temperature on hottest day (26-27 June) in 2011 (°C)		Mean room temperature in living room on hottest day (26-27 June) in 2011 (°C)	
		Mean	95% C.I.	Mean	95% C.I.
Yes	72	29.6	(29,30.1)	24.9	(24.2,25.4)
No	567	29.0	(28.8,29.2)	23.8	(23.5,23.9)

Base: Dwellings in the temperature sample for which the 26-27 June 2011 were the hottest experienced (n=639).

Table 13: Mean room temperatures in the bedroom on hottest day

During a typical summer (June to August), do you find it difficult to keep the main bedroom cool?	Sample size	Mean external temperature on hottest day in 2011 (°C)		Mean room temperature in bedroom on hottest day in 2011 (°C)	
		Mean	95% C.I.	Mean	95% C.I.
Yes	77	29.5	(28.9,30)	25.9	(25.3,26.4)
No	562	29.0	(28.8,29.2)	24.9	(24.6,25)

Base: Dwellings in the temperature sample for which the 26-27 June 2011 were the hottest experienced (n=639).

A question remains as to consider the suitability of using mean temperatures in this way for discerning the risk of overheating, and also whether the actual temperatures themselves used in the SAP categorisation are suitable. To investigate this we have examined the correlation between reported problems with overheating and the reported mean room temperatures when placed in these categories. Based on the actual mean temperature recorded for each room, each case in the EFUS temperature subsample has been assigned the risk level (Not significant, Slight, Medium, High) according to the temperatures in Table 10.

As shown in Table 14 and Table 15 there is some correlation between the categories, and the reporting of overheating problems by householders. Almost 70% of households who report a problem with overheating in the living room or bedroom would be assigned a medium or high risk of overheating based on their recorded mean temperatures in that room (compared to approximately 35-40% of those that do not report a problem). Although the correlation is imperfect, this gives us some confidence that the temperatures in Table 10 can act as a first approximation for problems with overheating. Some scope remains, however, for further disaggregation of these results, and investigation of refinements to the temperature thresholds and/or the addition of other variables which may assist in the identification of overheating risks.

Table 14: Correlation between SAP overheating risk and reported difficulty keeping main living room cool

Percentage of group in each overheating risk category.		Overheating risk (using SAP thresholds) based on recorded mean temperatures in living room				Total (row %)
		Not significant	Slight	Medium	High	
Q79 During a typical summer (June to August), do you find it difficult to keep the main living room cool?	Yes (n=72)	6.2%	25.9%	43.2%	24.7%	100.0%
	No (n=567)	25.8%	37.6%	28.7%	7.8%	100.0%
All dwellings		23.8%	36.5%	30.2%	9.5%	100.0%

Base: All households in the EFUS temperature subsample (n=843).

Table 15: Correlation between SAP overheating risk and reported difficulty keeping bedroom room cool

Percentage of group in each overheating risk category.		Overheating risk (using SAP thresholds) based on recorded mean temperatures in bedroom (row %)				Total (row %)
		Not significant	Slight	Medium	High	
Q63 During a typical summer (June to August), do you find it difficult to keep the main bedroom cool?	Yes (n=77)	7.1%	26.0%	47.6%	19.2%	100.0%
	No (n=562)	17.6%	40.1%	33.8%	8.5%	100.0%
All dwellings		16.3%	38.4%	35.5%	9.8%	100.0%

Base: All households in the EFUS temperature subsample (n=843)

4 Conclusions

The EFUS 2011 interview survey provides valuable information households experience of thermal comfort during the winter and the summer. Analysis has been carried out to determine the number and type of households experiencing difficulty keeping warm during the winter. It also considers a number of issues relating to overheating dwellings during the summer. There are social implications to the comfort levels during the winter that may be linked with household income and the physical condition of the dwelling. Overheating has a social impact on households, who may experience discomfort during the height of the summer, but it may also have an impact on energy consumption and carbon emissions if households use (or are likely to use in the future) electrical appliances to reduce the temperature in their homes.

The main conclusions resulting from the analysis to date are summarised below.

- The majority of households (94%) report being comfortably warm in their living room during the winter months; however, around 6% of households do not.
- 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'.

Initial bivariate comparisons suggest that factors determining whether a household will comfortably warm in their living room during the winter months are likely to be

- the dwelling characteristics of
    - dwelling type (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 and 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),
    - dwelling age (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),
    - heating system type and fuel (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),
    - insulation levels (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. 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)
- along with the household characteristics of

- tenure (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),
- age of occupant (households in which the 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),
- household income (households with incomes in the top two deciles of incomes are significantly less likely to report that they cannot keep comfortably warm in their living room during winter compared to households with incomes in the lowest quintile),
- under-occupancy status (households who are under-occupying are significantly less likely to report that they cannot keep comfortably warm in their living room during winter compared to households are not under-occupying) and
- fuel poverty status (households that are calculated to be in fuel poverty are significantly more likely to report that they cannot keep comfortably warm in their living room during winter compared to households not in fuel poverty).

- 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 room temperatures throughout the winter period compared to those reporting that they are able to keep comfortably warm.
- Overall, 20% of households report at least one room was overheating during the summer months.
- Over 40% of the households having difficulty in keeping at least one room cool reported 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 overheating every day during the summer months.

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).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.
- There is some correlation between the temperature thresholds and definitions used in the SAP overheating algorithm and reported problems with overheating.

These findings provide information on the perceived comfort in dwellings and the action to mitigate overheating. The findings of the temperature analysis confirm that households reporting problems in keeping comfortably warm in their living room are experiencing lower temperatures than other households.

