Programme Area: Smart Systems and Heat

Project: Consumer Response and Behaviour

Title: Quantifying heat energy needs and behaviours

Abstract:

This report was prepared for the ETI by the consortium that delivered the project in 2013 and whose contents may be out of date and may not represent current thinking. This study, conducted as part of the Consumer Response and Behaviour project, comprised a quantitative social survey of 2,313 British households which took place in January and February 2014. A quota sampling approach was followed to generate a nationally representative sample, with quotas set on tenure, property type and the presence of children. Respondents completed a face-to-face interview lasting around an hour in which they answered questions relating to their facilities for heating, cooling and hot water, their heat energy needs and their behaviour in relation to use of heat energy. Crucially, respondents completed a card sort exercise in which they organised a range of pre-defined heat energy needs into factors that had big, small or no influences on their heat energy behaviour. The items on the cards were informed by a literature review and qualitative research. Where respondents consented (89% of cases), interviewers conducted observations of the heating and hot water systems and physical features of the property. Respondents were given a paper self-completion questionnaire (covering mainly their recent and desired renovation activities); 78% of respondents returned the self-completion questionnaire.

Context:

The delivery of consumer energy requirements is a key focus of the Smart Systems and Heat Programme. The Consumer Response and Behavior Project will identify consumer requirements and predict consumer response to Smart Energy System proposals, providing a consumer focus for the other Work Areas. This project involved thousands of respondents providing insight into consumer requirements for heat and energy services, both now and in the future. Particular focus was given to identifying the behaviour that leads people to consume energy - in particular heat and hot water. This £3m project was led by PRP Architects, experts in the built environment. It involved a consortium of academia and industry - UCL Energy Institute, Frontier Economics, The Technology Partnership, The Peabody Trust, National Centre for Social Research and Hitachi Europe.

Quantifying heat energy needs and behaviours

Final Report

3 September 2014

Smart Systems and Heat (SSH) Technology Programme
Work Area 5: Consumer Response and Behaviour

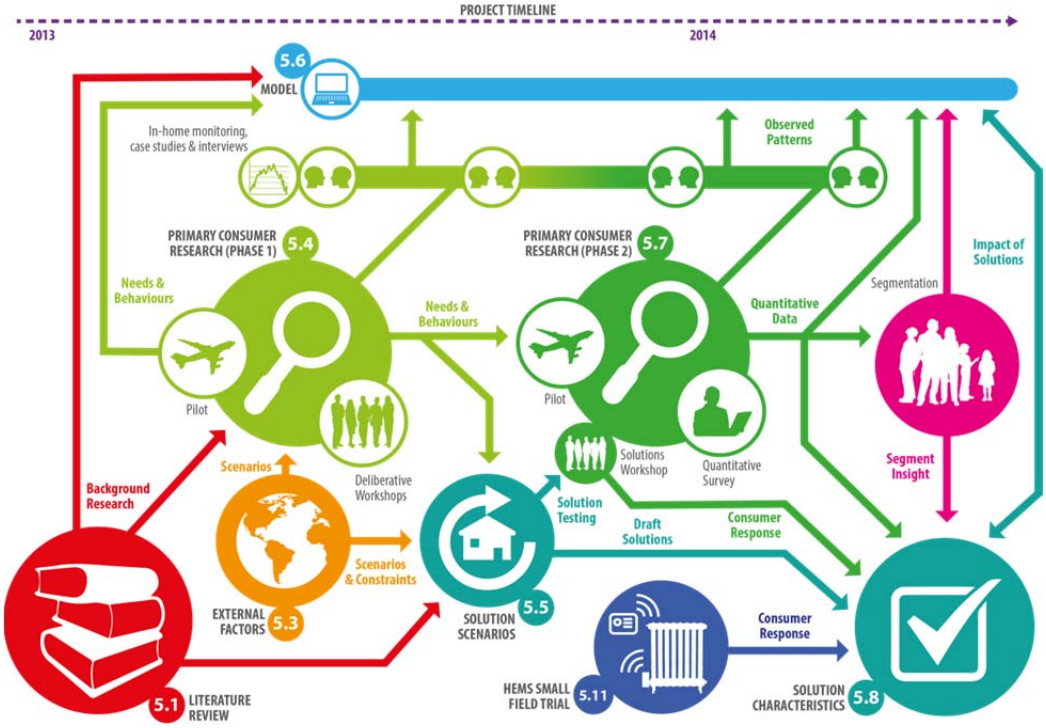
Context

This Report, *Quantifying heat energy needs and behaviours,* is one of the final deliverables of the Energy Technologies Institute's **Consumer Response and Behaviour** project, part of the **Smart Systems and Heat (SSH)** programme.

The ETI's Smart Systems and Heat Programme will create future-proof and economic local heating solutions for the UK. It will connect together an understanding of consumer needs and behaviour with the development and integration of new technologies and with new business models. The associated insight will deliver enhanced knowledge across industry and the public sector, resulting in industry and investor confidence to implement SSH influenced solutions from 2020 and thereby enable a UK energy system transition, focussed around effective delivery of heat, within an appropriate policy and support environment to deliver a cost-effective UK energy system transition.

The Consumer Response and Behaviour project is a multi-disciplinary research collaboration, combining qualitative and quantitative social research, physical monitoring, modelling and concept development supported by a thorough review of secondary literature sources.

The key research activities and work packages of the project are illustrated below.



This report comprises one of two key outputs of **Work Package 5.7 - Primary Consumer Research (Phase 2)** and details quantitative insights from a representative survey of British households.

The other key final deliverables are:

- *"What people need and do that involves heat energy: findings from qualitative research"* - an output of **Work Package 5.7 - Primary Consumer Research (Phase 2)** which details qualitative insights from workshops and interviews, and key case studies from the longitudinal in-home monitoring sample;
- "*Modelling Insights"* - a key output of **Work Package 5.6 - Model** which details modelled insights into the impact of current behaviours and the impacts of changes to the household or energy system;
- *"Smart Energy Solutions - The Consumer Perspective"* – an output of **Work Package 5.8 - Solution Characteristics** and details key insights to the design of future smart energy solutions based on inputs from the wider project.

Acknowledgements

The principal authors of this report are Liz Clery, Jerome Finnegan and Sarah Kunz (NatCen), and Clare Littleford and Gary Raw (UCL Energy Institute).

Cognitive testing of the questionnaire was undertaken by NatCen's Questionnaire Development and Testing (QDT) Hub, assisted by UCL.

Fieldwork was carried out by NatCen with interviewer briefings supported by UCL and PRP Architects.

Analysis was assisted by Matt Barnes and Zsolt Kiss (NatCen).

Executive Summary

This study was conducted as part of the Consumer Response and Behaviour project, which is within Work Area 5 (WA5) of the Smart Systems and Heat (SSH) Programme of the Energy Technologies Institute (ETI). The ETI commissioned the SSH programme in 2012, with the objective of informing the design, development and demonstration of a cost-effective smart energy system, suitable for future roll-out within the UK. The report presents analysis of data from the WP5.7 quantitative survey of British households in order to take forward our understanding of people's needs and behaviours that affect heat energy use at home. In doing so, it develops and quantifies learning from other strands of the project while also introducing new understandings and highlighting fundamental issues – particularly in relation to smart energy solutions.

Approach and methods

The Consumer Response and Behaviour programme aims to develop an understanding of consumer behaviour and provide insights into consumer needs in an energy systems context. Thus, while the SSH Programme as a whole is largely technological, this project provides an essential basis in the consumer perspective. Future energy systems will deploy new technologies and business models and will potentially feature a much greater degree of consumer involvement in the provision and management of energy-based services. It is therefore important to develop a clear understanding of consumer requirements and preferences, and build these into the design features of consumer-focused products, in this context.

The particular study reported here, a large quantitative survey of British households, formed part of Work Package 5.7 of the Consumer Response and Behaviour project. The study builds on the work carried out in other Work Packages and also provides input to other Work Packages. It aims to understand consumer needs and behaviour in relation to domestic energy usage, how these vary between different groups in the population, and their relevance to smart energy solutions. These aims are founded on the expectation that what people do in relation to heat energy in the home is in some way related to a set of needs. This distinguishes the project from much other research that aims to inform the technical design of smart energy systems. Much of our current understanding of what drives behaviour in relation to heat energy takes the physical characteristics of the property as its starting point. The rationale for this is understandable: the characteristics of the property (age, size, type of heating system and insulation, for example) set the boundaries of what is possible for people to do when trying to heat, cool and ventilate their home.

The study comprised a quantitative social survey of 2,313 households, which took place in January and February 2014. A quota sampling approach was followed in order to generate a nationally representative sample of British households, with quotas set on tenure, property type and the presence of children.

Respondents completed a face-to-face interview that lasted around 60 minutes in which they were asked a range of questions relating to their facilities for heating, cooling and hot water, their heat energy needs and their behaviour in relation to use of heat energy. Crucially, respondents were asked to complete card sort exercises in which they organised a range of pre-defined heat energy needs into factors that had big, small or no influences on their heat energy behaviour. The items on the cards were informed heavily by the literature review and qualitative research. Where respondents consented (which was in 89% of cases), interviewers conducted observations of the heating and hot water systems and physical features of the property. Respondents were given a paper self-completion questionnaire (covering mainly their recent and desired renovation activities); 78% of respondents returned the self-completion questionnaire.

Analysis of the survey data has produced a wealth of information that will facilitate a range of aspects of the development and implementation of smart energy solutions. There are some caveats and limitations to the methods used to conduct and analyse this survey, in relation to the overall representativeness of the quota sample and the interpretation of some of the analytical techniques. The methodology section and the technical appendices provide more information on this. All methodologies have limitations, however, and it is our view that the approach taken here (developed in collaboration between the consortium and ETI and its advisors) represents the most effective and pragmatic approach to the research problem we were faced with and in light of the practical constraints of time and budget.

The following sections describe the main findings, which are summarised in greater detail in the final chapter of this report.

Heat energy needs

British households have many needs relating to three heat energy domains (heating the home and keeping warm, cooling the home, and heating water and using hot water). Five needs out of the 21 asked about are identified as big factors influencing decisions in relation to heating the home by more than two-thirds of respondents: being comfortable, energy costs, avoiding wasting energy, being able to rest and relax, and wanting to feel clean. The least prevalent needs relate more to social factors and household routines. However, none of the needs is irrelevant: even the least prevalent is a big factor for 8% of respondents. Prevalence of individual needs relating to heating water are similar except for greater emphasis on needs related to cleaning.

The 21 needs occur in many and complex patterns in different households. It is of great value, therefore, that factor analysis[1] of the data has defined five underlying dimensions of need, common to both heating the home and heating water. For heating the home, these five dimensions relate to individual needs (as described on the cards used during the interviews), each of which has been given a label. These labels aim to capture the essence of the dimension as best as is possible, but they are more useful as a shorthand to refer to the dimensions rather than as a definitive description.

[1] The factor analysis technique and results is described in more detail in the main report and the technical appendices.

Other people
- How you and your home appear to other people
- The needs of visitors
- Wanting to avoid arguments/ disagreements within the home
- Caring for other members of the household
- Wanting to be productive

Comfort
- Being comfortable
- Being able to rest and relax
- Feeling in control

Hygiene
- Keeping healthy
- Wanting to feel clean
- Wanting to keep the home clean
- Keeping the home looking, feeling or smelling nice
- Wanting to feel safe and secure

Resource
- Energy costs
- The value or cost of your home
- Concern for the environment
- Avoiding wasting energy

Ease
- Doing what you think most people do
- Keeping to your everyday routines
- Doing what you have traditionally done
- Doing what is easiest

Both the individual needs and the underlying dimensions can be aligned with findings from qualitative research, supporting the validity of both streams while allowing different perspectives to be taken.[2] The most significant deviations from the qualitative findings are that health and comfort fall into separate dimensions, concern for the environment becomes an aspect of *Resource* rather than "Relational dynamics" and the need to be in control is closely associated with *Comfort* rather than "Agency".

A cluster analysis technique was then used to place the participating households into groups ("segments"), with similar scores on the five dimensions of need. This resulted in seven needs-based segments. While these segments illustrate how different needs group together, the resulting segments are not easily characterised by variables relating to households, dwellings or heating systems. So, while the segments can be used to guide the design of smart energy solutions, they are less useful for the implementation or targeting of a solution because it is difficult to assign a given household or set of households to a segment using readily available data. Nevertheless, the five dimensions of need offer a powerful and flexible means to characterise particular population groups (e.g. household types or households in different types of dwelling), as a guide for design and implementation of solutions. Examples of such "needs profiles" are provided in the report, showing how different groups emphasise different needs; this approach is sufficiently flexible that it can support deployment at local level, taking account of local household and dwelling characteristics.

Heating the home and keeping warm

What heating systems are present and used in British homes?

Heating systems and controls

By far the most common heating system is central heating with radiators (87% of homes); this is as expected but this apparent dominance may obscure a more diverse and complex set of approaches to heating the home. In fact, over half of the centrally heated homes also use some other form of heating to meet their needs – appliances that are either portable or a fixed in the room. In 3% of homes with central heating, the household did not use the central heating as the main way of heating the home.. While 53% of homes have some kind of heater fixed in one or more rooms, this is the main heating in only 12% of cases. Similarly, 25% have some kind of portable heater but it is the main heating in only 2% of homes. District heating is used in 2% of homes. The type of heating system is statistically associated with a range of dwelling and household characteristics that can be used to ascertain what types are popular in the different contexts that smart systems would need to engage with.

[2] Systematic analysis of the qualitative data was used to reveal the key needs that impact on day-to-day use of heat energy. This analysis was based on in-depth discussions whereas the quantitative research identifies groupings based on more immediate responses. See the project report "What people need and do that involves heat energy: findings from qualitative research" for further details. The application of the two groupings is discussed at length in the project synthesis report "'Smart' starts with the consumer".

Where interviewers were able to check the presence of controls in homes with central heating, 63% had a timer/programmer and both room thermostat(s) and TRVs. Most of the rest had a timer/programmer with either a room thermostat or TRVs but 8% had only thermostats. The location of controls was not always ideal, with 30% of timers/programmers being inside a cupboard and only 27% of room thermostats being in the living room (67% in a hall or on a landing).

Control of heating

Controls appear to be under-used, with manual control being preferred. Respondents report controlling temperature room-by-room (36%), centrally (26%), using both (26%) or not using either (10%). Of those who say they do not control the temperature, 73% saw no need to do so, 22% did not believe they had the means to do it and 6% believed it would increase energy use. Respondents also describe controlling the timing of the heating manually only (28%), using timing controls (31%), both (18%) or neither (1%).

Control strategies may be categorised according to whether temperature and timing are each controlled manually or by thermostat or timer ("set and forget"), or a combination of the two ("active control") or neither. This simplifies an otherwise complex range of strategies and allows strategies to be related to other dwelling and household characteristics. A strong effect of heating type on control strategy limits the possible effect of household demographics, hence there is relatively little variation among household types. This suggests that control strategies should not be seen as an inherent characteristic of households, but variable according to the heating system provided or chosen.

Use of rooms in the home

The size of the home and the number of rooms in the home will affect the use of heating and the amount of energy used for heating. We calculate from the survey data that 35% of households may be heating rooms that are rarely used. However, asked directly about "habitable rooms" (e.g. living rooms and bedrooms) respondents regard very few as 'not used', and in most homes there are very few rooms or none that are 'rarely used'.

This suggests that solutions aimed at reducing heating in rarely used or unused rooms may not have a large impact. The exception is in the larger homes (six or more habitable rooms), where we found there are more likely to be unused rooms. These homes also almost all have central heating (hence more likely to heat all rooms) and are almost exclusively owner-occupied. In smaller homes, zonal control is more likely to be attractive as a means of dealing with the different times when each room is used and possibly the different individuals using the rooms and the different activities carried out, rather than managing unused rooms.

What do people do to keep warm?

Common strategies

Households use a wide range of methods to keep warm at home on a typical winter day and each method itself has many variations. Unsurprisingly, the main heating is used in most cases (92%), with 19% using some other form of heating instead or in addition. While 67% close external windows/doors, fewer manage heat loss by closing curtains/blinds (45%) or internal doors (48%). Only 19% use the alternative of not heating all rooms (14% combine this with closing internal doors while 5% do not). Insulating the person is also common: using warm clothes (62% of households) and warm bedding in bed (45%) and when not in bed (31%). Respondents also report various ways of directly warming the person: using warm food or drink (45%); using a hot water bottle (23%) or something else warm to hold (3%); or having a bath or shower to warm up (15%).

While 72% of respondents say that what they usually do to keep warm 'Always' keeps the household warm enough, 23% say only 'Sometimes' does, and 4% 'Rarely' or 'Never'. These responses vary with a range of dwelling and household characteristics, which can be used in planning deployment of smart energy systems.

When the usual methods of keeping warm are not sufficient, the most common approach is to have the main heating on for more time and/or turn up the thermostat but the usual strategies are all repeated among the additional strategies. Also, while 2% heat more rooms, 5% heat fewer rooms and 3% go somewhere warmer, away from the home. Only 21% say they do not need to do anything extra because the usual methods of

keeping warm are always enough. A further 2% say they are always doing all they can, without this necessarily always being enough.

The methods of keeping warm have been categorised, as: using the *main heating;* using *other heating*; c*ontrolling* where heat goes (keep windows & external doors closed, shut doors between rooms, not heat all rooms, heat all rooms, close curtains or blinds); r*etaining* one's own warmth (wear warm clothes, use warm bedding in bed or when not in bed) and heating the *person* (warm food or drink, bathe or shower, use hot water bottle, use something else warm to hold, use electric blanket or bed warmer). Many combinations of these methods are used on a typical winter day. In 81% of cases, one form of heating is used, but 68% with some supplementary method. A further 15% use two forms of heating, always with some supplementary method. The most frequently reported approach (54%) is one form of heating, controlling where the heat goes plus insulating and/or heating the person. More surprising is that 5% do not use any heating.

In contrast to the usual methods of keeping warm, approaches other than room heating dominate the additional methods used to keep warm when the usual methods are insufficient: those using non-heating methods or doing nothing extra account for 53% of respondents. Of course, the available additional methods will depend on what is usually already being done.

Variation in heating with time of year and time of day

From November to February, most households are using their heating. More surprisingly, 8% are still using the heating for at least part of July and August (these are more likely to be older households and those where someone has a disability that is relevant to heating and/or hot water). The percentage using heating increases slightly more steeply between August and November than it declines from February to July. This perhaps arises from people being more aware of getting cold at some point during autumn than they are of the opportunity to be warm without the heating on as spring progresses. This suggests an opportunity to reduce heating energy demand by using signals that the home would be warm enough without heating.

Out of the whole sample, 20% say that, during the months when they use heating, it is on all the time. Out of these respondents, 60% say they do this because they would otherwise be too cold, 35% that it is for convenience, and 27% that they believe it costs less or uses less energy.

Weekdays and weekends follow a generally similar pattern with peak heating periods in early morning and early evening but 25% of homes also being heated at night. The overall pattern is very similar across household types, but with greater levels of daytime heating among households made up entirely of those aged over 60 and households with pre-school children. Those with district heating have less pronounced differences across times of day, including much higher levels of overnight heating. The qualitative research conducted as part of WP5.7 suggests that dissatisfaction with the lack of control over district heating (as revealed in the literature review and qualitative research for this project) may stem from district heating systems not providing an adequate level of control to produce the normally employed pattern of heating.

Circumstances when households change what they do

The circumstances under which households change something about how they heat the home are varied. The reason most frequently given was it being cold outside, followed by variations in someone being at home (the householders or visitors), especially if a visitor has a particular need to keep warm (e.g. babies, the elderly or those who 'feel the cold'). Only 64% reported changing something when they are away from home, which suggests significant potential for reducing energy demand among the remaining 36%.

The use of heating and dimensions of heating needs

To understand more about how household and dwelling characteristics link to needs, profiles of the five needs dimensions described above have been created for some key groups.

- Homes with central heating follow the average national profile of needs. Those with district heating place the least emphasis on *Resource*, and low emphasis on *Other people* and *Comfort*, perhaps because heat tends to be available all the time through a system that they have little control over. Those with portable heating also place little emphasis on *Comfort*, despite being least likely to say they usually feel warm enough but this may be explained by their emphasis on *Other people*.

- Looking at the combinations of methods people usually adopt to keep warm, there appear to be two poles: *Resource* is particularly important to those using the widest range of methods to keep warm whereas those who use the fewest methods tend to emphasise *Ease*.
- Regarding control of heating, those who control both temperature and timing manually do not strongly emphasise *Comfort*, while those who control both temperature and timing using a combination of manual and 'set and forget' emphasise *Comfort* above *Ease*. Those who do not control temperature at all (and those who have their heating on all the time) tend to emphasise *Ease* over *Resource*. The two most common control types ('set and forget' temperature and timing, with or without some manual control of timing) have the least range of needs, but slightly emphasise *Resource*.

Keeping cool

Avoiding overheating in winter

Households can be divided into those that keep cool enough by what they usually do (37%) and those that sometimes do one or more things extra in order not to overheat in winter (63%). The second group should not be seen as actually getting too warm – mostly they should succeed in avoiding overheating. However, the fact that so many households need to do something specific to avoid overheating indicates potential for improved control of heating with the dual aim of improving comfort and reducing energy demand.

Some methods by which households avoid overheating are targeted at the indoor: controlling heat gain (reducing heating or creating shade) or removing heat (e.g. using natural ventilation through windows or doors, or mechanical ventilation or cooling systems). Other methods are targeted at the people themselves: insulation (using light clothing or bedding), cooling the body from the inside (e.g. with a cold drink) or from outside (e.g. with a fan or shower), or a change of location (within the home or by leaving the home). The main combinations of methods involve reducing heating (80% of households), often together with natural ventilation (39%). This leaves 20% who do something else in preference to reducing heating, most often together with natural ventilation (16%). Less than 1% use air conditioning.

Older people (aged over 60) are most likely (and households with preschool children least likely) to say that it would not get too warm in winter. Consequently, older households are least likely to do anything to avoid overheating. Effects of age may arise because of age directly (e.g. some kind of physiological change), a cohort effect (i.e. particular life experiences that would not necessarily be repeated in another generation) or simply because older people have been longer in their current home and therefore understand better how to keep cool. Needing to do something to avoid overheating in winter is also more prevalent in households that are larger (until the number gets to five or more), owner-occupiers or have higher incomes, and in homes that are newer or have multiple glazing, or that have central heating or (especially) district heating.

The 72% of households who always feel warm enough in winter split into 49% who sometimes *overheat* in winter and 23% who do not. In contrast, the 27% who do not always feel warm enough in winter split almost equally into those who do and do not overheat in winter. This suggests some kind of conflict between ability to keep warm and ability to avoid overheating in winter.

Keeping cool in summer

What households do to keep cool in summer

In contrast to winter, only 9% of respondents say that it would not get too warm on a typical summer day, the remainder needing to take some action to avoid overheating. The combinations of methods used to keep cool in summer often appear not to include reducing heat input, but in most cases this is because the heating is not used in summer. Taking this into account, strategies are dominated by natural ventilation – used alone in 61% of households and with other methods in 32%. Other methods are using light clothing or bedding (60% of households), or cooling the body, e.g. with cold drinks or a fan (55%), circulating air within the building (36%), changing location (33%) and using shading (26%). By far the least prevalent strategies are mechanical ventilation (4%) and mechanical cooling (2%).

In general then, people use the home itself is used to keep cool, rather than mechanical systems, in particular using ventilation and air movement. Fewer use shading, and the shading is in the most effective

location (on the outside of the windows) in only 4% of the sample. External shading can be very effective and there is clearly potential for greater application in Britain, perhaps supported by smart control systems.

Of those who need to do something to keep cool on a typical summer day, 70% say that it does always keep them cool enough and 28% that it sometimes does. Only 2% say it rarely or never keeps them cool enough. Overall then, 73% always keep cool enough. By this measure, there are no clear trends by household size, income or age of property but keeping cool in summer is a greater issue for households aged under 60, those with no children; households occupying flats rather than houses or bungalows; and renters.

More than half of households use a wide range of additional strategies when their usual methods of keeping cool are not enough (for example on particularly hot days). There is no overriding strategy but the most prevalent actions are opening windows during the day (21%) or at night (17%), using an electric fan (19%), using lighter clothes (19%) or bedding (15%) or having cold drinks (17%). A familiar demographic pattern is seen, with older households and social renters being least likely to use any additional strategies.

Circumstances in which households do more to keep cool in summer

Besides the obvious situation when the weather is particularly hot, the main driver for households to change what they do to keep cool is when someone at home is unwell (15% of households), especially if there are children in the household. All other options are chosen by less than 10% of households.

Older households are least likely to change what they do and, unsurprisingly, households with “children who have started or completed school” are most affected by school holidays. There is no overall trend or large variation by dwelling type, age of property, tenure or income, but those in highest income quartile are more likely to change their behaviour when someone is working from home (18% as compared to 6% in lowest quartile), which likely reflects that people in this quartile are generally more likely to work from home.

Using windows

Opening windows and doors is a key strategy for cooling homes but opening windows also serves other purposes and this needs to be taken into account in smart energy system design. Almost all households open windows for some reason: for fresh air (85% of households), to keep cool (79%), to let out smoke or smells (44%), to sleep better (38%) or to avoid condensation (38%).

Respondents were asked whether there are times when they would like to open windows to keep cool but do not do so for a range of reasons. Only 32% said that this never happens. The most common barriers are concerns about security (30%), noise (24%) and other reasons to do with conditions outdoors, e.g. smoke, odours, wind or rain (18%). Older households and those with lower incomes are more likely to report no barriers to opening windows, so this may explain why they have fewer issues with cooling in general. Safety is of greater concern to households with young children. Noise is of greater concern to those living in a flat whereas security is of greater concern to those in a bungalow. If such barriers could be addressed through smart design, this could be a cost-effective means to address cooling issues without air conditioning.

Heating water and using hot water

Hot water systems

Across the whole sample, 54% of households had a combi boiler, 34% of households had a standard boiler with a storage tank/cylinder and 15% an immersion heater[3] (86% identified either a combi or standard boiler as their main system). Less prevalent systems included 2% of households with district heating, 1% with instant hot water taps and 1% with solar thermal water heating. Most households have a single system available to heat water.

In properties built up to 1980, combi boilers are the most prevalent system, whereas standard boilers are more prevalent than combi boilers in later homes (except that combi boilers are also more prevalent in post-2001 homes). The proportion of homes that have a standard boiler increases with the size of the home and

[3] Note that these figures are based on what people *said* they have. It is normal for a hot water cylinder to incorporate an immersion heater and many people therefore probably have without being aware of it.

is greater in houses and bungalows than in flats and maisonettes. Flats and the smallest homes are the least likely to have a boiler at all, relying instead on electric or district heating.

Households with children (and larger households) are the most likely to have a combi boiler, while older households (and smaller households) are the most likely to have a standard boiler. Standard boilers are most prevalent among owner-occupiers and least among the social renters (the prevalence of combi boilers follows the opposite pattern but with much less variation). The prevalence of combi boilers varies little between income quartiles, except that it is lowest in the highest quartile, whereas the prevalence of standard boilers increases with income.

The overall pattern of variation with dwelling and household characteristics can be accounted for by a combination of factors. Combi boilers need less space and provide better for households that are unpredictable as to when someone will be at home or need hot water. Standard boilers can more easily service multiple hot water outlets and maintain a satisfactory flow rate (and also can be combined with solar thermal water heating). So standard boilers may be favoured for larger homes but combi boilers for larger households: a clear conflict in choice of system.

Control of hot water

For the majority of households, the hot water system operates largely in the background of their everyday lives. This applies particularly to water temperature controls: the majority either do not use them at all or, having set them up once, do not use them afterwards. We can categorise households into three temperature control types: “Set and forget” (48%), “Active control” – although actual changes to settings are generally infrequent (26%) and “No control” – either because there actually is no control or because they do not know about it (22%). The figures are similar for both boiler types although there is some tendency for households with a combi boiler to be more likely to be “Active control” (31% compared with 25% for those with standard boilers) and less likely to be “No control” (17% compared with 22% for those with standard boilers).

How respondents control the timing of hot water can also be categorised into three types: “On demand” – a combi boiler or instant hot water tap (54% of households), “Available all the time” (14%) and “Controlled” – manually or with timers/programmer settings and “boost” controls (32%). Looking just at households with a standard boiler, 72% were categorised as controllers but, of the respondents who say that they have hot water at times when they have set the controls for it, the majority never change the controls.

“Active control” of temperature and “Controlled” timing are both more prevalent among owner-occupiers, households with higher income, and households without children. Comparing the timing control types by the distribution of needs dimensions, the strongest effect is that the “Available all the time” households emphasise *Ease* above *Resource*. Households classified as “Active control” for temperature put more emphasis on *Resource*, *Other people* and *Comfort* than on *Hygiene* and *Ease*. The “No control” households place little emphasis on *Resource* and *Comfort*; it may be that this emphasis results in this group not seeking out the means to control, or the emphasis could be as a result of the system they have or resignation to their situation.

Using hot water

Using hot water at home

The ways in which households use hot water are many but relatively predictable; the most common are for washing themselves, clothes or dishes, cleaning the home, and cooking (or making hot drinks). While most homes use a washing machine for laundry, hand-washing is more prevalent for dishes. Less common uses are washing vehicles, washing pets, and brushing teeth with hot water.

Households use showers more often than baths in both winter and summer, and more baths and showers in summer than in winter. In a winter week, the mean number of showers per household is 18 and the mean number of baths is 15 (5 and 2 per person, respectively). In a summer week, the mean number of showers per household is 26 and the mean number of baths is 20 (6 and 2 per person, respectively). Households are more likely to use showers in the morning (or both morning and evening) and baths in the evening. Households without children are more likely to have showers in the morning than households with children, while households with children are more likely to have baths in the evening. The percentage of households that have showers in the morning decreases with increasing household size, whereas the percentage that

have showers in the evening varies little and the percentage having showers both morning and evening increases with household size (there is a similar pattern for baths).

Presented with scenarios in which they might increase the hours when they heat water, 60% of respondents without “On demand” hot water say “None of these”. This reinforces the suggestion that hot water systems tend to operate in the background of people’s lives. However, some households do increase the hours they have their hot water on in specific scenarios, principally if there are visitors. Presented with scenarios in which they might decrease the hours when they heat water, 70% of households say “None of these” but 24% say that they would do so if they go away for a long period of time and 13% when they go away for a night.

Using hot water away from the home

The majority (65%) of households say they never use hot water away from home (other than when away for a night or more). However, over a third (35%) of people do use hot water away from the home: 21% say that they use showers elsewhere and 6% that they use baths; 15% said that they washed a car elsewhere and 3% said that they wash clothes elsewhere. The reasons most often given are to get clean after activities and because it is more convenient. Only 5% of those who use showers away from home and 6% of those who use baths say that they do it to save money, and even fewer to save energy.

Drying laundry

Households tend to use at least two ways to dry laundry: 67% say that they do this outdoors, 46% in a tumble drier, 38% using radiators and 37% somewhere else around the home. This has implications for heating the home (with a requirement for both warmth and good ventilation) and the distribution of heat (with a requirement for localised heat sources such as radiators). Flexibility around heating the home might be increased by providing secure, covered outdoor drying areas.

Heat energy solutions

Demand for greater control

Future solutions for heating the home, cooling and heating water

Respondents were asked about specific aspects of their current situation that they might like to change, specifically in relation to the household’s ability to control heating, cooling or hot water. These stated desires give an initial indication of the acceptability of aspects of potential future heat energy solutions.

Overall, 35% of respondents did not want more control over any aspect of heating the home and a further 9% said that it would be better to have more automation instead. There is no single aspect that most respondents would like to change, 23% selecting the most popular options (the temperature in each room and being able to heat rooms more quickly), followed by being able to control the heating system remotely from outside the home (19%), or from any from any room (16%).

Despite the general absence of technologies for cooling the home, there is less demand for more control, compared to heating the home: 47% of respondents said they did not want greater control over any aspect of cooling, compared to the 35% in relation to heating, and again 9% expressed a preference for more automation. The most popular options were being able to cool the home more quickly (19%), avoiding over-heating during heat waves (18%), being able to cool particular parts of the home (17%), to make the home cooler than is currently possible (14%) or to be able to control the cooling from any room in the home (11%).

There was even less demand for increased control over heating water: 55% did not want greater control over any aspect and 7% favoured greater automation. The most popular options were how quickly the water heats up (18%), the temperature the water is heated to (12%) and the amount of hot water that is available (10%). The desired changes can be related to current problems that respondents report: 17% say that they have to run their tap for a long time to get hot water, 16% that they have more hot water than they need, 15% that they do not have enough hot water, 9% that their hot water is at low pressure, 9% that their water is not hot enough and 5% that it is too hot.

Demand for increased control over heating water was generally lower in households that used a combi boiler as the main system for heating water and the top three desired changes also differed. Amongst those with a

standard boiler, 19% had a desire for more control over how quickly the water heats up, 12% over the temperature the water heats up to and 14% over the amount of hot water that is available. Amongst those with a combi boiler, 16% had a desire for more control over how quickly the water heats up, 11% over the temperature the water heats up to and 6% over the amount of hot water that is available.

In summary, the most commonly favoured changes involve the amount or extent of heating, hot water or cooling required or the speed at which the process of heating the home, heating water or cooling should occur. There is less support for the concept of remote control (either from within or outside of the home) or feedback on others' involvement with the heat energy systems.

Who would like more control over heating the home, cooling and heating water?

The data allow the overall desire for change, and the desire for specific changes, to be related to a wide range of household and dwelling characteristics, in a way that could be applied to specific local populations or to Britain as a whole. The specific characteristics and aspects of control have a complex set of interrelationships that will have greatest meaning in practical applications of the data, rather than in the abstract context of this report. However, the overall *absence* of desire for change in heating control is relatively little affected by property characteristics but greatest:

- among those who are always warm enough on a typical winter day;
- among households with no children and all adults aged over 60;
- in single-person households, reduced in two-person households and levelling out at three persons;
- in households in the lowest income quartile, and decreasing markedly in the top quartile;
- in homes with district heating, only slightly less in homes that rely on central heating only, or central heating plus fixed heaters, and least in homes that rely on portable heaters;
- among households that have heating on all the time with a "set and forget" approach to temperature, and least among those that manually control timing and temperature (with or without some use of controls).

In relation to cooling the home and heating water, we found that:

- household type again makes a difference, households with children being the most likely to want additional forms of control and the oldest households being the least likely to do so;
- support for increased control rises with household size;
- those in the highest income quartile are more likely to favour additional forms of control;
- there was no clear trend by age of property or type of property.

The few households already using mechanical ventilation or cooling are more likely to favour a greater degree of control. This could mean that these households have cooling systems because they have a high demand for control, or they have come to appreciate cooling systems and therefore want more from them. For heating water, those with a private landlord are more likely to want additional control than owner occupiers. Using a combi boiler is associated with a lesser appetite for increased control over heating water.

Overall, demand for greater control is related to the types of systems that households currently have and how they interact with them, as well as the make-up of households. The characteristics of the property appear to make little difference. One implication is that the desire for greater control is not easily predictable from area-level property statistics: individual households need to be characterised.

Separately, respondents were asked express a preference between the heating being serviced, maintained and repaired for a fixed annual fee, or being responsible themselves for arranging and paying for these things as and when they are needed. The first option was preferred by 60% of respondents but this appears to be influenced heavily by the current heating arrangements, being greatest for those with district heating (74%) and least for those with only portable heaters (39%) or fixed heaters (44%). Generally, preferences were not related to characteristics of the household, the respondent's role in managing energy accounts or use of energy in the home; but there was greater demand among social tenants and households with pre-school children.

Do heat energy needs link to appeal of solutions?

Those who desire improved control are clearly differentiated from those who do not want any more control (or who would prefer more automation) – by the latter's emphasis of *Ease*. This perhaps reflects a perception that greater control will make things more complicated. The need consistently expressed more strongly by those favouring more control is *Resource*. This may be because part of the desire for control is to avoid waste and to reduce energy costs.

Heat energy solutions and renovation of the home

Respondents were asked what changes the household (or their landlord or freeholder) had made to the home in the past five years, the main reasons for these changes, and what the priorities for the future would be. It may be that the most successful approach to heat energy solutions would be to integrate them into existing household renovation; the questions therefore included options that were not specific to heat energy. Many types of changes had been made to homes in the last five years, with the following general patterns.

- Changes that are not specifically energy-related (involving adding or re-fitting rooms) had been made by 94% of households, painting or redecorating being the most popular (75%).
- Work on the heating or hot water system is reported by 75% – most commonly servicing a boiler or air heater unit (37%) or replacing a boiler (28%).
- Changes to heating or hot water controls are reported by 61%, including installing TRVs (22%); replacing or installing a heating thermostat (19%) or timer/programmer for central heating or hot water (18%). Slightly fewer (58%) had undertaken insulation or draught-proofing, most commonly loft insulation (31%).
- Only 7% had made any changes to generate electricity, most commonly using solar photovoltaic panels.

Respondents' choices about where they would like to make changes over the next five years broadly reflected the relative prevalence of work undertaken over the previous five years, but at around half the prevalence in each case. Generating electricity was the only exception to this: there was a higher demand for undertaking changes than was evidenced by the proportion who had actually done this in the recent past.

The reasons that respondents give for the changes made vary with the type of change. As echoed by the qualitative research in WP5.7, adding or refitting rooms is motivated primarily by a wish to improve the look of the home. In contrast, the other areas of renovation are overwhelmingly motivated by a wish to improve energy efficiency and to save money. Comfort and heath are also frequently cited in relation to all types of change except "Generating electricity" whereas this last category is the only for which there is substantial mention of making the home environmentally friendly. System breakdown is relevant to changes to heating and hot water systems and controls.

The other motivations recorded had less influence on decisions to make renovations to the home. It is particularly notable that the wish to make life at home easier and more practical was cited by around a third of respondents in relation to adding or retrofitting rooms but not cited by more than one-fifth in relation to any of the areas directly relating to heat energy systems. This can be seen to confirm the finding reported above, in relation to heat energy needs of households with a desire for improved control, that the desire to change is primarily driven by considerations relating to *Resource*, rather than considerations relating to *Ease*.

CONTENTS

1 Introduction

1.1 Report aims

This report presents analysis of data from the WP5.7 quantitative survey of British households in order to take forward our understanding of people's needs and behaviours that affect heat energy use at home. In doing so, it develops and quantifies learning from other strands of the project while also introducing new understandings and highlighting fundamental issues – particularly in relation to smart energy solutions.

1.2 Background and context

This study was conducted as part of the Consumer Response and Behaviour project, which is within Work Area 5 (WA5) of the Smart Systems and Heat (SSH) Programme of the Energy Technologies Institute (ETI). The ETI commissioned the SSH programme in 2012, with the objective of informing the design, development and demonstration of a cost-effective smart energy system, suitable for future roll-out within the UK.

Consumer Response and Behaviour aims to develop our understanding of consumer behaviour and provide insights into consumer needs in an energy systems context. Thus, while the SSH Programme as a whole is largely technological, this project provides an essential basis in the consumer perspective. Future energy systems will deploy new technologies and business models and will potentially feature a much greater degree of consumer involvement in the provision and management of energy-based services during the period to 2050. It is therefore important to develop a clear understanding of consumer requirements and behaviour in this context, and build these into the design features of consumer-focused products.

The particular study reported here, a quantitative consumer survey, formed part of Work Package (WP) 5.7 of the Consumer Response and Behaviour project. It aims to understand consumer needs and behaviour in relation to domestic energy usage, how these vary between different groups in the population, and their relevance to smart energy solutions.

The study builds on the work carried out in other Work Packages and our findings provide input to these Work Packages.

- WP5.6: informing the model, by providing evidence to refine understanding of actual behaviour in the home.
- WP5.4 and WP5.7 qualitative research: quantifying the needs and behaviours evidenced qualitatively so as to understand their wider relevance.
- WP5.8: establishing the needs and behaviours – and patterns of them – that the design and implementation of smart energy solutions should take into account.

The analysis focuses on these six of the 10 research questions (RQs) that were agreed for the Consumer Response and Behaviour project as a whole.

- RQ1. What needs do consumers want to meet, that involve energy use?
- RQ2. What do people currently do that uses energy?
- RQ3. Why do consumers exhibit particular energy-using behaviours?
- RQ4. How do consumer needs, behaviour, motivation and rationale vary across the population?
- RQ7. What is the likely consumer response to potential smart energy system solutions?
- RQ8. How can smart systems meet current and future needs?

These questions are founded on the expectation that what people do in relation to heat energy in the home is in some way related to a set of needs. This distinguishes the project from other large surveys in the literature that aim to inform the technical design of smart energy systems. Much of our current understanding of what drives behaviour in relation to heat energy takes the physical characteristics of the property as its starting point. The rationale for this is understandable: the characteristics of the property (age, size, type of

heating system and insulation, for example) set the boundaries of what is possible for people to do when trying to heat, cool and ventilate their home.

Despite the intuitive and pragmatic basis for starting with the physical characteristics of the property, the research presented here takes a different starting point. What we want to understand is not only what constrains and enables behaviour *when* people engage in heat energy behaviour, but the underlying goals and motivations that drive and structure their behaviour, routines and habits. Both are important; but to design smart energy solutions that are holistic and sustainable it will be crucial to understand the basic and more complex human needs we have for heat energy, not just how we currently interact with it. This forms the rationale for the overall design of the project. Without this understanding of consumer requirements at the heart of solutions design, it is possible that solutions may be technically sound but not meet the complex needs of different types of household.

The uniqueness of this study rests in this starting point of understanding consumer needs and relating them to current behaviour with current technology, and to preferences for future smart energy solutions.

At the outset of the Consumer Response and Behaviour project, we adopted a deliberately broad definition of needs to ensure we captured the full range and diversity of goals that people seek to achieve through heat energy behaviours and use. This initial definition understood heat energy needs as what people are aiming to achieve through, or achieve as a consequence of, using heat energy. This definition encompassed a wide range of needs, from those objectively essential for life, to preferences based on individual perceived requirements or values. The analysis presented in this report takes this forward by seeking to understand the different types and roles of needs, how individual needs may be characterised in terms of underlying dimensions, and how this can inform the design and implementation of smart energy solutions.

1.3 Methods

1.3.1 Sampling approach

The WP5.7 quantitative survey employed a quota-based sampling approach. Quota-based sampling involves issuing interviewers with a set of quota characteristics (e.g. tenure) and a corresponding number of interviews to be achieved in each category of each characteristic (e.g. owner-occupiers and renters). Its aim is to achieve a representative sample by reflecting the demographic make-up of the areas where interviews are sought. However, as quota sampling is not carried out using random sampling techniques, it is not possible to determine the representativeness of a sample, in particular due to the risk of sampling bias during respondent selection.

A total of 250 sample points were selected at random, covering England, Scotland and Wales, with interviewers being asked to achieve 10 interviews in each. Sample points were based on groupings of Census Output Areas, derived from the 2011 Census, and contained an average of 300 addresses.

Interviewers were issued with quotas based on three characteristics (tenure, property type and the presence of children aged under 18) and were provided with quotas in relation to binary categories of each (owner vs renter, house/bungalow vs flat, children aged under 18 vs no children aged under 18). These quotas were selected as findings from other Work Packages have shown them to be closely linked to heat energy needs and behaviours.

The sample was based upon household, rather than individual characteristics – as the primary aim was to collect data from individual respondents, relating to their household's heat energy needs, behaviours and systems. For this reason, there was no systematic respondent selection within households with regard to, for example, who pays the energy bills, who makes more of the energy decisions or who spends most time at home. Interviewers were asked to interview anyone aged over 18 living at the address without selection (or encouraging self-selection) on the basis of how householders saw their role in relation to energy (although this role was later recorded in the interview). This was to try to avoid selection bias with regard to knowledge of heat energy in the household and to avoid a sample lacking respondents with limited knowledge or understanding of heat energy in their household. We stressed to interviewers that potential respondents should be reassured that we wanted to hear from individuals with a range of involvement in (and knowledge of) heat energy use within the household.