The data collected provides a good basis for setting a baseline of information on overheating. It provides quantitative data on the level of overheating in dwellings, and confirms that households who report problems with overheating are experiencing increased temperatures in their homes. The limited correlation between the SAP threshold temperatures and reported problems with overheating provides some additional confidence in this methodology.

Glossary

Age of dwelling: This is the date of construction of the oldest part of the dwelling. Recorded by surveyors in the EHS physical survey.

Age of HRP: The Household Reference Person (HRP) is the person in whose name the dwelling is owned or rented or who is otherwise responsible for the accommodation. In the case of joint owners and tenants, the person with the highest income is taken as the HRP. Where incomes are equal, the older is taken as the HRP. This procedure increases the likelihood that the HRP better characterises the household's social and economic position. The age of the HRP is derived from householder responses to q167/168/169/170 in the EFUS 2011 Interview survey for new households and from variables obtained from the EHS Interview survey for households that had not changed since the earlier EHS interview.

Annual gross income of the HRP and partner weighted quintiles: This is the annual income of the Household Reference Person and (any) partner. This includes income from private sources (regular employment, self-employment, government schemes, occupational pensions, private pensions and other private income), state benefits/allowances and tax credits, as collected on the EHS survey (this includes housing benefit/Local Housing Allowance but excludes council tax benefit and Support for Mortgage Interest) and interest from savings. It is a gross measure i.e. income before Income Tax or National Insurance deductions.

Children Present: Anyone in the household who is 16 years old or younger. Derived from householder responses to q167/168/169/170 in the EFUS 2011 Interview survey for new households and from variables obtained from the EHS Interview survey for household that had not changed since the EHS interview.

Dwelling insulation: The number of insulation measures where positive responses for 'Fully double glazed', 'Insulated walls' and having loft insulation greater than 200mm count as insulation measures.

Dwelling type: Classification of dwelling on the basis of the surveyors' inspections during the EHS physical survey.

Employment status of HRP and Partner combined: Information on employment status was not re-collected as part of the EFUS and is as reported in the EHS interview survey (and some households may have changed status in the period between the two interviews).

Fuel Poverty – LIHC definition: Under the **Low Income High Cost** definition a household is considered to be fuel poor where:

- They have required fuel costs that are above average (the national median level)
- Were they to spend that amount, they would be left with a residual income below the official poverty line.

Please refer to the following documents for more information.
https://www.gov.uk/government/uploads/system/uploads/attachment

_data/file/66570/6406-fuel-poverty-changing-the-framework-for-measureme.pdf
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/226988/fuel_poverty_stats_methodology_handbook_2013.pdf

Fully double glazed: Derived from the 'dblglaz4' variable as measured by surveyors in the EHS physical survey. Fully double glazed is 'entire house double glazed'. Not fully double glazed is anything less than fully double glazed.

Household size: Number of persons in the household, banded into 5 groups, derived from the 'hhsizex' variable from the EHS Interview survey.

In during the day: See the EHS interview documentation for full details of occupancy questions asked as part of the EHS (question 'Hmwtht'). A household has been classified as being 'in during a weekday' if they indicate being generally in the house on weekdays during the winter, for any period between 9am and 5pm. It should be noted that this information was not re-collected as part of the EFUS, and some households occupancy patterns may have changed in the interval between the two interview surveys.

Insulated walls: Derived from the 'wallinsx' variable as measured by surveyors in the EHS physical survey. 'Insulated' are 'cavity with insulation'; 'Not insulated' includes 'cavity without insulation' and 'other' wall types.

Loft insulation: Banded variable of 'loftinsx', the level of loft insulation recorded by surveyors in the EHS physical survey.

Main fuel: As determined by surveyors in the EHS physical survey. Grouped into 'mains gas', 'electricity' and 'other', which includes bottled gas, bulk gas, solid fuels, oil and community schemes.

Pensioner Present: Anyone in the household who is 65 or over (male) or 60 or over (female). Derived from householder responses to q167/168/169/170 in the EFUS 2011 Interview survey for new households and from variables obtained from the EHS Interview survey for households that had not changed since the EHS interview.

Region: Government Office Region that the dwelling is located in. Obtained from the EHS.

Rurality: Is the dwelling in a rural (village or isolated hamlet) or urban (urban or town or fringe) location. Derived from the 'rumorph' variable in the EHS.

SAP rating: The energy cost rating as determined by Government's Standard Assessment Procedure (SAP) and is used to monitor the energy efficiency of dwellings. It is an index based on calculated annual space and water heating costs for a standard heating regime and is expressed on a scale of 1 (highly inefficient) to 100 (highly efficient with 100

representing zero energy cost).

Tenure: Derived from householder responses to q01 in the EFUS 2011 Interview survey.

Type of heating: Central heating or non-central heating. Determined from householder responses to Q06 in EFUS 2011 interview survey. Non-central heating includes storage radiators, gas fires, electric heaters, coal/wood/ smokeless fuel fires or stoves and other.

Under-occupying: A household is considered to be under-occupying if the dwelling is more than large enough for the number (and type) of occupants living there. For the full definition of under occupancy, see the fuel poverty methodology handbook, which is available at: http://www.decc.gov.uk/assets/decc/Statistics/fuelpoverty/614-fuel-poverty-methodologyhandbook.pdf

Useable floor area: The total usable internal floor area of the dwelling as measured by the surveyor in the EHS physical survey, rounded to the nearest square metre. It excludes integral garages, balconies, stores accessed from the outside only and the area under partition walls. Grouped into 5 categories.