1.3.2 Questionnaire design and piloting

The questionnaire design process was iterative in nature and involved extensive collaboration between partners in the consortium and the Energy Technologies Institute. This was particularly necessary as the survey was seeking to quantify certain needs, behaviours and attitudes to solutions uncovered or highlighted by other strands of the project. In addition, the qualitative research undertaken under WP5.4 provided considerable learning in terms of the terminology used by the public to discuss heat energy needs and behaviours, which was taken on board in the design of quantitative survey questions.

The full questionnaire was tested in a pilot in September 2013 and certain elements (especially those aspects relating to the measurement of heat energy needs) were subject to cognitive testing in October 2013.

The questionnaire pilot was undertaken using a PAPI (paper-based) approach. Pilot fieldwork lasted three weeks and involved five interviewers, who were asked to achieve 10 interviews each, using the sampling approach, procedures and doorstep materials being developed for the main-stage survey. The aims of the pilot were to:

- test the feasibility of the sampling approach and procedures being proposed for the main-stage survey;
- ascertain what guidance and documentation would be most helpful to interviewers to assist them in implementing the sampling approach, explaining the purpose of the study and securing agreement on the doorstep;
- collect accurate data on the length of the current version of the questionnaire, and its component parts;
- test individual questions to determine whether they are understood and can be answered effectively by all sections of the public, and whether they yielded data that would enable us to explore the issues being addressed by this project

Cognitive testing focussed on three proposed sort card exercises as well as some specific issues of terminology pertinent to the design of survey questions. Overall, 16 respondents were interviewed, one-to-one, lasting approximately 1-1.5 hours. The respondents who were interviewed represented different household types, dwelling types, tenure types and included both men and women and people of different income groups.

Based on the findings of the pilot and cognitive testing, the final content, structure and order of the interview materials were agreed in collaboration between the consortium and ETI in December 2013. The final questionnaire employed CAPI (computer-assisted personal interview) with respondents' answers being entered by interviewers on a laptop. In addition, two or three sort card exercises were undertaken by each respondent, focussing on the household's heat energy needs, interviewers made observations of the household's heating systems and controls and respondents were asked to fill in a self-completion questionnaire in a paper booklet.

WP5.1 and WP5.4 identified a large number of potential heat energy needs, with many participants identifying a subset of these needs as being particularly relevant. We viewed measuring heat energy needs as a central purpose of the questionnaire. The sort card approach was ideally placed to capture the subset of needs relevant to each respondent and their household – without having to ask about many needs that would not be relevant or even meaningful to them. The sort card exercise also provided an effective way to identify which needs always and which sometimes applied. More detail of the method is provided in Section 2.3 and in section 8.2.4 of the technical appendix.

1.3.3 Fieldwork

Briefings of all interviewers took place in England, Scotland and Wales in January 2014. There were 14 briefings altogether, each attended by small groups of interviewers. The fieldwork period ran from 13th January until the end of February.

The final achieved sample consisted of 2313 productive interviews. This sample closely represented the population on the three issued quotas and a range of patterns of characteristics at the population level that were not specifically accounted for in the sample design (such as age of property and size of household).

Levels of co-operation in relation to the additional aspects of the interview were relatively high: 89% of respondents agreed to an interviewer observation of their heating systems and controls, while 78% returned the self-completion questionnaire. In addition, 75% of respondents agreed to be re-contacted in the future.

1.3.4 Data preparation

Researchers developed editing and coding instructions based on an early data-set and briefed a team of data coders selected to work on the project. Coders reviewed all "other" answers and additional free-code information provided by respondents to ascertain if any how any could be re-coded into the pre-existing question code frames, or whether further codes were required. Any queries that could not be answered by the coders were reviewed by the researchers.

Before the start of analysis, consideration was given as to the need to weight the data. Because the achieved sample closely matched the population of interest on a wide range of characteristics (including the three that formed the bases of the quotas), there was less necessity to do this than in a scenario where the key subgroups of interest were not accurately represented in the final data. Nevertheless, a set of weights was developed – with the key discrepancies addressed relating to region (with households in London being under-represented) and tenure (with owner-occupiers having an over-representation of those who owned their homes outright and an under-representation of those buying their homes on a mortgage). Because none of our analysis focussed on these characteristics, all of the findings data presented in this report are based on unweighted data.

1.3.5 Approach to analysis

At the end of fieldwork, the questionnaire was reviewed to identify a bespoke set of derived variables, to be saved on the main data-set and used consistently by all analysts working on the report. An initial run of derived variable frequencies was undertaken, so as to identify a suitable level of aggregation for particular characteristics, as the basis of which to take forward the analysis.

Analysis was undertaken in SPSS. All "Don't know" and "Refusal" responses were included in bases, as they are regarded as valid response in relation to questions around heating needs, behaviours and systems. Statistical significance testing primarily involved Chi Square tests, with the creation of binary variables, and t-tests to compare frequencies or (where dependent variables were ordinal) to compare means for groups defined by an independent variable.

Analysis of the survey data has so far focused on descriptive and bivariate analysis. This is a logical starting point, and essential for understanding the data and subsequently focusing on the most relevant variables, but multivariate analysis will be required in order to gain a more complete understanding of the findings and implications. While such analysis is beyond the scope of the project as currently set up (particularly the timescale and resources), we recommend that ETI undertake further analysis in this direction.

In a small number of instances, more complex multivariate analysis has been undertaken – in the form of factor analysis and Latent Class Analysis. Factor analysis was undertaken in order to identify whether a larger number of variables could be reduced into a small number of underlying dimensions; analysis of this type was undertaken in relation to respondents' reported heat energy needs and for activities involving heating water. Finally, Latent Class Analysis was undertaken to attempt to segment households on the basis of their heat energy needs; its aim is to group people using data on associations between measures. In the Technical Appendix, Section 8.7 (p.167ff) provides more detail on this analysis and its strengths and weaknesses.

1.3.6 Data conventions

The following conventions were applied consistently throughout the report.

- While "Don't know" and "Refusal" responses are always included in the base, they are only set out in tables where they are relevant to interpretation of the findings.
- Bases (numeric) are included, along with descriptions of base membership for all tables.
- Cells containing no cases are marked "-". Cells containing less than 0.5% of cases are marked "*".

- Question text, where directly quoted, appears in speech marks and is italicised.
- We refer to differences between proportions only where they have been shown to be statistically significant – or are of substantive interest and would be significant given a larger sample size (in which case this is stated explicitly).

1.4 Report overview

This chapter has introduced the project and summarised the methods employed in the fieldwork and analysis. **Chapter 2** looks specifically at the way respondents have reported their needs and whether the data can be used to define underlying dimensions of need and/or needs-based segments of households. The dimensions proved the more useful approach and they are taken forward into the analysis presented in the following chapters.

Chapters 3, 4 and 5 present analysis on the three domains of heat energy use that represent the core of the survey:

- heating the home and keeping warm (abbreviated to “heating the home” in most of this report);
- cooling the home;
- heating water and using hot water (abbreviated to “heating water” in most of this report).

These chapters use data from the survey to explore the over-riding analysis questions and a set of more detailed questions, including those presented below.

Overriding questions:

- What is the prevalence of different heat energy systems and behaviours across British households?
- What is the relationship between systems and behaviour? Do those with different systems have different needs and behaviours?
- What are the variations in households’ heat needs?
- Do those with different needs use their available systems differently?

Detailed questions:

- What combinations of systems and controls for heating the home, heating water and cooling do British households have available to them?
- How far do respondents accurately understand the systems and controls available to them and how these are set up? This was not addressed directly in the survey but a certain amount can be deduced from combinations of data.
- In what ways and to what extent do British households use the systems and controls available to them, for heating the home, cooling and heating water?
- Are individual households consistent in what they do or do they tend to vary their behaviour in exceptional circumstances or at different times?
- Which socio-demographic characteristics or features of the home are associated with particular patterns of behaviour?

Chapter 6 pulls together the evidence from all the analysis to present insights relating to the design and implementation of smart energy solutions.

Chapter 7 presents the main conclusions from each chapter.

A **Technical Appendix** provides further details of the research method.

2 Findings: Developing a segmentation of households' heat energy needs

2.1 Key insights

1. British households have many needs that influence their use of heat energy, with good consistency between the number and priority of needs related to heating the home and heating water, and coherence with the findings from qualitative research.
2. The five particular needs most frequently identified in relation to heating the home are: being comfortable, energy costs, avoiding wasting energy, being able to rest and relax, and wanting to feel clean.[1] The least prevalent needs are related more to social factors and household routines but even the least prevalent is included by 8% of respondents, showing that none of the needs is irrelevant.
3. The many needs can be represented by five underlying dimensions of need, common to heating the home and heating water – *Hygiene*, *Ease*, *Resource*, *Other people* and *Comfort*.
4. Using these five dimensions, British households can be divided into seven needs-based segments. Although there is some evidence of segments differing in some characteristics of the household, dwelling and heating system, the relationships are not sufficiently strong to allow easily observable characteristics to act as a proxy for segment membership.
5. So, while the segments can be used to support the design of smart energy solutions, they are less useful for implementation (e.g. targeting offers, explaining the benefits) because it will be difficult to assign individual households to a segment using readily available data. Nevertheless, the underlying dimensions provide a potentially powerful means to characterise any population group that can be defined using the survey data, as a guide for design and implementation of smart energy solutions.

2.2 Introduction

This chapter uses data from the WP5.7 quantitative survey to explore the feasibility of developing a segmentation of British households' heat energy needs. In doing so, it builds on the evidence base gained to date through other areas of the project. The WP5.4 qualitative research identified the range of heat energy needs that exist among British households and how these are defined and described by the public. This learning, in conjunction with the findings of the WP5.1 literature review, informed the design of a section of the survey questionnaire to test the prevalence of these needs across British households and the relationships between them.

The WP5.4 qualitative research also suggested a possible categorisation of heat energy needs, based on four main categories (health and wellbeing, relational dynamics, agency and resources) – while more recent qualitative research under WP5.7 has refined this categorisation into a continuum of heat energy needs, along which all households will inevitably move. Here, we test the validity of these categorisations and models by exploring if and how far they are reflected in the combinations of needs reported by the population of British households as a whole.

A segmentation of British households' by heat energy needs is potentially invaluable in the development and implementation of future heat energy solutions – if it enables the heat energy needs of a household or group of households to be easily discerned and matched with a solution that both meets these needs and is acceptable to that household. WP5.1 suggested an initial theory-driven segmentation of households, and the sampling strategy for the WP5.7 quantitative survey was devised around these proposed segments (with quotas being employed to ensure a sufficient representation of households with children of specific ages, for example).

The exploration of the feasibility of the development of such a segmentation involves the following three linked stages of analysis and exploration, around which this chapter is organised.

1. The analysis of **descriptive data on the prevalence of heat energy needs**. This analysis will reveal the numbers of heat energy needs British households are trying to meet within three domains of practice: heating the home, cooling the home and heating water. In addition to showing the overall prevalence of individual needs, it will assess the extent to which heat energy needs are consistent across these three domains – both at the population level and within individual households.
2. Exploration of **whether there are a small number of underlying dimensions of need**. Here we consider whether the large number of heat energy needs measured are sufficiently correlated to enable the identification of a smaller number of underlying dimensions, on which each household can be scored. Such an approach will enable top-level analysis of the patterns of needs within different types of households, which is much easier to interpret going forward and to use as a basis on which to segment households.
3. Consideration of **how to identify and define the heat energy needs of particular types of households in a way that would be useful for those developing and implementing future heat energy solutions**. Our primary focus at the outset was on developing a needs-based segmentation; however, it was recognised that, even if such a segmentation exists, it may be of little utility to those involved in the development and implementation of heat energy solutions, given the likely difficulties in identifying the specific segments 'on the ground' using readily available demographic data – as highlighted by the WP5.1 literature review. To confirm whether this is the case, we explore how the segments developed relate to particular characteristics in relation to people, property, and energy systems and control strategies – to ascertain whether one or several characteristics exist that can serve as a "proxy" for a household's needs-based segment. We also explore an alternative approach – using the small number of dimensions of heat energy needs (developed at stage 2) as a tool for identifying the likely priorities of particular types of households – an approach which we feel could have a straightforward application to the design and implementation of heat energy solutions.

2.3 Approach to measuring households' heat energy needs

The Technical Appendix (p.158ff) presents detailed information on our methodological approach to collecting quantitative data on British households' heat energy needs. However, it is worth setting out up-front the two key aspects of our intentions for the data analysis which, as outlined above, guided our approach to its collection.

- To explore the feasibility of developing a segmentation of British households' heat energy needs, we needed data that measured a wide range of possible heat energy needs for each household in relation to the three domains of interest – heating the home, heating water and cooling. This indicated an approach where each household is required to record information in relation to each heat energy need, in relation to each of the three different domains.
- We wanted households to be considering all of their behaviours in relation to a particular domain, when they were asked about which needs they were trying to meet. For this reason, data were collected on heat energy needs after first asking detailed questions in relation to behaviours involved in heating the home, cooling and heating water. The intention was that the range of behaviours would be "top of mind" at that stage, thus increasing the likelihood of respondents taking all relevant issues into account, although the actual impact cannot be stated with certainty. Keeping the sorting exercises in sequence eliminates risk of the card sorts progressively influencing responses in the previous three sections; is quicker and easier for respondents and interviewers; and makes it clearer how the three sorts differ.
- However, there are also some potential risks to keeping the order the same in that the first sort may influence respondent choices in subsequent sorts. However, the focus of our analysis is on the card sort relating to heating the home. Had we have randomised the order of the cards the effects on the heating the home exercise would have been unpredictable, weakening the analysis of this set of data. The data also show that there was variation across in how the cards were sorted by respondents.

Data on households' heat energy needs were collected using two or three sort card exercises with each respondent. In each exercise, the respondent was asked to identify which of 21 possible heat energy needs constituted "big factors", "small factors" or were "not a factor" for their household when deciding how to heat the home and keep warm, deciding how to heat water, or deciding how to cool the home. Those households

identifying five or more heat energy needs as “big factors” were asked to identify up to three that were the most important to them. The 21 heat energy needs asked about were identified from the WP5.4 qualitative research and WP5.1 literature review, with the former also guiding the terminology that was used to describe them to respondents. In addition, we provided domain-specific examples of heat energy needs to respondents, so that they could see some specific examples of how a particular heat energy need might occur in practice.

While all respondents were invited to complete the sort card exercises in relation to heating the home and heating water, it was recognised that cooling is an area in which only a minority of households will have systems or technology in place to assist them (specific details on numbers are presented in Chapter 4 of this report). Only those respondents who used an air conditioning system, mechanical ventilation or a heat pump in order to keep cool at any point in the year were asked to complete the sort card exercises on cooling the home. While this means that the data collected are relevant to only a subset of the population of British households (83 in total in our sample), it may provide some indication of the cooling needs households would be trying to meet, were these systems to become more popular or to be integrated into more general heat energy solutions (as in the case of a heat pump). Nevertheless, it must be recognised that this subset may constitute “early adopters” of technologies – a behaviour which it itself may be driven by quite specific needs, experiences and preferences.

2.4 The number, range and consistency of heat energy needs among British households

2.4.1 Introduction

We first consider the number, range and consistency of heat energy needs among British households. In addition to providing useful descriptive data in relation to this topic, the data presented will enable us to answer three preliminary questions in relation to potential further analyses of heat energy needs.

1. Which level should any further categorisation or segmentation of households’ heat energy needs focus on – those needs that respondents identified as “big factors”, those that are identified as being a factor at all or those identified as the 3 most important factors?
2. How varied are households in the number and range of their heat energy needs? Does this level of variation suggest that further categorisation/segmentation will be effective?
3. How consistent are British households in the needs they are seeking to meet in relation to heating the home, heating water and cooling? Does this suggest that any more complex analyses can be limited to one single domain, or that three separate exercises are needed?

2.4.2 Number of heat energy needs

As shown in Table 2.1, British households report that they are trying to meet a large number of heat energy needs when heating the home, heating water and cooling; this needs to be understood when designing smart energy solutions. The picture in relation to heating the home and heating water is rather similar: respondents identified mean of 9.4 and 8.6 big factors respectively, with around half of the remaining heat energy needs asked about being classified as small factors – 5.5 in relation to heating the home and 5.4 in relation to heating water. A mean of just 5.3 possible heat energy needs were categorised as being not a factor in relation to heating the home, while the comparable number for heating water was 5.5.

For the subsample of respondents asked about cooling the home, the picture that emerges is rather different. Fewer needs on average are identified as being big factors (7.0) although a similar number of needs were selected as not being a factor in their decision-making (6.9).

Table 2.1 Mean number of heat energy needs identified as big factors, small factors and not a factor

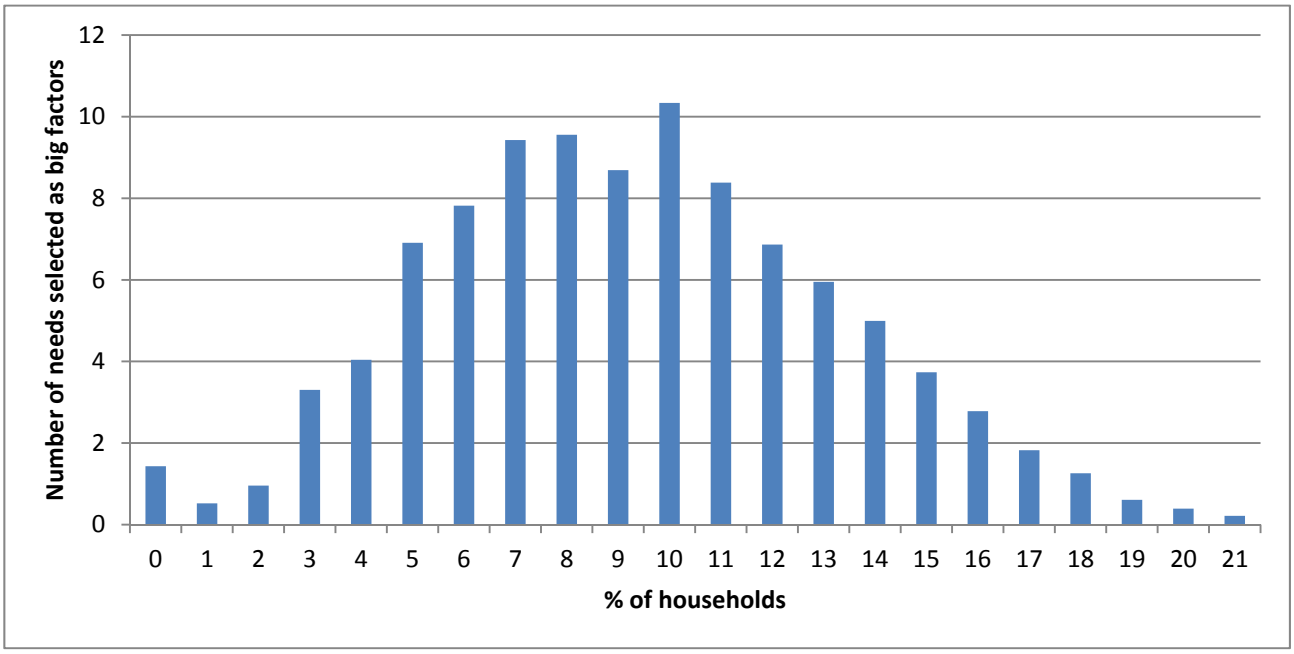
Heat energy domain	Big factors	Small factors	Not a factor	Base
	Mean number of needs placed in category			
Heating the home	9.40	5.52	5.29	2287
Heating water	8.62	5.42	5.52	2287
Cooling	6.99	5.18	6.90	83

Base: all respondents who completed each sort card exercise.

While these data indicate that British households are, on average, seeking to meet a considerable number of heat energy needs, particularly when heating the home and heating water, they do not tell us the extent to which this varies across British households as a whole. Do these averages conceal the fact that many households are in fact attempting to meet a much larger or smaller number of needs – or are households generally rather similar in the number of needs they are trying to meet?

Figure 2.1 presents data on the numbers of heat energy needs different households are trying to meet when heating the home. It demonstrates that this figure varies quite dramatically among households. While there is a clear peak between 5 and 12 needs, considerable proportions of households report trying to meet a greater or smaller number of needs than this. No specific number of needs was identified by more than 10% of households, indicating just how varied they are on this matter.

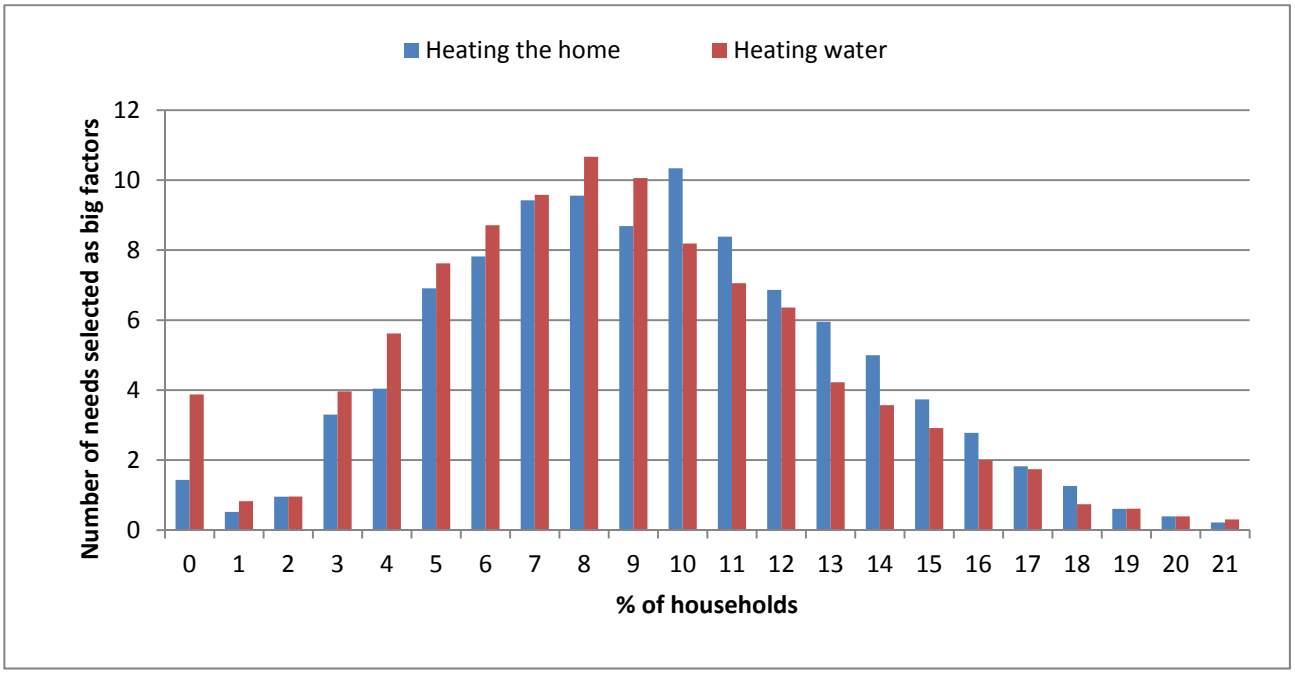
Figure 2.1 Number of energy needs when heating the home identified as big factors



Base: all respondents who completed heating home sort card exercise (2287).

When we plot the number of needs households are attempting to meet when heating water, compared to when heating the home (Figure 2.2), we see that patterns of numbers of needs in relation to these two domains are rather similar – though there is a slight tendency for households to be seeking to fulfil smaller numbers of needs when heating water – as suggested by the mean numbers of needs reported above.

Figure 2.2 Number of energy needs identified as big factors, for heating the home and heating water

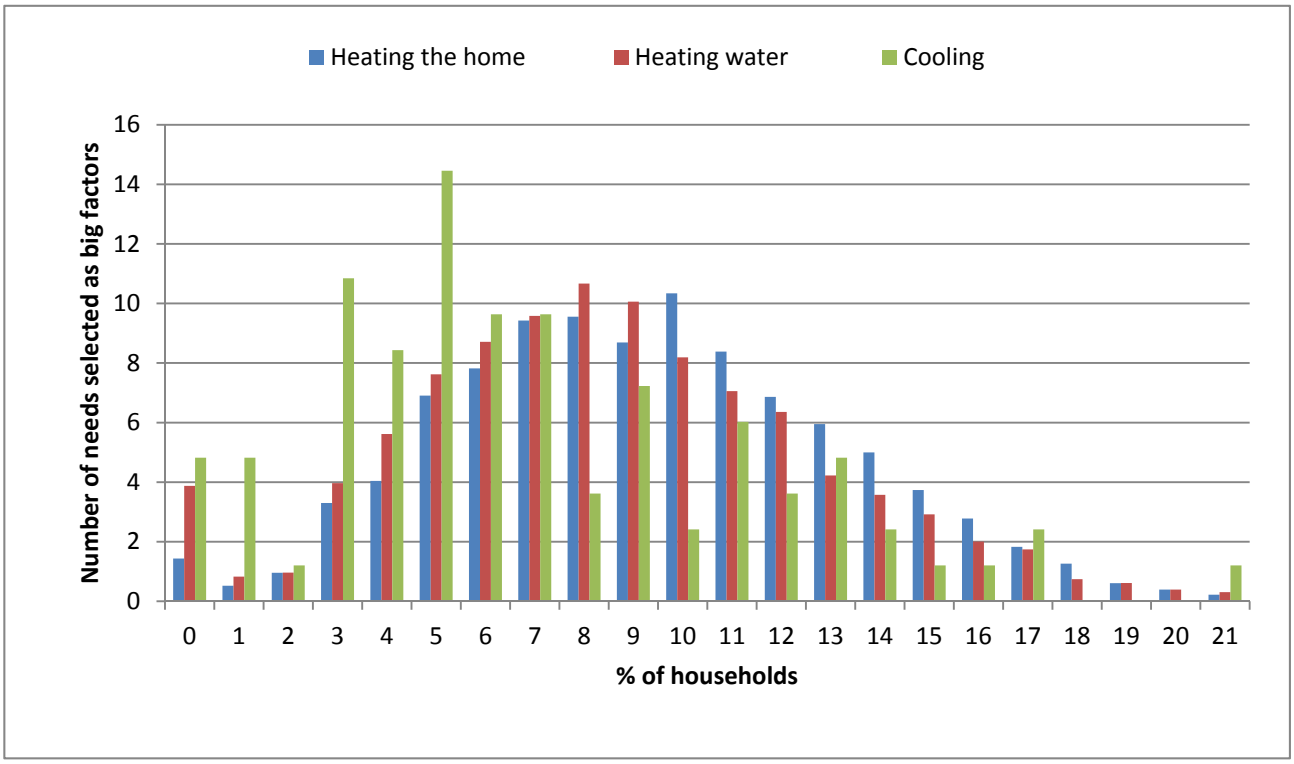


Base: all respondents who completed heating home sort card exercise (2287) and heating water sort card exercise (2287).

However, the number of needs in relation to cooling the home, reported by the subset of households asked about this domain, is rather smaller (Figure 2.3). There is a peak at three and five needs, after which the proportion of households reporting particular numbers of needs tails off. However, this should be treated as indicative, as just 83 households used equipment or technology (other than windows and doors) for cooling the home, making them eligible for the card sort exercise.

In addition, this subsample might be different from the population of British households as a whole – they might be better off, enabling them to purchase technology for cooling, or they might be early adopters of all types of technology. When we compared the numbers of needs being met when heating the home and heating water, compared to those for cooling, for this subsample alone, we found that the numbers of big factors they selected for the two other domains (heating the home and heating water) were very similar to those for the population as a whole – at 9.5 big factors and 9.0 factors respectively. So, even those with systems or technologies for cooling report fewer needs in relation to this domain.

Figure 2.3 Number of energy needs identified as big factors, for heating the home, cooling the home and heating water



Base: all respondents who completed heating home sort card exercise (2287), heating water sort card exercise (2287) and cooling sort card exercise (83).

2.4.3 Range of heat energy needs

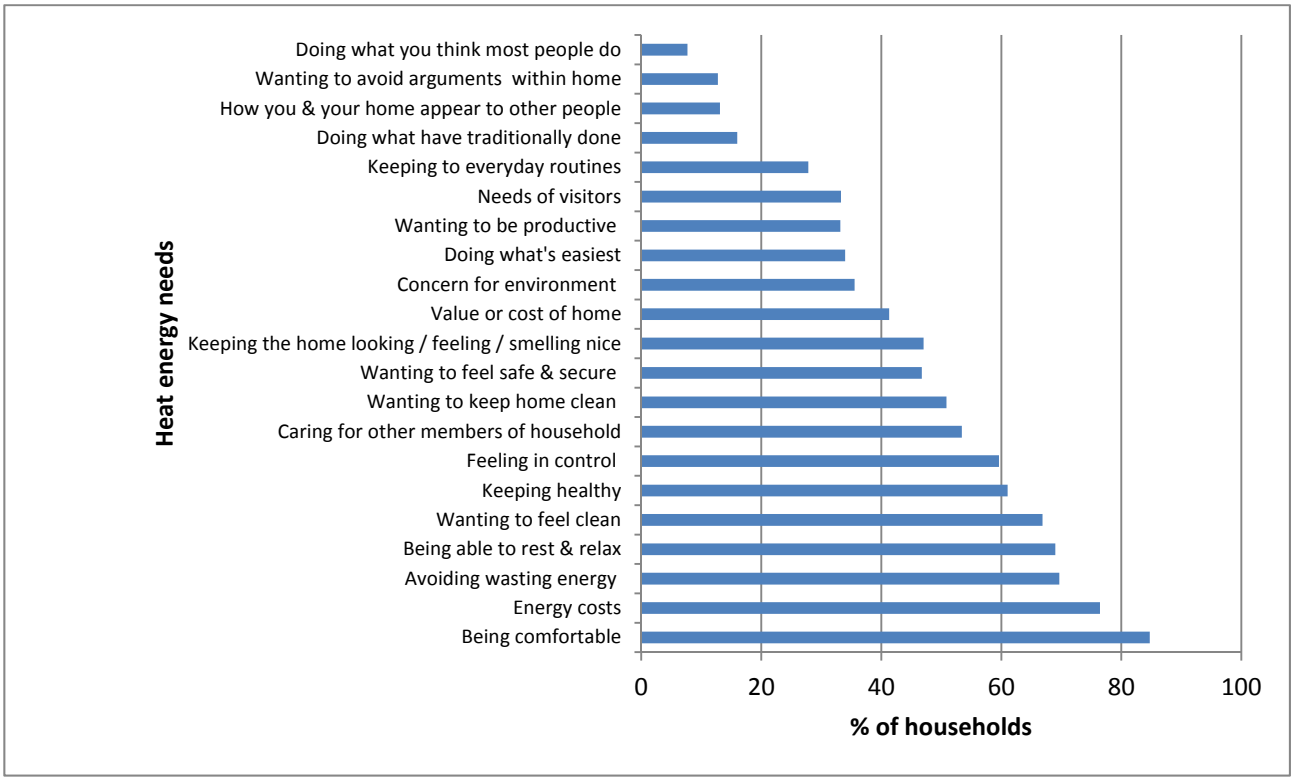
While British households clearly vary in the number of needs they try to meet when heating the home, heating water and cooling, it may be there is more uniformity in the particular needs that they are trying to meet – in that some may be much more universal and others relatively rare.

As demonstrated in Figure 2.4, when it comes to heating the home the prevalence of the 21 heat energy needs asked about varies substantially. More than two-thirds of households identify five particular heat energy needs as being big factors for them – being comfortable, energy costs, avoiding wasting energy, being able to rest and relax, and wanting to feel clean.[4] This reflects the findings of the WP5.7 qualitative research, which argued that comfort and energy costs were primary needs when heating the home for all types of households and that other needs were not considered substantially until these needs had been met. Health was also identified as a primary need; the survey findings confirm that it is important although in sixth place behind he needs mentioned above (most likely because it is a met need in most cases).

Some of the 21 needs asked about, identified from the WP5.1 literature review and WP5.4 qualitative research, turn out to be relatively rarely prioritised by British households – particularly those that were classified in WP5.4 as sitting in categories of need defined as “Agency” or “Relational dynamics”. Less than three-tenths of households indicated that keeping to everyday routines, doing what has traditionally been done, how they and their home appeared to other people, wanting to avoid arguments within the home and doing what they thought most people do were big factors for them when deciding how to heat the home. This may, however, reflect a general tendency for people to believe they are not influenced by what other people think or do; in the qualitative research, these needs were not necessarily “top of mind”, but arose from in-depth discussions with respondents. The qualitative research also characterised these needs as being more peripheral than the “core” needs that were more frequently identified as big factors in the survey.

[4] In the context of heating the home, “wanting to feel clean” relates to the options provided by heating, such as having a warm bathroom of having radiators on which to dry clothes.

Figure 2.4 Prevalence of heat energy needs as big factors, when heating the home

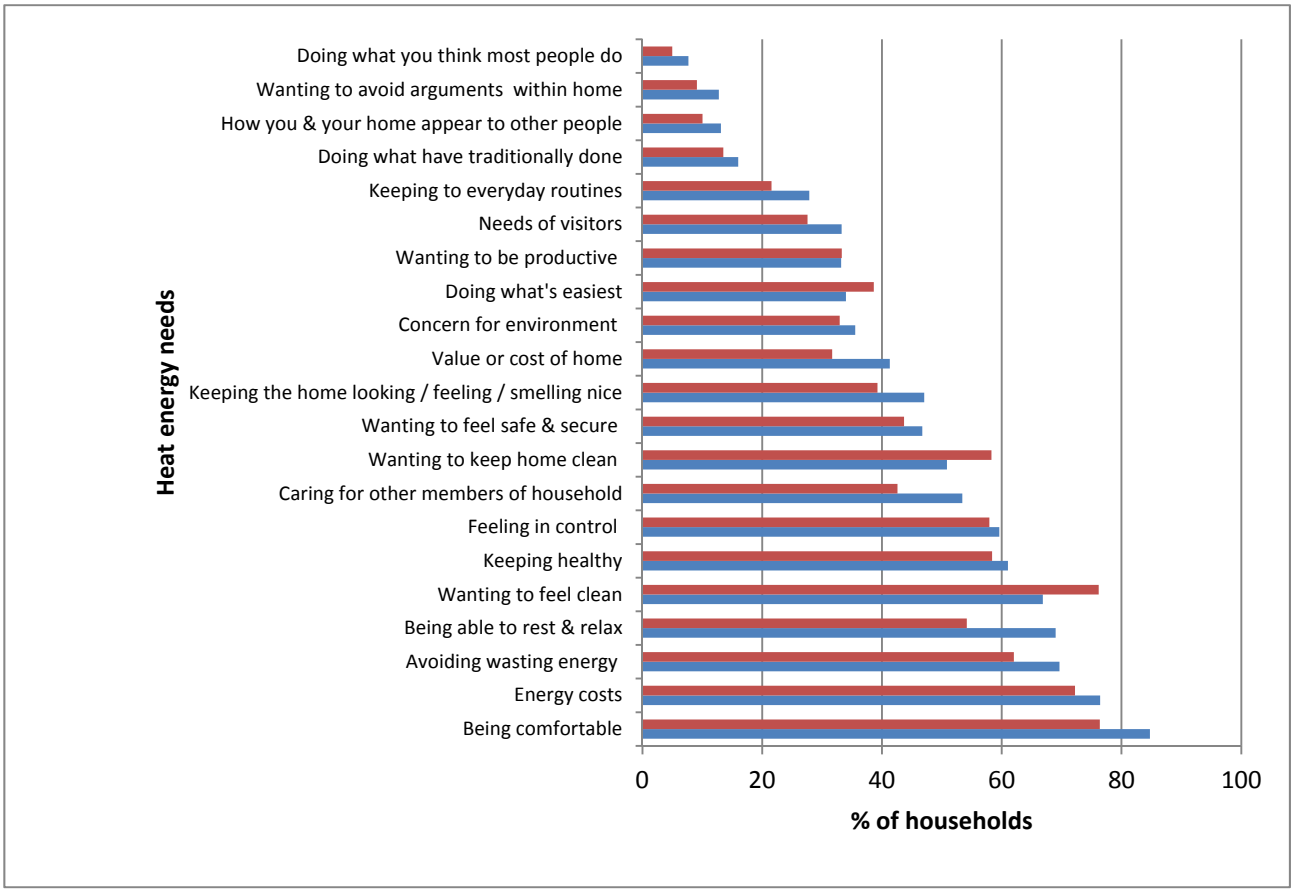


Base: all respondents who completed heating home sort card exercise (2287).

When we map the prevalence of individual needs for heating water, identified as big factors, against those for heating the home considered above, the picture that emerges is extremely similar (Figure 2.5). In the vast majority of cases, the proportion of British households identifying a particular need as a "big factor" is very similar in relation to heating the home and heating water. However, some significant and substantive differences emerge.

- Most needs are more commonly reported in relation to heating the home compared to heating water. This significant for being comfortable (85% vs 76%), avoiding wasting energy (70% vs 62%), being able to rest and relax (69% vs 54%), caring for other members of the household (53% vs 43%), and the value or cost of home (41% vs 32%).
- Exceptions to this are a greater prevalence for heating water, compared to heating the home, for wanting to feel clean (76% vs 67%) and wanting to keep the home clean (58% vs 51%). These exceptions are not surprising, given some of the key uses of heating water are for cleaning the person and the home (see Chapter 5 for further details).

Figure 2.5 Prevalence of heat energy needs as big factors, when heating the home and heating water



Base: all respondents who completed heating home sort card exercise (2287) and heating water sort card exercise (2287).

2.4.4 Households' most important heat energy needs

As noted previously, those respondents who identified more than five heat energy needs as being big factors in relation to any of the domains were asked to indicate up to three of these five needs that were the most important to them. Their answers were integrated with data on big factors for those respondents who provided fewer than five big factors in the first instance, which can be taken as being broadly comparable. These data potentially provide further insight into the prioritisation of heat energy needs in relation to different domains for British households.

A number of key trends and variations emerge.

- **Being comfortable and energy costs are the most popular "top 3" factors for British households when it comes to heating the home** – being selected by 58% and 51% of respondents respectively. This endorses the conclusion of the WP5.7 qualitative research, which argued that these constitute fundamental needs for British households. However, the fact that almost half did not prioritise these needs as being among their top 3 merits further consideration. It may be that, for these households, these needs are already easily being met – meaning the households are prioritising other, harder to meet, needs. The qualitative research argues that needs operate along a continuum, with households invariably trying to achieve those that are most essential (comfort and health) first.
- No other "top 3" need for heating the home is selected by more than 30% of households. Interestingly, almost half of the 21 needs asked about (10) are only "top 3 needs" for less than one-tenth of households. This suggests a considerable degree of consistency among British households in their prioritisation of the most important needs when heating the home.

- Less consistency is evident in households' top 3 needs when it comes to heating water. Once again, being comfortable and energy costs predominate – being identified by 42% and 48% of households respectively. However, wanting to feel clean also emerges as a key priority need, being selected by 40% of households in relation to heating water (compared to just 17% in relation to heating the home). This is not surprising; as mentioned above, some key activities undertaken with water involve keeping clean.
- Once again, around half of the heat energy needs asked about (11) are identified as being "top 3" needs for less than one-tenth of households.

A number of conclusions can be drawn from the data presented above. Clearly, there is considerable consistency among British households in the heat energy needs that they prioritise as being most important when heating the home and heating water – though it should be remembered that no "top 3" need was selected by more than six-tenths of respondents in relation to either of the two domains. Although some differences emerge between the two domains, which clearly relate to the different activities households are undertaking when using heat energy, there is a considerable degree of similarity among households in the prevalence of the heat energy needs that are the most important to them.

In terms of utilising these data for segmenting British households, these findings suggest two approaches.

- In order to segment households on their heat energy needs, it is likely to be more appropriate and meaningful to include all of those needs that were identified as big factors, not just the top three. On the one hand, this will allow our segmentation to account for diversity in numbers of heat energy needs reported by different households. On the other, it will ensure that any segmentation developed does not over-simplify what is clearly a complex picture – with the average British household prioritising around 9 heat energy needs when heating the home and heating water. All the needs were identified as big factors by a proportion of respondents (see Section 2.4.3). If far fewer needs had been identified as big factors, it might have been necessary to include needs identified as small factors to establish priority needs. However, the statistics indicate that the big factors are sufficient for this task and we therefore concentrate on these in the subsequent analysis.
- The number of heat energy needs and the prevalence of individual needs are remarkably similar in relation to the domains of heating the home and heating water. Although further investigation, presented below, is necessary as to the extent to which this is the case within individual households (as well as at the population level), this degree of similarity suggests that one segmentation or categorisation might adequately be developed to describe simply the heat energy needs of British households in relation to both domains.

2.4.5 Consistency of heat energy needs

As noted above, the prevalence of different heat energy needs is generally very similar in relation to heating the home and heating water, with some discrepancies that can clearly be explained on the basis of the activities that these domains involve. However, we cannot necessarily conclude from the degree of similarity, at the population level, that individual households are consistent in the extent to which they prioritise individual needs; it is this matter that we consider next.

Table 2.2 sets out the proportions of respondents categorising individual needs in particular ways in relation to heating the home and heating water, with the first column of percentages showing the proportion who allocated each need consistently (either as being a big factor in relation to both domains or as not being a big factor in relation to both domains). The remaining four columns show in detail the consistencies and inconsistencies.

While there is a clear trend for respondents to categorise particular needs in the same way in relation to the two domains, there is a degree of variation that exists that implies that this cannot simply be a function of completing two card sort exercises in quick succession. The greatest degree of consistency is evident in relation to the categorisation of the need "doing what you think most people do" – with 92% of respondents placing this in the same category in relation to the two domains. On the other hand, just 65% of respondents categorised the need to keep the home clean in the same way, when considering heating the home and heating water.

Table 2.2 Extent to which individual households categorise individual needs in the same way for heating the home and heating water

Need	% categorising the need in same way for both domains*	% selecting the need as a big factor for:			
		both heating the home and heating water	neither heating the home nor heating water	heating the home but not heating water	heating water but not heating the home
Doing what you think most people do	92	2	89	5	2
Wanting to avoid arguments within home	89	5	83	7	4
Doing what have traditionally done	87	8	78	8	5
How you & your home appear to other people	87	5	81	8	5
Concern for the environment	83	26	57	9	7
Energy costs	82	65	17	11	7
Being comfortable	78	69	9	15	7
Caring for other members of household	77	37	40	17	6
Keeping to everyday routines	76	13	63	15	9
Value or cost of home	75	24	51	17	7
Needs of visitors	75	18	57	15	9
Avoiding wasting energy	74	53	21	16	9
Keeping healthy	72	45	26	15	13
Feeling in control	70	44	26	15	14
Doing what's easiest	70	21	49	12	17
Wanting to be productive	69	18	51	15	15
Wanting to feel safe & secure	68	29	39	17	14
Keeping the home looking / feeling / smelling nice	68	27	41	19	12
Able to rest/relax	67	45	22	24	9
Wanting to feel clean	67	55	12	11	21
Wanting to keep home clean	65	37	28	14	21

*I.e. categorising the need consistently for heating the home and heating water (as a big factor in both instances or not a big factor in both instances).

Base: all respondents who completed both heating home and heating water sort card exercise (2280).

To some extent, the degree to which respondents are consistent in their allocations can be explained by differences between the two domains being considered and the nature of the heat energy needs themselves – some of which would necessarily link to much broader underlying values and preferences (such as concern for the environment and energy costs, the latter for example may link to a more general concern

about finances). Those needs that are categorised in the same way by fewer than seven-tenths of respondents (wanting to be productive, wanting to feel safe and secure, keeping the home looking, feeling and smelling nice, being able to rest and relax, wanting to feel clean and wanting to keep the home clean) in many cases have rather different relationships with the two domains of activity – which might explain these differences. Nevertheless the fact remains that in the majority of cases (15 out of 21 needs), households view individual needs in much the same way in relation to heating the home and heating water – suggesting that a segmentation or categorisation of needs, developed on the basis of one of these domains, would be likely to be generally applicable and relevant to the other.

In the sections above, we have discovered that British households are trying to meet a large range of needs when heating the home, heating water and cooling. Some needs are much more prevalent than others, though a greater degree of consistency emerges when we consider households' three most important needs. In general, there is a considerable degree of consistency between the range and prevalence of heat energy needs in relation to heating the home and heating water – both across the population as a whole and among individual households.

In the next sections, we consider whether a higher level categorisation or segmentation of heat energy needs exists, that could be applied more readily to the development and implementation of heat energy solutions. We first consider whether data in relation to the 21 heat energy needs reviewed above can be combined in such a way as to develop a top-level categorisation of households' patterns of heat energy needs. We then consider whether households within Britain can be usefully grouped, depending on their pattern of needs.

2.5 Do underlying dimensions of heat energy needs exist?

To establish whether a smaller number of underlying dimensions of heat energy needs exist, we undertook two factor analyses – one in relation to heating the home, the other in relation to heating water. Part of the rationale for undertaking the two analyses was to test our hypothesis, outlined above and supported by an initial review of the data, that the heat energy needs that exist in relation to the two domains are broadly similar for British households – and thus that any more refined categorisations developed will also be largely similar.

The Technical Appendix (p. 169) includes detailed information on our approach and outputs. In the subsequent sections, we focus on the information that will assist with the interpretation of the findings of the analyses and the assessment of their validity.

2.5.1 Factor analysis for heating the home

An initial review of the data suggested that sufficient correlation exists between all pairs of heat energy needs in relation to heating the home for factor analysis (which seeks to generate a smaller number of underlying dimensions) to be an appropriate technique to apply to the analysis of these data. Moreover, there is no evidence of multi-collinearity (near-perfect correlation between any pair of variables) which would suggest that they were measuring the same need, and would invalidate this approach.

Our analysis suggested that five underlying factors (dimensions) of need exist for heating the home; in combination, these dimensions explain 44% of the variance in the data. This figure indicates that a considerable proportion of the variation in the data (more than half) cannot be explained by the five underlying dimensions and, in effect, does not fit into a neat pattern or series of patterns across the population as a whole. This reflects both random variance and the sheer diversity identified in other areas of the programme in relation to the range and balance of heat energy needs that exist across different households. Nevertheless, such levels of variance explained are fairly common for models of this type and a review of relevant statistics suggested that this factor solution was a very effective one for summarising the underlying data (see Technical Appendix, p.167, for further details).

These five dimensions and the individual heat energy needs that they encapsulate are presented in Table 2.3. The range of needs that contribute to each of the five dimensions suggested that these dimensions could be labelled as *Hygiene*, *Ease*, *Resource*, *Other people* and *Comfort*. The five dimensions can be characterised as follows.

- *Other people* is defined by five individual needs: caring for other members of the household, wanting to avoid arguments within home, needs of visitors, how you & your home appear to other people, and wanting to be productive. This dimension represents a concern for other people, whether within or outside the household. The inclusion of productivity is intriguing, suggesting that this need may be interpreted in relation to being able to get on with work within the home, facilitated by cordial relationships and mutual support.
- *Comfort* is defined by three individual needs: being comfortable, feeling in control, and being able to rest and relax. Whereas the specific need, "being comfortable" relates primarily to thermal comfort, the *Comfort* dimension has broader connotations of being at ease, in control and free of concerns.
- *Hygiene* is defined by five individual needs: wanting to feel clean, wanting to keep the home clean, keeping the home looking/feeling/smelling nice, keeping healthy, and wanting to feel safe & secure. It represents hygiene in both the specific modern English sense relating to cleanliness and the broader (original) sense of healthiness[5]. It also relates to Herzberg's two-factor theory of occupational psychology, in which "hygiene factors" (including work conditions) do not positively create satisfaction or motivation, whereas dissatisfaction results from their absence. In our context, this dimension denotes basic needs that tend to be regarded as fundamental but often taken for granted if they are met.
- *Resource* is defined by four individual needs: energy costs, avoiding wasting energy, the value or cost of the home, and concern for the environment. This dimension has a clear financial focus although "waste" can also be seen from a non-financial perspective as something that is inherently wrong. It is particularly interesting that concern for the environment fits in this dimension, perhaps indicating that protecting the environment is seen as a consequence of the same actions that save money and avoid waste, rather than being a strong motivator in its own right.
- *Ease* is defined by four individual needs: doing what's easiest, keeping to everyday routines, doing what you have traditionally done, and doing what you think most people do. It represents convenience and simplicity, adopting (perceived) norms and other familiar behaviours which serve to make life easier because we do not have to think about what we are doing every time we do it., in this case managing the heating in home.

While we view these labels as largely self-explanatory and data-driven, it is worth noting that the *Hygiene* label in particular is intended to denote those very basic needs in the areas of health, security and so on that tend to be regarded as fundamental to households and individuals (though are often taken for granted if they are met).

[5] Hygiene is therefore used here in its broad sense, as adopted by British Occupational Hygiene Society (http://www.bohs.org/aboutus/) – and the American equivalent (https://www.aiha.org/Pages/default.aspx).

Table 2.3 Underlying dimensions in relation to heating the home and their link to the original set of heat energy needs

Detailed heat energy needs	Dimension of heat energy needs				
	Hygiene	*Ease*	*Resource*	*Other people*	*Comfort*
Wanting to feel clean	++				
Keeping healthy	+				
Wanting to keep home clean	++				
Wanting to feel safe & secure	+				
Keeping the home looking / feeling / smelling nice	++				
Doing what's easiest		++			
Keeping to everyday routines		++			
Doing what have traditionally done		++			
Doing what you think most people do		++			
Energy costs			++		
Avoiding wasting energy			++		
Concern for environment			++		
Value or cost of home			+		
Caring for other members of household				++	
Wanting to be productive				+	
Needs of visitors				++	
How you & your home appear to other people				+	
Wanting to avoid arguments within home				++	
Being comfortable					++
Feeling in control					+
Being able to rest and relax					++
Base	2287				

Note: + denotes a positive relationship between the specific heat energy need and the underlying dimension of need – interpreted by a component score greater than +0.2 or -0.2 (++ denotes a factor score greater than +0.3 or -0.3).

Interestingly, these five dimensions and their linkages with the original 21 heat energy needs are rather similar to the initial categorisation developed from the WP5.4 qualitative research.

- The qualitative research suggested four broad categories of need (Health and well-being, Relational Dynamics, Agency and Resources) of which 8 specific sub-needs that were found to be have the most influence on daily, routine behaviour (health and comfort, cost and waste, control and convenience, harmony and hospitality). The factor analysis applied to the survey data indicates the existence of five dimensions of need within the population as a whole. In essence, the Health and well-being category identified through the qualitative research was found to divide into two different dimensions – labelled *Hygiene* and *Comfort*.
- The qualitative research sought to place individual heat energy needs in the different broader categories of need, whereas our factor analysis indicated which individual needs significantly contributed to the different dimensions (as set out in the table above). The two approaches to the categorisation of heat energy needs produced broadly similar results, with four notable exceptions:
  - the qualitative research categorised concern for the environment under Relational Dynamics whereas our analysis found it to contribute to the *Resource* dimension;
  - the qualitative research categorised the need to be productive as an element of Health and well-being whereas our analysis found it to contribute to *Other people* (because it tends to co-occur with the other needs in this dimension, not necessarily for any theoretical reason);
  - the qualitative research regarded the need to be in control as an element of Agency, whereas our analysis found it to contribute to the *Comfort* dimension;

- the value or cost of the home was categorised as a need relating to Resources by the qualitative research, but was not found to contribute strongly to any of the five dimensions of need generated from the quantitative data (although it was most closely related to *Resource*).

Nevertheless, it should be emphasised that the two different methodological approaches to the identification of underlying dimensions of heat energy needs for heating the home produced remarkably similar results, with 17 of the original 21 heat energy needs being categorised in the same way – confirming the validity and wider applicability of each approach.

The qualitative research also found that households' needs shift over time – sometimes within a day. This might suggest that households will move between segments and the needs profiles and segments themselves will be unstable. While this cannot be tested directly by using the survey data, there are three factors that make it unlikely.

- The survey asked for a general response rather than a response at a particular point in time.
- Respondents could choose any number of needs and so could identify any that are sufficiently important to them – they were not restricted to needs that are relevant at a particular time or in a particular context.
- While individual households might change over time, the survey provides data at population (or sub-population) level rather than individual level. Changes in individual households should therefore "cancel out" so long as a sufficiently large number of households are included in the population or sub-population.

Reflecting on the third point, the needs should vary over a lifetime and that is part of their value: it is possible to observe what is important to households that are at different stages. This is observable and interpretable variation, rather than instability. The factors (and any derived segments) remain, while individuals may move in or out of them over a period of years.

2.5.2 Factor analysis for heating water and using hot water

As indicated above, a similar analysis was undertaken for the heat energy needs reported by households in relation to heating water. Again, five underlying dimensions of need were identified by the factor analysis which, combined, accounted for 46% of the variance among households in their categorisations of the original 21 measures of need. Our consideration of these dimensions and their relationships with the original needs suggests an identical approach to labelling to that outlined above in relation to heating the home, although the ordering of the underlying dimensions occurred differently in relation to the two domains, as shown in Table 2.4. This difference in ordering simply indicates that, for instance, the *Ease* explains a greater proportion of the variance in relation to heating the home than heating water, while *Other people* explains a greater proportion of variance in relation to heating water. In practice, the variance explained by each of the five individual dimensions was very similar for the two models (see Technical Appendix, p.167 for further details).

Table 2.4 Underlying dimensions of heat energy need, heating the home and heating water

	Dimension of heat energy needs				
Domain	1st dimension	2nd dimension	3rd dimension	4th dimension	5th dimension
Heating the home	*Hygiene*	*Ease*	*Resource*	*Other people*	*Comfort*
Heating water	*Hygiene*	*Other people*	*Resource*	*Comfort*	*Ease*

When we consider how the original 21 heat energy needs relate to the five underlying dimensions across the two factor analyses, the patterns of linkages identified are rather similar, as depicted in Table 2.5. Where an individual need contributes to the same underlying dimension across the two factor analyses, the appropriate cell is coloured in red; this was the case in relation to 17 of the 21 original needs, indicating that the relationships between the individual heat energy needs and broader dimensions of need are extremely similar in relation to heating the home and heating water. Orange and blue cells indicate that the original needs contribute to different dimensions for heating the home (orange) and heating water (blue). Question marks of the same colours indicate a potential degree of uncertainty about this, resulting from component scores on one dimension that are smaller but where the need might nevertheless help to inform how the dimension is characterised.

Comparing the needs that contribute to each dimension for heating the home and for heating water, the following differences can be noted.

- *Hygiene*: wanting to feel safe & secure is included for heating the home (where it relates more to the basic safety of the heating facilities) but not for heating water (see *Other people*).
- *Ease*: three of the same needs appear for heating the home and heating water but, in relation to heating water, it also includes avoiding arguments within the home (which could mean, for example, having a routine or system for who bathes when). In contrast to heating the home, the heating water dimension does not include doing what is easiest (which could relate to how water is used by individuals – e.g. the choice of shower over bath – more than ease of managing how water, which tends to be more of a background activity, as explained in Chapter 5).
- *Resource* is defined by the same four needs in each case.
- *Other people* is defined by four of the same needs in each case but wanting to be productive appears for heating the home but not for heating water, where it appears for comfort instead. If wanting to feel safe & secure appears anywhere for hot water, it is in this dimension, where it pertains to scalding risk.
- *Comfort* is defined by three of the same needs in each case. For heating water, it also includes doing what's easiest and wanting to be productive. As noted under *Ease*, heating water might relate to how water is used by individuals more than ease of managing how water

Table 2.5 Patterns of linkages between heat energy needs and underlying dimensions, heating the home and heating water

Detailed heat energy needs	Dimension				
	Hygiene	*Ease*	*Resource*	*Other people*	*Comfort*
Keeping healthy					
Wanting to feel clean					
Wanting to keep the home clean					
Keeping the home looking, feeling or smelling nice					
Wanting to feel safe and secure				?	
Doing what you think most people do					
Keeping to your everyday routines					
Doing what you have traditionally done					
Doing what is easiest					
Energy costs					
The value or cost of your home	?			?	
Concern for the environment					
Avoiding wasting energy					
How you and your home appear to other people					
The needs of visitors					
Wanting to avoid arguments / disagreements within the home					
Caring for other members of the household					
Wanting to be productive					
Being comfortable					
Being able to rest and relax					
Feeling in control					

The needs would also tend to have different expressions, even if included in the same dimension; for example, wanting to feel clean could relate to heating the home to achieve a warm, comfortable bathroom but be more directly related to heating water as a means to get clean. This is an example of one need being

met by first meeting another. Nevertheless, while the underlying needs are expressed differently for heating the home and heating water, the same dimensions can be discerned. The dimensions make logical sense and clearly validate the categorisation developed for the WP5.4 qualitative research, while suggesting that a small number of needs should be re-aligned when we explore this categorisation at the population level.

Given this similarity, it seems logical to focus on heating the home and develop just one segmentation of British households' heat energy needs, on the basis that any comparable exercise for heating water would produce results that would be largely similar. It can also be observed that – while the two card sorts do show distinct differences – the one for heating water might have been influenced to some extent by the prior one for heating the home. Hence the data for heating the home have greater *prima facie* validity.

2.6 Can we segment British households by their heat energy needs?

In this section, we explore whether British households can be segmented on the basis of the needs they try to meet when heating the home, using the five underlying dimensions of need reported above. To do this, we undertook Latent Class Analysis. This is a technique used to identify "latent classes" or segments of people or, in this case, households – based on a range of pre-specified measures. These classes or segments are identified on the basis of the association of different measures within the data (in this case the five underlying dimensions of heat energy needs) – rather than any specific measures that can be observed directly from the data.

Further details on this approach can be found in the Technical Appendix (p.167).

The Latent Class Analysis indicated that a seven-class model was optimal for segmenting households. Ideally (although unrealistically in practice), the result of the analysis should be that each individual has a probability of one of being in one class and zero of being in other classes, showing that the model assigns individuals into their designated class with complete accuracy. An examination of the average membership probabilities indicated that the probability of being assigned to a class for which households have the highest probability was 0.78; in other words, the likelihood of assigning an individual household to the class that best fits their need profile is 78%. The percentage of households that had a class membership probability of less than 0.6 was between 13% and 23% for different classes. This suggests that there is still some variability within classes, which can make interpretation difficult because there are some households that cannot clearly be assigned to one of the derived classes or segments. However, the levels of these probabilities are not unusual for Latent Class Analysis of this sort – but they need to be borne in mind in the interpretation and application of these classes through additional analyses and development.

In Table 2.6 and Figure 2.6, we summarise the characteristics of the derived segments, in relation to the size of their membership and their heat energy needs profile – based on their average number of heat energy needs and their average scores on each of the five underlying dimensions of need. From these data, we can discern the following.

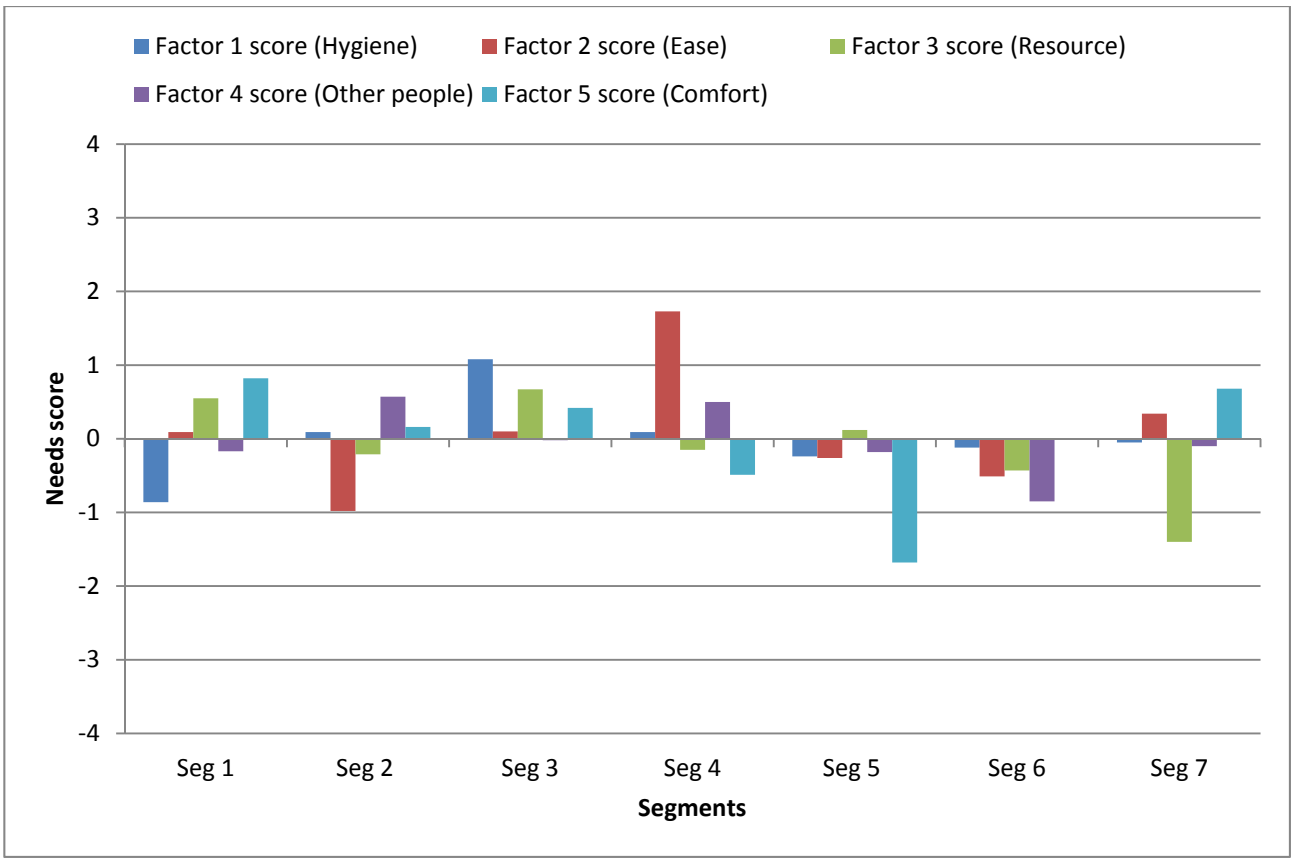
- The seven needs-based segments are relatively evenly sized – each covering between around one-tenth and two-tenths of the population of British households.
- Some segments have a much higher number of heat energy needs than others on average. Segments 3 and 4 identify an average of 14 and 12 big factors that they consider when heating the home, whereas Segments 5 and 6 both report an average of 6 heat energy needs as being big factors for them. This indicates that the segmentation is based upon numbers of, as well as combinations of, heat energy needs.
- The coloured text in the table indicates that particular segments vary markedly in their relationships with the five underlying dimensions of heat energy need (as we would logically expect, given that these were the data on which they were segmented). Green implies a significantly higher than average score on that dimension while red implies a significantly lower than average score.

Taken together, this information can be used to define the seven needs-based segments, as shown in Table 2.6.

Table 2.6 Characteristics of needs-based segments

	Seg 1	Seg 2	Seg 3	Seg 4	Seg 5	Seg 6	Seg 7
% of households in segment	19%	18%	17%	12%	14%	11%	9%
Average number of heat energy needs	9	9	14	12	6	6	8

Figure 2.6 Characteristics of needs-based segments



* Scores greater than +/-0.4 are interpreted as being significantly different from the average population score (0).

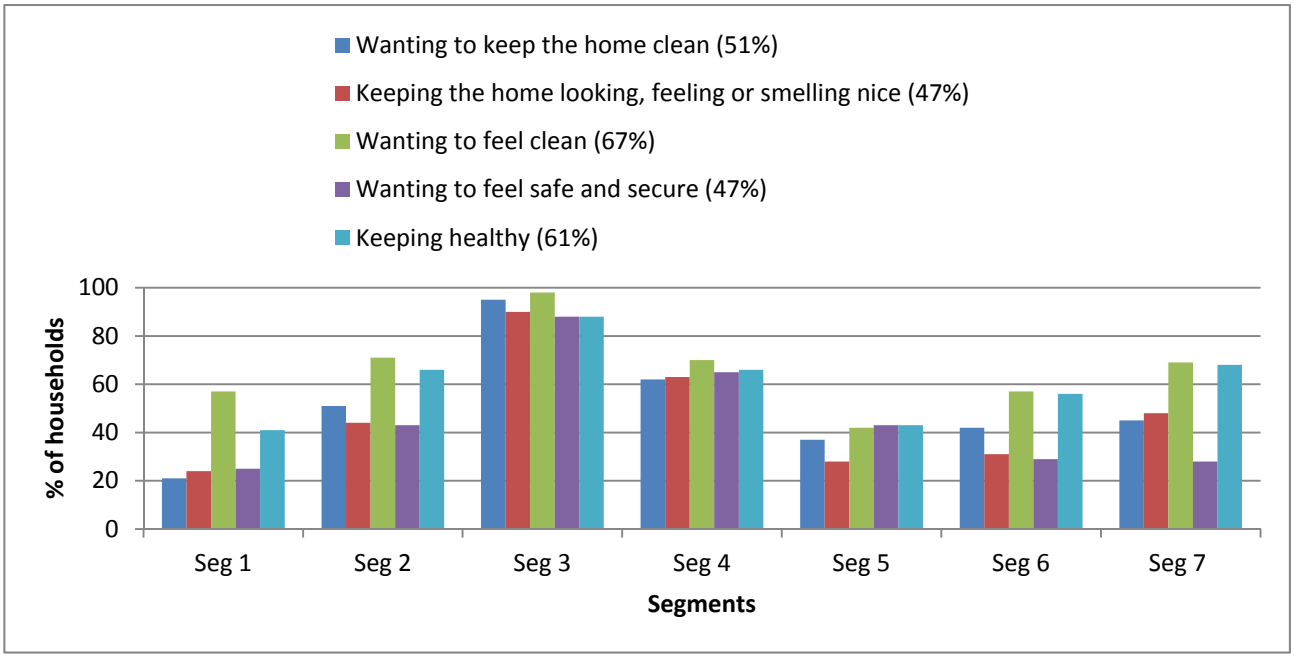
Table 2.7 Descriptions of needs-based segments

- Segment 1 – households with an average number of heat energy needs, who prioritise *Comfort* and *Resource* over *Hygiene*.
- Segment 2 – households with an average number of heat energy needs, who prioritise *Other people* over *Ease*.
- Segment 3 – households with a greater than average number of heat energy needs, who prioritise *Hygiene*, *Resource* and *Comfort* in particular.
- Segment 4 – households with a greater than average number of heat energy needs, who prioritise *Other people* over *Comfort*.
- Segment 5 – households with a lower than average number of heat energy needs, who do not prioritise *Comfort*.
- Segment 6 – households with a lower than average number of heat energy needs, who do not prioritise *Other people*, *Ease* or *Resource*.
- Segment 7 – households with an average number of heat energy needs, who prioritise *Comfort* over *Resource*.

This segmentation is quite different to others that have been attempted because it focuses on needs underpinning a particular set of behaviours rather than general attitudes to energy, climate change or the environment. It is also different because it is based purely on one characteristic of households – their heat energy needs, without seeking to combine this with demographic variables. Section 2.8 explains how data on needs and demographic variables (relating to the household or the dwelling) can be combined in an approach that is more flexible in application than a traditional segmentation.

To explore the segmentation further, below we present five charts (one for each needs dimension) to depict more clearly how the seven needs-based segments relate to the original 21 heat energy needs that respondents were able to choose from. These data enable us to identify the extent to which the actual reported needs of households vary among the segments. For example, in Table 2.7 we described Segment 3 as prioritising *Hygiene* and Segment 1 as prioritising other needs at the expense of *Hygiene*. Figure 2.7 indicates that households in Segment 3, on average, are the most likely to identify heat energy needs relating to *Hygiene* as big factors and households in Segment 1 are the least likely to do so. Most markedly, 95% of households in Segment 3 indicate that wanting to keep the home clean is a big factor when they heat the home, compared to 21% in Segment 1. However, it is important to note that, despite their lack of prioritisation of *Hygiene*, wanting to feel clean remains a big factor for more than half (57%) of Segment 1.

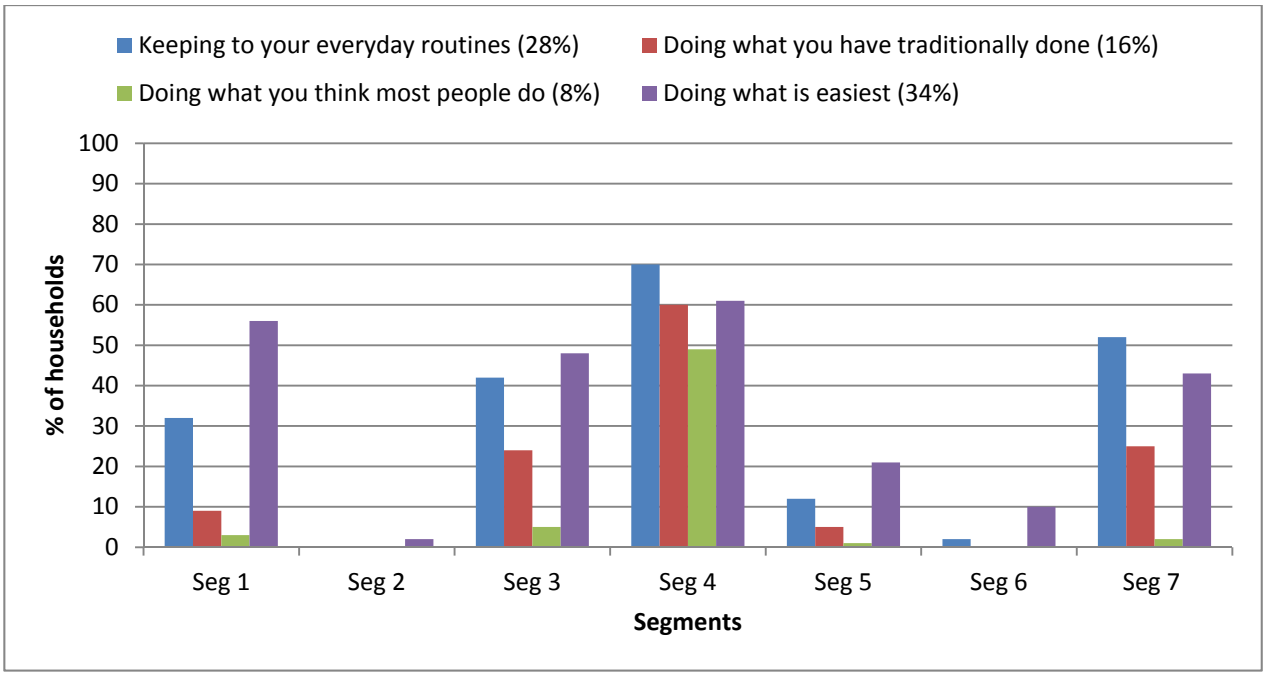
Figure 2.7 Proportions of needs-based segments reporting needs that comprise the *Hygiene* dimension



Base: all respondents who completed both heating home sort card exercise (2287).

When it comes to the underlying dimension of *Ease*, our description of segments suggests that Segments 2 and 6 specifically prioritise other dimensions at its expense, while Segment 4 prioritise *Ease* and *Other people*, at the expense of *Comfort*. This interpretation is clearly reflected in Figure 2.8, where we see that no households, or very few, in Segments 2 and 6 identify any of the specific heat energy needs relating to *Ease* as being big factors for them. On the other hand, more than four-tenths of those households assigned to Segment 4 prioritise each of the individual needs relating to *Ease* as being big factors for them. Interestingly, "doing what you think most people do" is identified by almost half (49%) of those in Segment 4 as being a big factor, compared to less than one in 20 in any of the other six segments. The differences between segments in relation to "doing what is easiest" and "keeping to your everyday routines" are less pronounced.

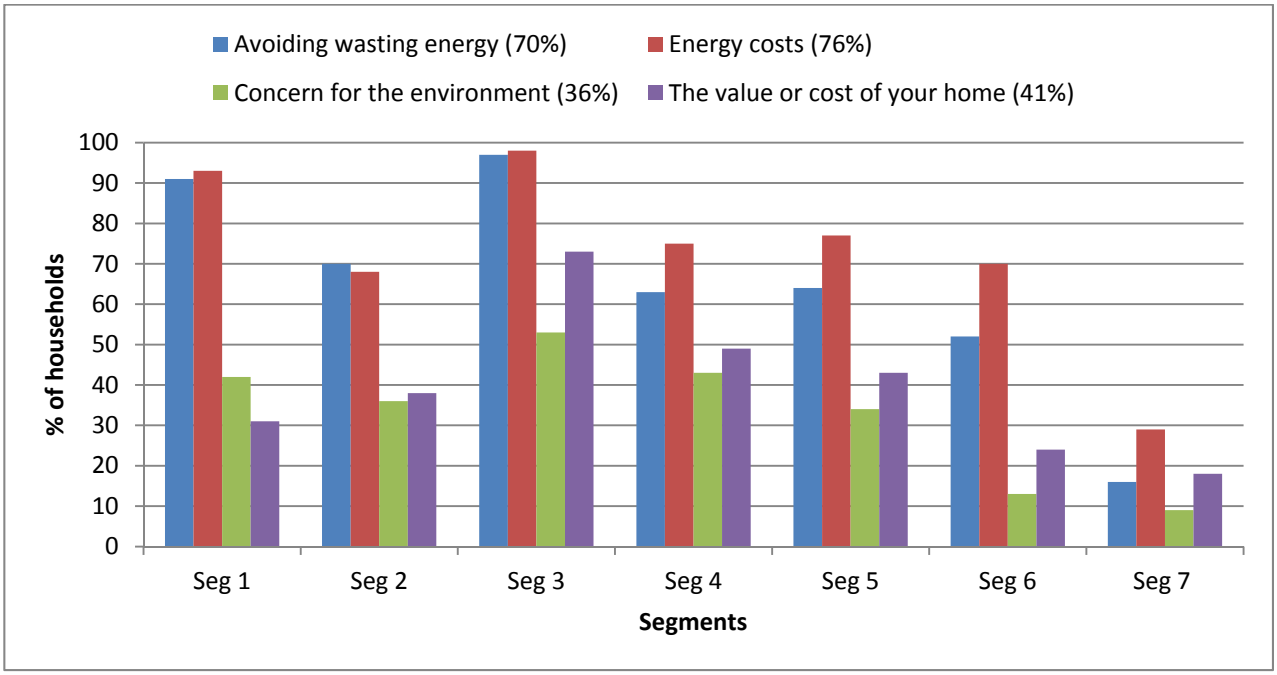
Figure 2.8 Proportions of needs-based segments reporting needs that comprise the *Ease* dimension



Base: all respondents who completed heating home sort card exercise (2287).

When it comes to the underlying dimension of *Resource*, we found above that this was prioritised by Segments 1 and 3 but that other dimensions were more important to Segments 6 and 7. This is evident to some extent in Figure 2.9; for example, 93% and 98% of Segments 1 and 3 respectively identify energy costs as a big factor in determining how they heat the home, compared to 70% and, most markedly, 29% of those in Segments 6 and 7. This suggests that Segment 7 is unique in that energy costs are not generally a big factor for this segment; the same is also true for avoiding wasting energy, identified as a big factor by just 16% of households in this segment, compared to more than half of those each other segment.

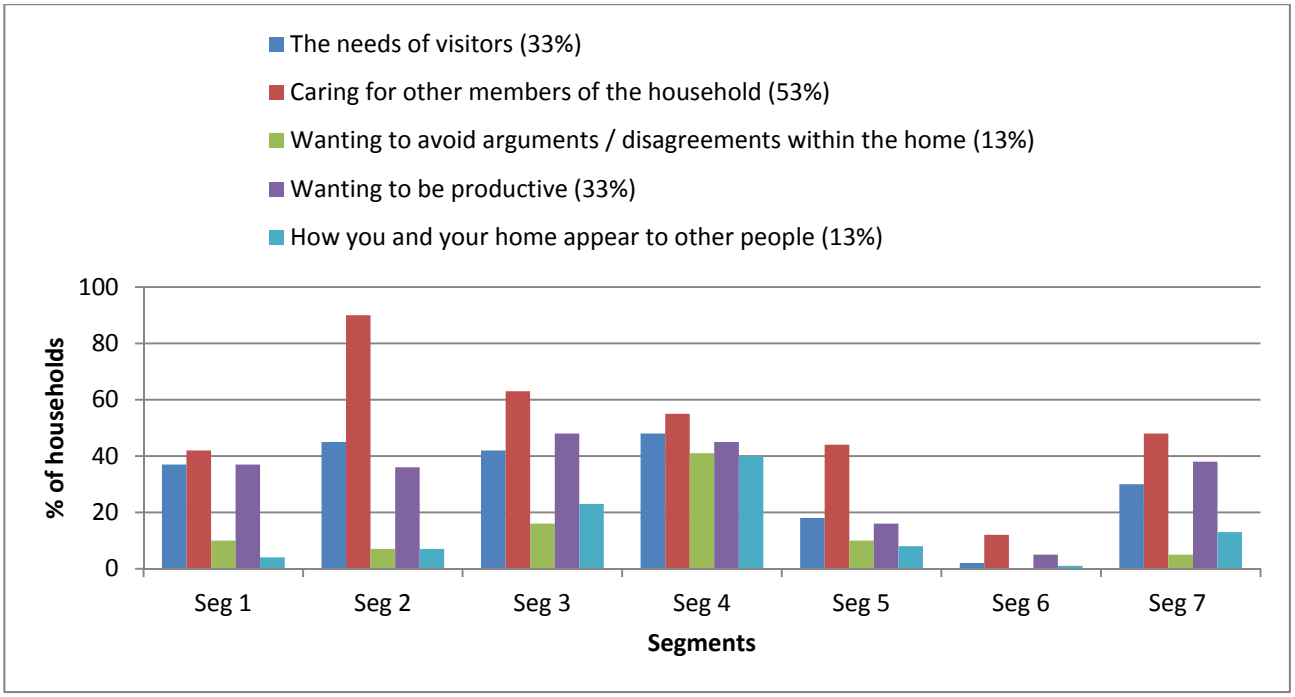
Figure 2.9 Proportions of needs-based segments reporting needs that comprise the *Resource* dimension



Base: all respondents who completed heating home sort card exercise (2287).

We found that the underlying dimension of *Other people* was prioritised by Segments 2 and 4, but that other dimensions were prioritised at its expense by Segment 6. The latter tendency is particularly marked in Figure 2.10, with around one-tenth or fewer households in Segment 6 identifying each of the individual needs relating to *Other people* as being big factors. Segments are particularly distinct in the extent to which they prioritise the need to care for other members of the household; 90% of households in Segment 2 identify this as being a big factor, compared to a population average of 53% and just 12% of those in Segment 6.

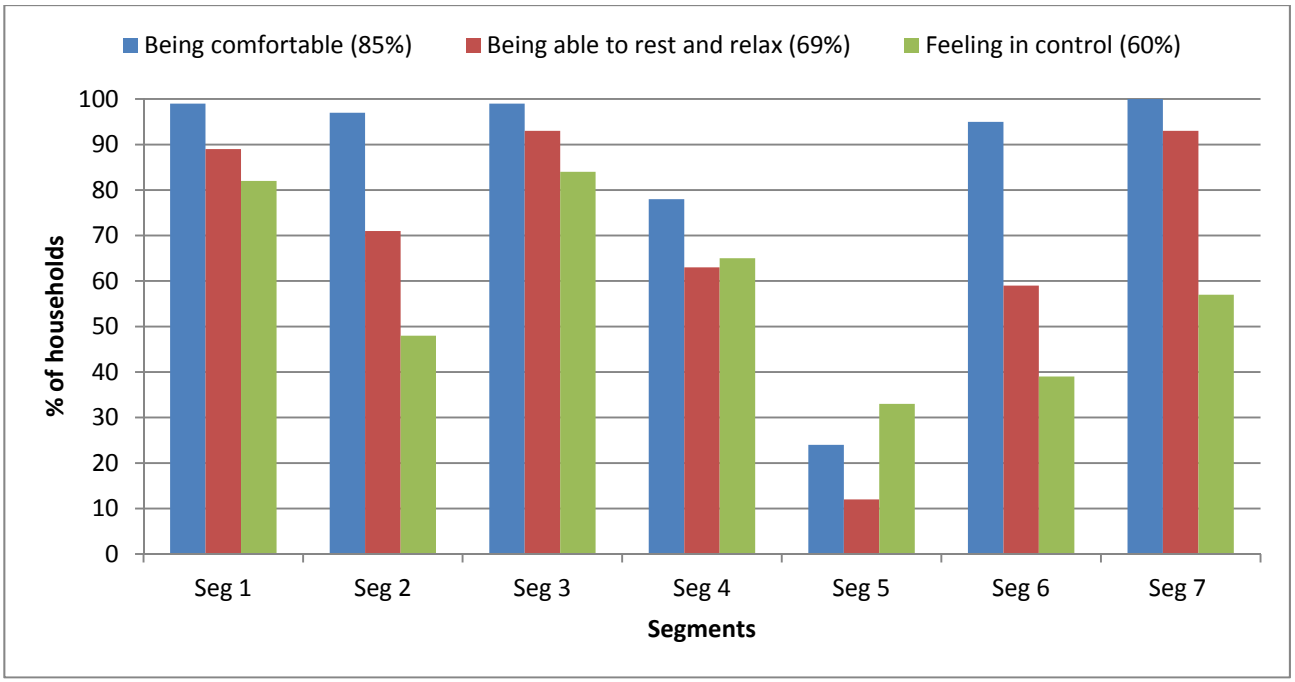
Figure 2.10 Proportions of needs-based segments reporting needs that comprise the *Other people* dimension



Base: all respondents who completed heating home sort card exercise (2287).

Finally, we saw that the dimension of *Comfort* was relatively key in differentiating between segments – being prioritised by Segments 1, 3 and 7, but with other dimensions being prioritised at its expense by Segments 4 and 5 (see Figure 2.11). The latter pattern is particularly marked in relation to Segment 5 – with fewer than one-third of households identifying each specific need associated with *Comfort* as a big factor – despite more than six-tenths of the population doing so on average. It was noted previously that the qualitative research identified comfort as a fundamental need for households – and this is largely reflected in the fact that it is identified as a big factor by more than seven-tenths of households in six of the seven segments. However, Segment 5 is unique in that less than one-quarter (24%) do this – while households in this segment also do not prioritise any other dimension of need to any great extent. It may be that, for this segment, comfort is not prioritised in the "top of mind" needs reported, because households feel that it is already met to a sufficient degree.

Figure 2.11 Proportions of needs-based segments reporting various needs that comprise the *Comfort* dimension



Base: all respondents who completed heating home sort card exercise (2287).

The data presented above indicate that, while seven needs-based segments of a fairly even size exist among British households, the pattern of heat energy needs for individual segments is rather complex – and should be understood in terms of the prioritisation of needs and dimensions of need, rather than in terms of certain segments holding certain needs exclusively at the expense of others. In addition, certain of the original 21 heat energy needs much more clearly differentiate between segments than others.

Accepting these innate complexities in the relationships between our seven segments, the five underlying dimensions of need and the original 21 heat energy needs, we next consider whether the potential exists for these segments to inform the design and implementation of future heat energy solutions.

2.7 Using categorisations in future heat energy solution planning and implementation

We next consider if and how far the two needs-based categorisations developed above (one identifying five underlying dimensions of need, the other grouping households on the basis of these dimensions) might be used to assist in the design, marketing and other implementation aspects of future heat energy solutions.

We begin by considering the seven needs-based segments. In theory, if the segment in which a household or group of households sit could be easily discerned, then appropriate heat energy solutions could be developed and marketed to them – with their priority dimension(s) of need being emphasised and with less attention being paid to the dimensions of less importance to them.

However, the challenge that exists is identifying a straightforward way to assign any household or group of households to a segment. Both the existing literature, summarised in the WP5.1 literature review, and the WP5.4 qualitative research, indicate that demographic characteristics and those relating to property and heating system are poor predictors of households' heat energy needs and behaviour. To test how far this is the case in relation to the seven segments we have developed, we analysed the segments by a range of characteristics relating to people, property and heating system and control – all areas that have been shown to impact on and interact with households' heat energy needs and behaviours – and where we might potentially see a relationship with segment membership.

Table 2.8 presents data on people-related characteristics for the seven segments, with any characteristic reported for a significantly higher or lower proportion of any given segment being shown in green or red respectively.

The overriding conclusion to be draw form this table is that there is little variation in the types of household of which the different segments are comprised. The highlighted data, while indicating significant variation, could in no way be used confidently to predict segment membership, though a number of relatively minor patterns are evident.

- **Segment 2** households are more likely to be multi-person and to include children under age 18 (although it is still the case that more than half of them do not). They also tend to be younger and more highly educated on average then the population as a whole. This may help to explain why they prioritise the dimension of *Other people* – this could be a function of the fact that there are likely to be more people within these households.
- **Segment 3** households are more likely to contain an individual in the oldest age group (aged 60+).
- **Segment 4** households are less likely to be highly educated and are more likely to be concentrated in the lowest quartile of household income. They are more likely to contain no children and for all adults to be aged over 60 years.
- **Segment 6** are more likely to be single-person households. This may explain why they are the least likely segment to prioritise the *Other people* dimension.
- **Segment 7** households are more likely to contain no children and all adults over 60.

Table 2.8 Characteristics of segments by people-based characteristics

Characteristic	Category	Overall %	% of households in segment with the characteristic						
			1	2	3	4	5	6	7
Type of household	Children under school age	8	4	13	4	7	9	5	12
	Children started or completed school	24	24	29	20	22	28	18	19
	No children and all adults over 60	36	37	26	42	44	29	38	44
	No children and at least one adult under 60	33	36	32	33	27	33	39	26
Number of children <18	None	66	69	54	72	70	60	75	68
	1	13	11	18	10	12	15	10	17
	2	14	15	20	10	10	15	11	10
	3+	7	5	7	7	8	10	5	6
Age of oldest person	Up to 39 years	22	16	28	16	18	25	24	26
	40-59 years	31	37	34	28	30	34	28	23
	60+ years	47	47	39	55	52	41	48	52
Size of household	1	27	28	13	28	34	25	37	34
	2	35	36	38	38	31	30	33	35
	3	15	15	20	14	14	16	11	14
	4	14	14	19	12	11	18	11	10
	5+	9	7	10	7	10	12	7	9
Highest qualification	Degree level +	29	34	39	23	16	29	27	25
	Another kind of qualification	48	49	47	50	47	50	46	46
	No qualification	23	17	13	27	37	21	27	30
Disability that affects heating or hot water	Yes	19	15	19	24	22	18	15	20
	No	81	85	81	76	78	82	85	81
Household Income	Lowest quartile	25	20	20	27	37	24	26	25
	2nd lowest	20	19	21	24	17	22	18	21
	2nd highest	15	18	19	13	11	15	13	19
	Highest quartile	16	21	20	14	9	13	15	13
	Missing	24	22	20	23	27	26	28	23
Base		2287							

Base: all respondents who completed heating home sort card exercise.

When we undertook comparable analysis for characteristics relating to property type, the story we found was very similar: there was little evidence of characteristics by which segments vary significantly, let alone that we could use confidently to predict segment membership. Once again, a number of slight but significant relationships are evident.

- **Segment 2** are less likely to report experiencing no problems such as condensation at home in the winter. On the other hand, **Segment 4** households were significantly more likely to report not experiencing any such problems.
- **Segment 6** households are slightly more likely to live in small properties (fewer than 6 rooms) and, linked to this, are more likely to live in flats or maisonettes.

Table 2.9 Characteristics of segments by property-based characteristics

Characteristic	Category	Overall %	% of households in each segment with the characteristic						
			1	2	3	4	5	6	7
Tenure	Own	65	72	68	67	62	62	59	62
	Social landlord	20	16	15	21	27	18	24	23
	Private landlord	15	13	17	12	11	20	17	15
Age of property	Pre 1919	16	18	16	15	12	18	18	15
	1919-1944	16	18	15	20	15	15	15	15
	1945-1964	18	17	21	19	17	16	13	19
	1965-1980	21	21	18	18	28	22	22	21
	1981+	24	24	24	25	24	25	23	28
	Missing	5	3	6	3	5	5	8	3
Number of problems in home in winter[6]	No problems	37	37	29	36	45	35	41	44
	1 problem	31	30	35	29	30	29	31	29
	2+ problems	32	33	36	35	25	36	28	28
Dwelling type	Flat/maisonette	21	16	18	22	22	26	30	20
	Bungalow	13	15	12	14	14	8	10	17
	House	66	69	70	64	64	66	60	63
Extent of dwelling attachment	Flat	21	16	18	22	22	26	30	20
	Mid-terrace	19	17	18	16	21	20	23	20
	Semi	35	38	34	37	35	33	29	37
	Detached	25	29	30	25	23	22	18	24
Number of rooms	6 or less	15	13	12	14	18	16	25	14
	7-10 rooms	40	38	36	41	42	42	36	44
	11-15 rooms	37	40	40	37	34	34	36	36
	16+ rooms	8	9	11	8	6	8	3	7
Base		2287							

Base: all respondents who completed heating home sort card exercise .

Finally, when we examine characteristics relating to heating systems, types of heating control and households' attitudes to the energy used for heating, we find little evidence of variation among our seven segments. The only significant difference to note is that **Segment 7** households are less likely to express concern about energy bills – a tendency that relates to their lack of prioritisation of the *Resource* dimension of need and, in particular, the much lower extent to which they identify energy costs as being a big factor for them when heating the home, compared to the other six segments.

[6] We asked respondents to indicate which of the following problems they experienced in the home in winter: cold draughts, condensation, any other damp, mould on surfaces or furnishings within the home.

Table 2.10 Characteristics of segments by characteristics relating to heating systems, types of control and relationships with energy used for heating

Characteristic	Category	Overall %	% of households in each segment with characteristic						
			1	2	3	4	5	6	7
Main heating system	District Heating	2	1	1	2	2	2	2	4
	Central Heating	85	89	87	87	86	82	82	80
	Fixed in individual room	12	11	10	11	11	15	15	15
	Portable	2	1	2	2	1	3	2	2
Approach to controlling heating	Manual temperature, manual time	13	8	13	12	15	17	15	8
	Active temperature, active time	14	15	16	16	9	10	14	15
	Active temperature, set and forget time	6	5	6	9	5	6	6	6
	Set and forget temperature and time	23	29	22	20	25	20	20	22
	Set and forget temperature, active time	18	19	20	17	15	20	20	10
	No control of temperature, any control of time	10	8	8	9	10	10	12	13
	Active temperature, always time	7	8	7	6	10	6	3	11
	Set and forget temperature, always time	10	9	8	11	10	10	11	16
Level of concern about energy bills	Concern about 1 or more of 3 issues[7]	85	88	86	88	89	87	79	75
	Not concerned by 1+ issue	37	38	37	38	32	33	39	48
Connection to gas grid	Off gas grid (respondent-defined)	11	12	12	12	7	12	7	12
	Doesn't use gas (but respondent unsure if on grid)	5	3	4	5	6	6	8	8
Base		2287							

Base: all respondents who completed heating home sort card exercise.

We can therefore conclude definitively that identifying the needs-based segment in which a household or group of households is located would not be possible by using proxies of easily observable or recordable characteristics relating to the people in the household, the property or the heating system. We have found remarkably little variation in the profiles of the seven segments in relation to these spheres – although the variation we do identify can, in some instances, logically be linked with the dimensions of need that particular segments prioritise.

[7] Respondents were asked to indicate how far they agreed or disagreed with three statements – "Keeping up with energy bills is difficult at the moment", "It's difficult to predict how much energy is going to cost before the bill or statement arrives" and "I worry about the cost of energy over the next few years". Two derived variables were created and are used in this analysis – the first recording whether the respondent expressed concern about at least one of the three statements, the second recording whether the respondent did not express concern about at least one of the three statements.

While these findings indicate that the seven segments will not be a useful tool for implementing heat energy solutions, the segments should be useful at the design stage. The segments each represent a particular common combination of dimensions of need; designers can use these in two ways:

- as a starting point for design, to develop solutions that address the needs of one or more segments;
- to check a potential solution design as to whether it is likely to meet the needs of one or more segments.

The underlying dimensions can also be used in this way, and possibly more effectively so. If a design addresses all five dimensions, it should also address all seven segments. However, if it is not possible to address all five dimensions, it should at least address one or more the common combinations, as represented by the segments. In the next section we consider whether the five underlying dimensions of heat energy needs might usefully be employed also at the implementation stage.

2.8 Using underlying dimensions of need to describe households

While seven needs-based segments exist among British households, they would clearly be impossible to identify on the basis of the types of information that might be available in local areas – regarding the local population, housing stock and so on – or by using a small number of key demographic or behavioural questions as proxies by which to assign a household or groups of households to their likely segment.

In this section, we therefore turn this potential approach on its head to consider whether, by analysing profiles of underlying dimensions of heat energy need for certain groups of households, we might be able to discern the types and features of heat energy solutions that would be most relevant and acceptable to them. By “needs profile”, we mean the relative importance that a group assigns to each of the five dimensions of need. In other words, can we use the characteristics of households to predict their pattern of needs and, if so, which characteristics differentiate most clearly between different needs profiles? We believe this will be more useful that using the segmentation because it is more flexible in characterising different groups and local areas, more precise in that characterisation, and relies on a lesser level of abstraction from the data than the segmentation. We also observe that logical relationships between group characteristics and needs profiles give greater confidence in the needs dimensions themselves.

In this section we consider this question in relation to a range of general categorisations of households, identified as being of relevance to their heat energy needs in other areas of the programme. In Chapters 3, 4 and 5, we consider how dimensions of need relate to behaviours in the three key domains of heat energy use – heating the home, cooling and heating water. In Chapter 6, we consider whether those who favour certain aspects of heat energy solutions have particular needs – adding another dimension to our understanding of the relationship between dimensions of heat energy need and the acceptability of particular heat energy solutions. Further, in the longer-term, the WP5.7 quantitative data-set could potentially be used in a similar way to predict the likely needs profiles of households in a given local area (assuming them to be relatively homogenous on the characteristics being analysed).

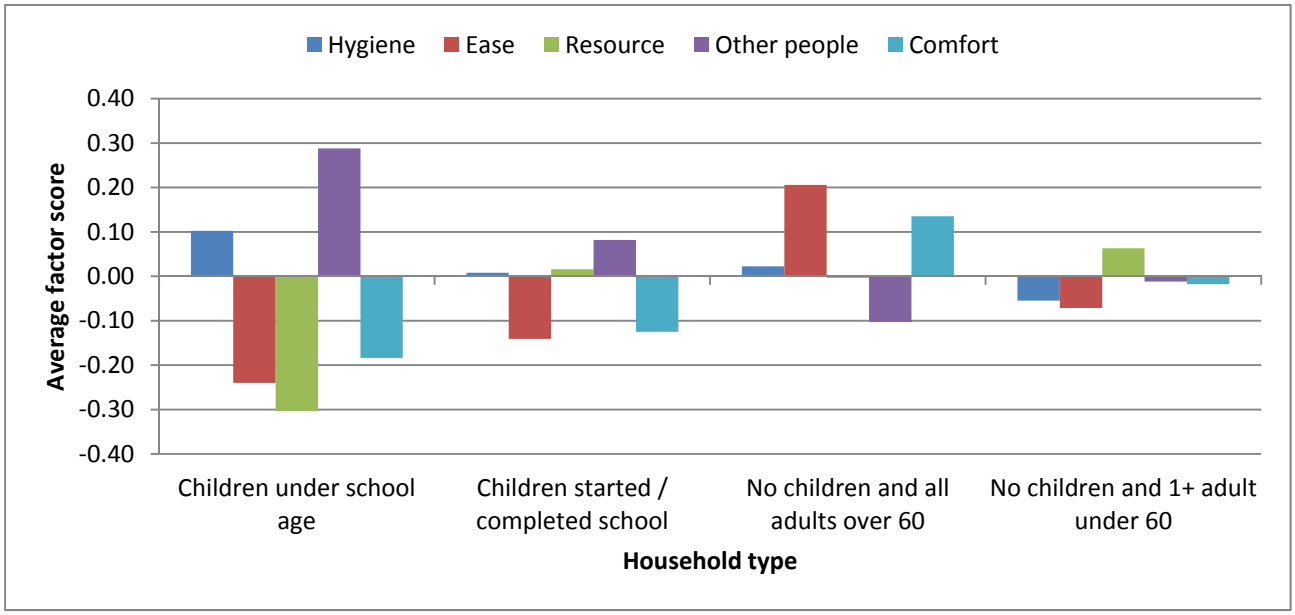
First of all, we analysed the underlying dimensions of heat energy needs for the four categories of household identified as key to understanding heat energy needs by the WP5.1 segmentation and WP5.4 qualitative research. Figure 2.12 (and the subsequent figures) depict the pattern of average scores on the five heat energy dimensions for different types of households, where a score of zero would represent the average for the population of British households as a whole. In other words, scores on the dimensions have been standardised to enable a depiction of the degree of variation between different groups in relation to their scores on the five dimensions.

For example, we see in Figure 2.12 that significant relationships exist between individual household types and average scores on each of the five underlying dimensions of need. Households with children under school age stand out as having the greatest variation in their average score on the five dimensions. Households in this group clearly prioritise *Other people* and, to a lesser extent, *Hygiene*, at the expense of *Ease*, *Resource* and *Comfort* to a considerable degree – suggesting that an acceptable heat energy solution for this group would need to meet this particular profile of needs. Once children have reached school age, *Hygiene* becomes less important and *Resource* more important, although both dimensions are close to average. Households containing all adults over 60 are rather different, prioritising *Ease* and *Comfort* at the expense of *Other people*. Households without children but with at least one adult under 60 are most similar

to the general population in their profile of needs – indicating that the data does not suggest that the development of a bespoke needs-based solution for this group would be a profitable strategy.

The WP5.4 qualitative research also concluded that a typology of decision-making exists, which determines how households prioritise their needs in practice, with households operating as "You" "Me" and "Us". In Figures 2.13 and 2.14, we present data for two derivations of this typology of decision-making, based on answers to questions included in the survey by which respondents self-assigned the behaviour of their own household.[8]

Figure 2.12 Average scores on dimensions of need, by household type



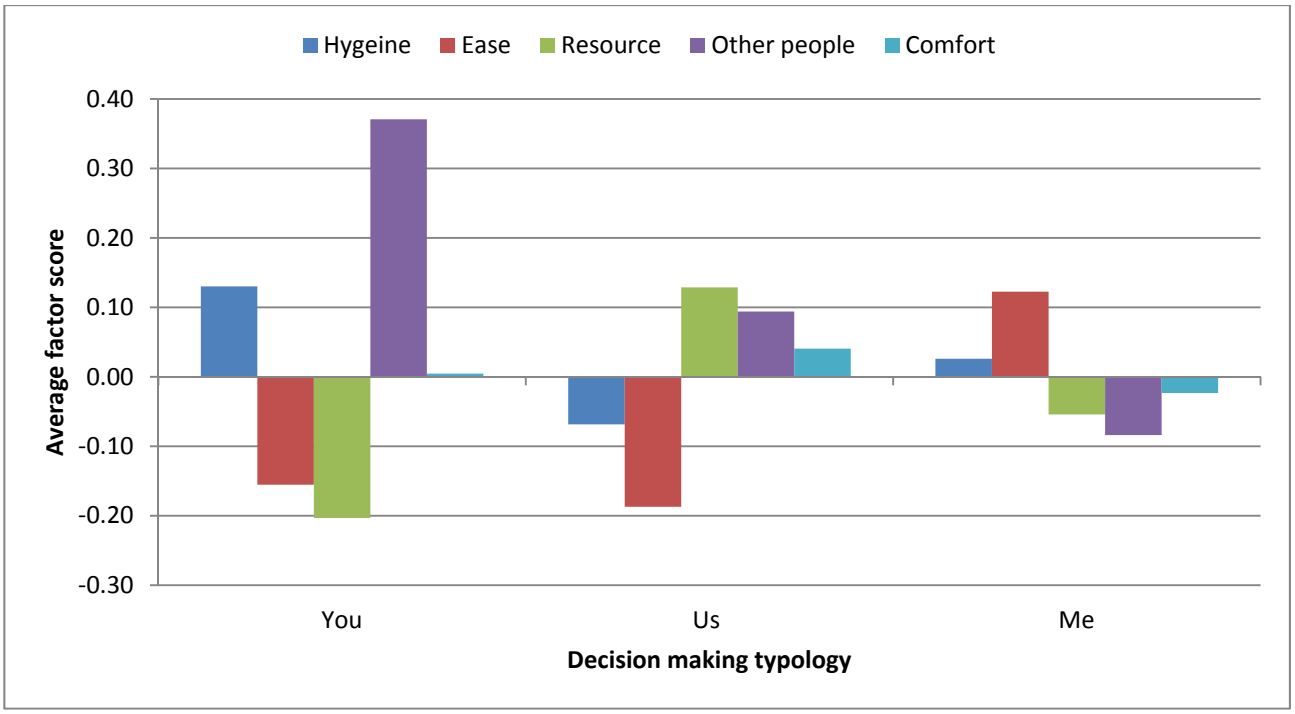
Base: all respondents who completed heating home sort card exercise (2287).

Figure 2.13 assigns all households as Me where they are either single-person households (giving them no option other than to operate in this way) or multi-person households but the individuals therein operate on an individual basis in their relationship with the heating.

These charts indicate a prioritisation of dimensions of need among You, Me and Us households, which chimes with the findings of the qualitative research in identifying dimensions by decision-making patterns – although the actual patterns of the prioritisation of needs are rather different. Significant differences exist in relation to the scores of the three types of households on all of the five dimensions of need, with the exception of *Comfort*. The qualitative research suggests that comfort is the most fundamental need addressed by heating, so it is not surprising that it varies least across households that adopt different approaches to achieving comfort. "You" households are most distinct in the degree to which they prioritise *Other people* and, to a lesser extent, *Hygiene*, at the expense of *Ease* and *Resource*. The main difference with "Us" households is that they are less likely than average to prioritise *Hygiene* and more likely to prioritise *Resource*. "Me" households, on the other hand, whilst being more typical of the population average, stand apart from "You" and "Us" households in the extent which they prioritise *Ease* over the other dimensions of need.

[8] Respondents in multi-person households were asked two questions in relation to the three domains of heat energy use, The first question asked how the household decides about heating. The second question asked the respondent how much influence they personally have over decisions about heating. Answer options from both questions allowed households to be classified into the You, Me, Us typology as outlined in the Technical Appendix (Section 'Analysis and reporting', p.176)..

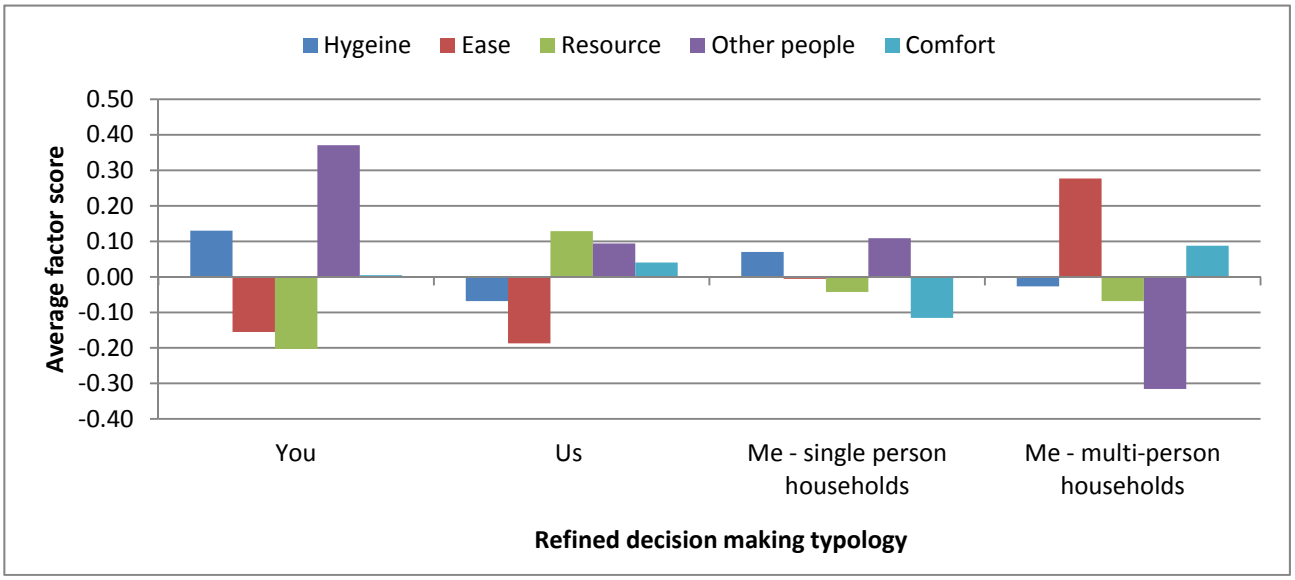
Figure 2.13 Average scores on dimensions of need, by decision-making typology



Base: all respondents who completed heating home sort card exercise (2287).

However, it is worth considering that "Me" households who choose to operate in this way and those who do so because of their single occupancy status (who might potentially operate in other ways were they to be in a multi-person household) might be rather different. In Figure 2.14, we present separately the scores on the five dimensions of need for single-person "Just me" households and self-selecting "Me" households. This presentation of disaggregated data reveals that, in fact, the two categories of "Me" household are rather different. Multi-person "Me" households are most distinct – primarily in the extent to which they prioritise *Ease* at the expense of *Other people*. This is not the case for "Just me" households who are rather more similar to the population average in their pattern of needs. The fact that the two types of "Me" household are rather different in their profile of needs suggests that a four-category, rather than a three-category, derivation should most usefully be taken forward in the development of our understanding of how households prioritise their heat energy needs.

Figure 2.14 Average scores on dimensions of need, by refined decision-making typology

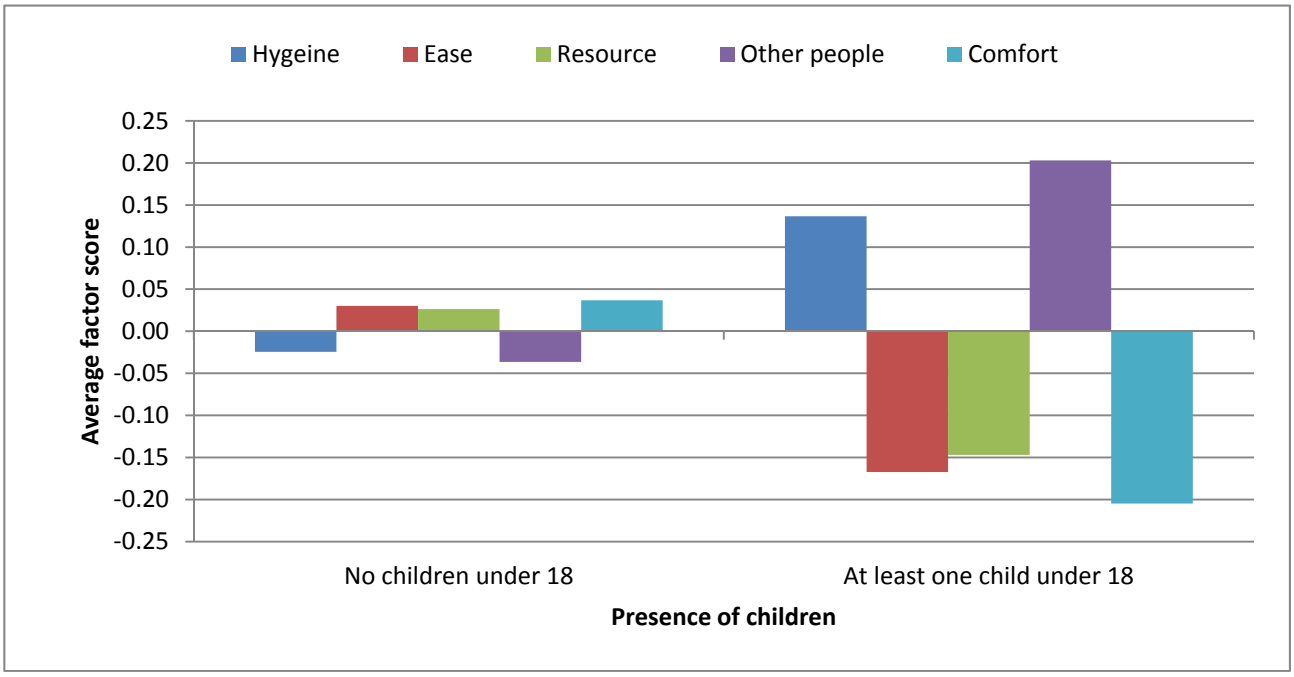


Base: all respondents who completed heating home sort card exercise (2287).

We analysed average scores on the five dimensions of needs by a range of other factors relating to people and properties, in order to characterise the different groups that exist within the population of British households. In general we found that household characteristics, rather than characteristics relating to the property, tended to produce different profiles of heat energy needs. We found no marked differences between the needs profiles of those with different tenures, dwelling types or property ages. However, households identified by the presence of children, household size, education levels and household income varied quite markedly.

In Figure 2.15, we see that households with children have a much more varied profile of needs, compared to the population as a whole, and compared to households not containing children. This is not surprising; we saw in Figure 2.12 that this was the case, especially for households containing any children under school age. Here we see that households with children prioritise *Other people* and *Hygiene* at the expense of the other three dimensions – *Resource*, *Ease* and *Comfort* – while households without children are much more similar to the general population in their average score in relation to each of these dimensions.

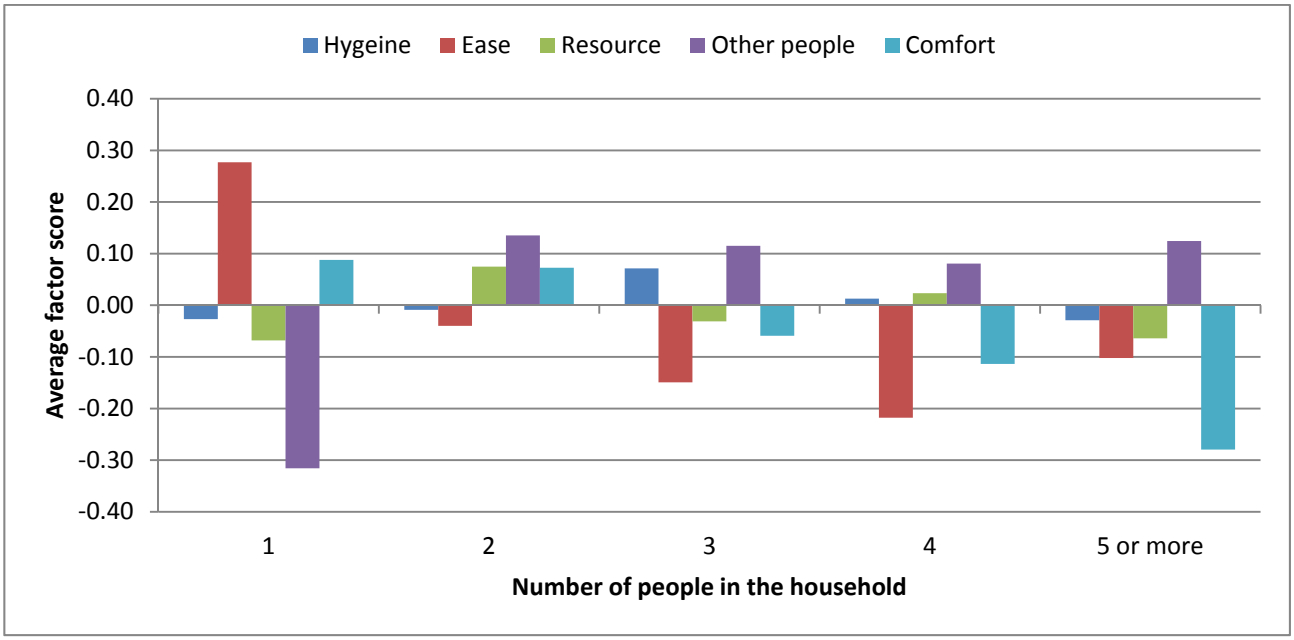
Figure 2.15 Average scores on dimensions of need, by presence of children aged under 18 in household



Base: all respondents who completed heating home sort card exercise (2287).

As shown in Figure 2.16, household size is another characteristic associated with variations in profiles of heat energy needs. Single-person households are most markedly different, in the degree to which they prioritise *Ease* over *Hygiene*. Yet we see *Ease* becoming comparatively less important as household size rises – a pattern that is also evident in relation to *Comfort*. The dimension *Other people* is, unsurprisingly, more important to households of more than one person.

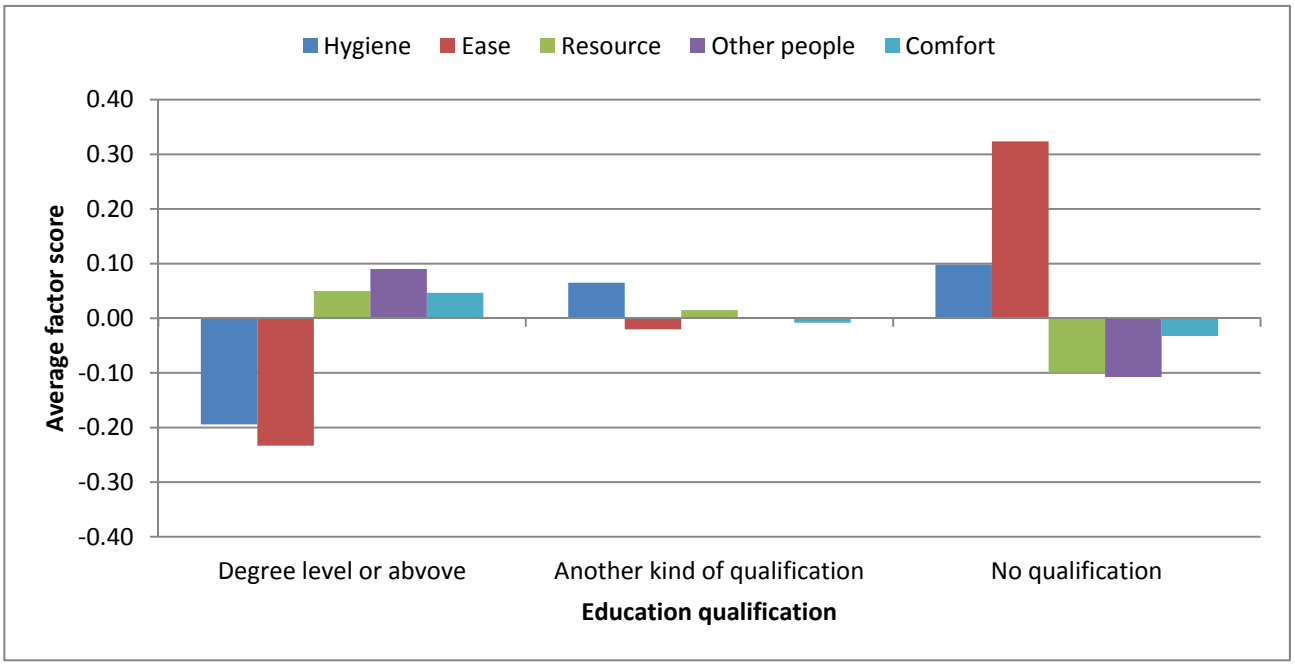
Figure 2.16 Average scores on dimensions of need, by household size



Base: all respondents who completed heating home sort card exercise (2287).

While we might expect the pattern of prioritisation of needs to change in an incremental way as household income increases, analysis by this characteristic indicates that this is not the case – suggesting other variables are at play and that this is not a useful characteristic on which to profile households' heat energy needs. However, the pattern in relation to the highest level of education within the household is more coherent. As shown in Figure 2.17, as the highest level of education within a household declines, *Hygiene* and *Ease* assume a greater importance – with the pattern in relation to *Ease* being particularly marked. This suggests that a heat energy solution that supports the dimension of *Ease* would be much more desirable to less educated households than for those with a qualification at degree level or above.

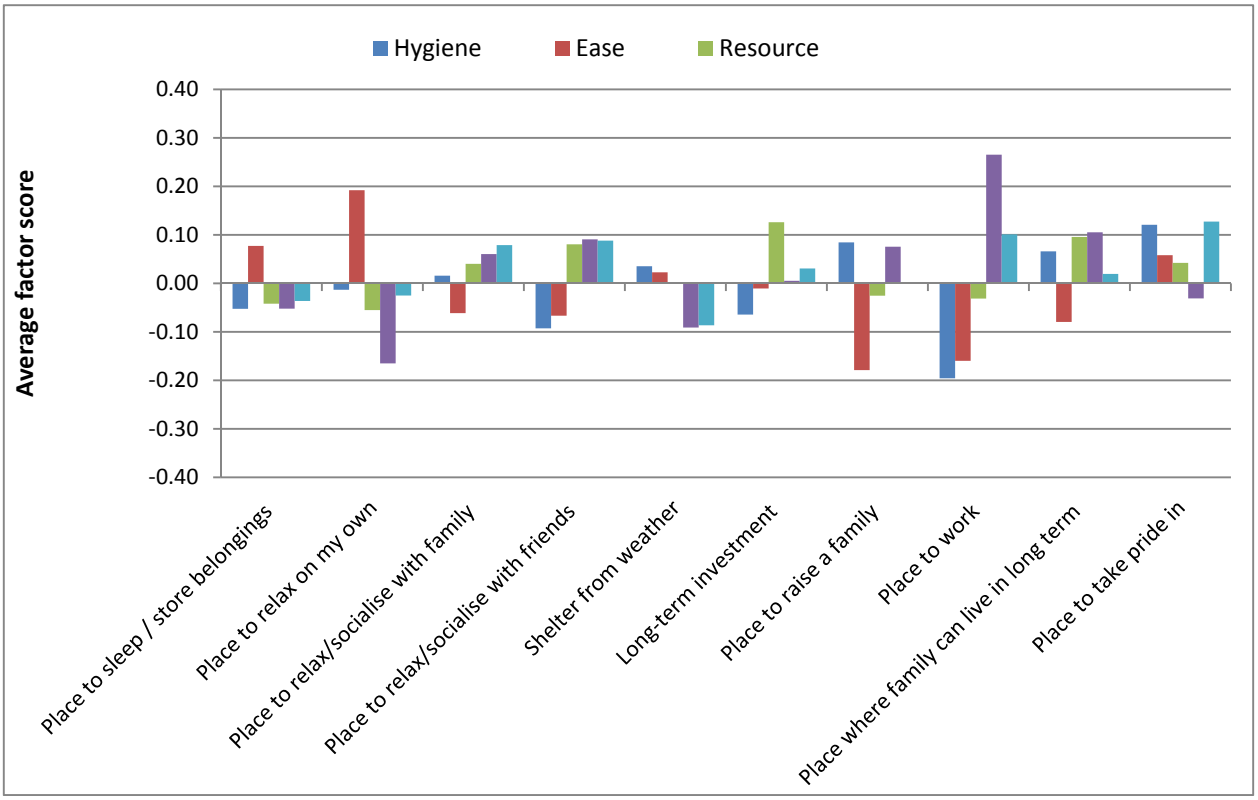
Figure 2.17 Average scores on dimensions of need, by highest educational qualification



Base: all respondents who completed heating home sort card exercise (2287).

Finally, there is some evidence from elsewhere in the programme regarding the linkages between attitudes to the home and heat energy needs – the hypothesis being that the way a household views their home might influence or inform what they are trying to achieve when heating the home. A question was included in the WP5.7 quantitative survey, inviting respondents to indicate which three out of 10 statements best reflected their feeling about their current home. The average dimension scores for respondents who selected each of these 10 statements as being among their "top 3" are presented in Figure 2.19.

Figure 2.19 Average scores on dimensions of need, by attitudes to the home



Base: all respondents who completed heating home sort card exercise (2287).

Clearly, some attitudes to the home are associated with a much more varied profile of heat energy needs that are others. In particular, those who view the home as a place to work stand out in the extent to which they prioritise *Other people* at the expense of *Hygiene* and *Ease* – although we should bear in mind that the subgroup who work from home may have fairly distinct characteristics in other areas too, driving this pattern (they are also relatively few, just 100 respondents expressed this attitude to the home). Those who view the home as a place to "relax on my own" are also relatively distinct – notably in the degree to which they prioritise *Ease* at the expense of *Other people* – an order of priority clearly implied by their holding of this specific attitude to the home. Finally, those who regard the home as a place to "raise a family" stand out in the extent to which they do not prioritise *Ease*, preferring to rate other dimensions of need more highly, especially *Hygiene* and *Other people*. So, while further work is needed to conceptualise the public's attitudes to the home, which might include developing a combined measure of their scores in relation to the 10 different statements, this initial analysis clearly indicates that this is an avenue worth further exploration in developing an understanding of the characteristics that can be used to distinguish British households with different patterns of heat energy needs.

3 Findings: needs and behaviours related to space heating

3.1 Key insights

1. While the most common main heating system is overwhelmingly central heating, this is often supplemented by individual fixed or portable secondary heating, and substantial numbers of households rely on individual heaters (sometimes even when central heating is installed).
2. The type of heating system is related to a range of dwelling and household characteristics that can be used to ascertain what types are popular in the different contexts that smart systems would need to engage with.
3. The majority of homes with central heating have some form of controls available for timing and temperature, although this is not universal. With or without such controls, households exhibit a wide range of strategies (including no strategy at all) for controlling when the heating is on, and the room temperatures achieved – various combinations of manual control and setting control devices (frequently or on a "set and forget" basis).
4. The control strategy is dependent particularly on the type of heating system; this sets a background against which any effects of household demographics need to be seen, effectively constraining the possibilities. Hence, control strategies should not be seen as an inherent characteristic of persons or households, but variable according to the heating system provided or chosen.
5. It is relatively unusual to have rooms that are not heated at all, although this does happen, but more common to have rooms that are used infrequently but still heated (the likelihood of this increasing with the total number of rooms in the home). Therefore, except in the largest homes, solutions involving zonal control of temperature are more likely to be attractive as a means of dealing with the different times when each room is used and possibly the different individuals using the rooms and the different activities carried out, rather than managing unused rooms.
6. Households exhibit many strategies for keeping warm, with various combinations of between one and five of these main methods: using the *main heating; u*sing *other heating*; c*ontrolling* where heat goes (keep windows & external doors closed, shut doors between rooms, not heat all rooms, heat all rooms, close curtains or blinds); r*etaining one's* own warmth (wear warm clothes, use warm bedding in bed or when not in bed) and heating the *person* (warm food or drink to keep warm, bathe or shower to warm up, use hot water bottle, use something else warm to hold, use electric blanket or bed warmer).
7. While use of the main heating is the single most prevalent method of keeping warm on typical winter days, other methods become more important on days when they need to do something extra. However, the overall range of methods is similar in each case and the extra methods are not systematically related to the usual methods at this level of description.
8. About one-fifth of households say they do not need to do anything extra because the usual methods of keeping warm are always enough. The remaining households may be expected to show more interest in improving their heating and they are differentiated by a range of household and dwelling characteristics.
9. Of those households who always feel warm enough in winter, a large majority sometimes overheat in winter whereas, for those who do not always feel warm enough in winter, similar numbers do and do not overheat in winter. This suggests some kind of conflict between ability to keep warm and ability to avoid overheating in winter. The cause might be related to the fabric of the building or to the heating systems and controls.

10. The percentage using heating increases more steeply in between August and November than the decline from February to July. This perhaps arises from people being more aware of getting cold at some point during autumn than they are of the opportunity to be warm without the heating on as spring progresses. This would indicate an opportunity to reduce heating energy demand by using feedback that signals to the household that the home would be warm enough without having the heating on.
11. Out of the whole sample, 20% of respondents reported that, during the months when they use their heating, the heating is on at all times, including overnight and when there is nobody at home. While 60% of these respondents report that they do this because they would be too cold otherwise, this leaves at least 40% who could benefit from smarter timing controls.
12. Diurnal variation in heating is similar for all types of heating system except district heating, where there is less pronounced variation. Dissatisfaction with the lack of control over district heating may stem from not providing the pattern of heating that households normally adopt.
13. Apart from the weather, the reasons that respondents most frequently give for varying how they heat the home are variations in people being at home - either the householders themselves or visitors. Nevertheless, over half of respondents would do nothing different when there are visitors unless the visitor has a particular need to keep warm (e.g. babies, the elderly or those who feel the cold), in which case around three-quarters would do something different. Only 64% reported changing something when they are away from home, which suggests significant potential for reducing energy demand.
14. The profile of the five needs dimensions varies (between households, dwellings, heating systems and behaviour patterns) in ways that provide insight into the different motivations of households with different heating systems, methods adopted to keep warm, and strategies used to control the heating.

3.2 Introduction

This chapter examines the prevalence of different heating systems and controls, how rooms are used and heated, the strategies households adopt to keep warm, whether they actually keep warm enough, variations in heating over the year and over a day, and the circumstances in which households vary their heating.

3.3 What heating systems are present and used in British homes?

3.3.1 Introduction

3.3.2 This section describes the prevalence and combinations of the various means of heating the home (including the heating controls) that are present in UK homes.

3.3.3 The means of heating

The prevalence of heating systems and associated fuels are shown in Tables 3.1 and 3.2. As would be expected, the most common main heating system is overwhelmingly central heating and the most common fuel is mains gas. While over half the sample have some kind of heater fixed in one or more rooms, this is the main form of heating in only 12% of cases. More informative is the common combinations of heating systems that are used, as shown in Table 3.3. Over half the homes with central heating also use some other form of heating and, in 3% of all cases, the central heating is not used as the main form of heating.

Table 3.1 Main types of heating: % of cases[9]

Type of heating	Present	Main heating
District heating	2	2
Central heating	88	84
With radiators	87	
With warm air	1	
Other	1	
Fixed in room	53	12
Electric storage heaters	8	
Electric panels, radiators or heated towel rails	6	
Gas fire fixed	24	
Other fires	21	
Portable	25	2

Table 3.2 Main fuels used for heating: % of cases[10]

Fuel	Any heating	Main heating	Other than main heating
Mains gas	86	87	62
Electricity	35	35	41
Delivered fuel	9	9	10
Other	4	4	5

[9] Base: 2310 cases. The percentages add to more than 100% because some homes use more than one type of heating (resulting in a mean of 1.7 types per home).

[10] Base: 2182 cases. The percentages add to more than 100% because some homes use more than one fuel (resulting in a mean of 1.3 types per home). Questions on fuel used (routing dependent on heating type): "What fuel does the central heating use? / What fuel do the fixed heaters use? / What fuel do the portable heaters use?" Answer options: Mains gas / Oil/ Solid fuel / Electricity/ Other".

Table 3.3 Common combinations of means of heating: % of cases[11]

Combination of means of heating	%
District heating	2
Central heating only	36
Central heating plus fixed heater(s)	29
Central heating plus other form(s) of heating	19
Fixed heater(s) only	12
Portable heater(s) only	2

Statistics on the heat source used for central heating are instructive from the perspective of both the prevalence of each type and the respondents' knowledge of what the heat source is. This is shown in Table 3.4. If the interviewer observations are taken to be more reliable, most respondents were able to identify the heating system in their home. Where there was confusion, this tended to be around less common systems such as combined heat and power (CHP). Where only one party said there was CHP, the other said there was a combi boiler, suggesting a mainly linguistic confusion. In reality, the combi boiler is more likely and the CHP figures should be treated with caution. For this reason, CHP and boilers were merged into one category in further analysis.

Table 3.4 Heat sources for central heating: number of homes[12]

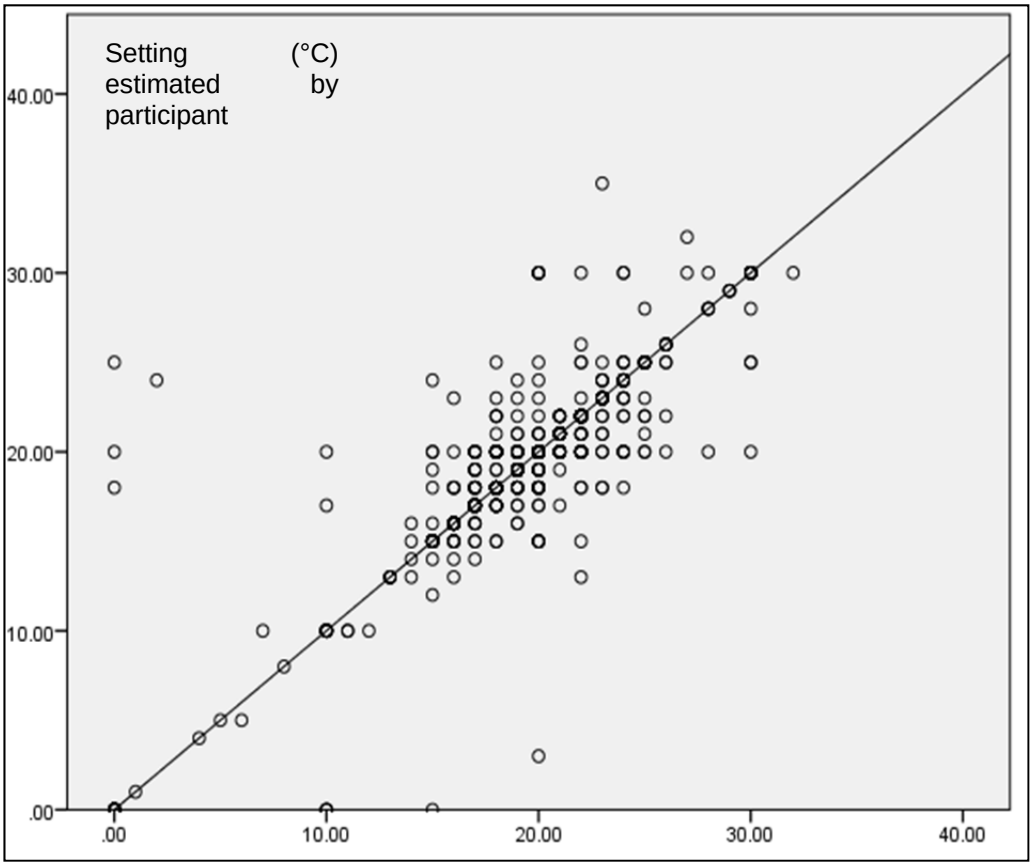
Heat source for central heating	Reported only	Observed only	Reported and observed	Neither reported nor observed
Boiler or air heater	275	27	1619	85
Range/stove	13	11	10	1701
Ground source heat pump	0	1	1	1734
Water source heat pump	1	0	0	1735
Air source heat pump	1	0	3	1732
Combined heat and power	21	19	46	1649
Other	17	13	5	1700

The general awareness of respondents is also evidenced by reports of thermostat settings – see Figure 3.1, where the diagonal line indicates equal values given by interviewers and respondents. While there is some scatter, there is good correspondence and no clear bias to over- or under-estimate over most of the range of observed settings (although there may be a tendency to underestimate high settings and overestimate low settings). Some of the scatter is likely to be due to digital thermostats sometimes showing the current temperature rather than the set point. In addition, the mean reported and observed temperatures were both 19.2°C.

[11] Base: 2287 cases.

[12] Base: 2010 cases for boiler or air heater. 1736 cases for other heat sources.

Figure 3.1 Respondent estimates and interviewer observations of room thermostat settings[13]



3.3.4 Heating systems and characteristics of the property and household

To understand more about the prevalence of different heating systems, we analysed how the five main combinations of means of heating identified in Table 3.3 break down according to a range of dwelling and household characteristics. Beginning with the property itself, Figure 3.2 identifies that the age of the property does have some relationship to the type of system installed. While the proportion of properties with only fixed or portable heating is roughly constant across five ranges, the reliance solely on central heating increases in more modern properties, with a commensurate decrease in combinations of additional heating used alongside central heating. District heating is most commonly found in properties built between 1965 and 1980.

The combination of means of heating also relates to the dwelling type. Figure 3.3 reveals that, while bungalows and houses have a similar breakdown, the profile for flats or maisonettes looks very different. Flats or maisonettes are most likely to rely solely on central heating, with reliance solely on fixed heating second most likely. As expected, these are also where most of the cases of district heating are found. By contrast, systems in bungalows or houses are more likely to involve combinations of different means of heating alongside central heating, as well as a high proportion relying solely on central heating.

[13] Base: 821 cases. Fahrenheit values have been converted to Celsius.

Figure 3.2 Percentage of respondents reporting each combination of means of heating, by age of property[14]

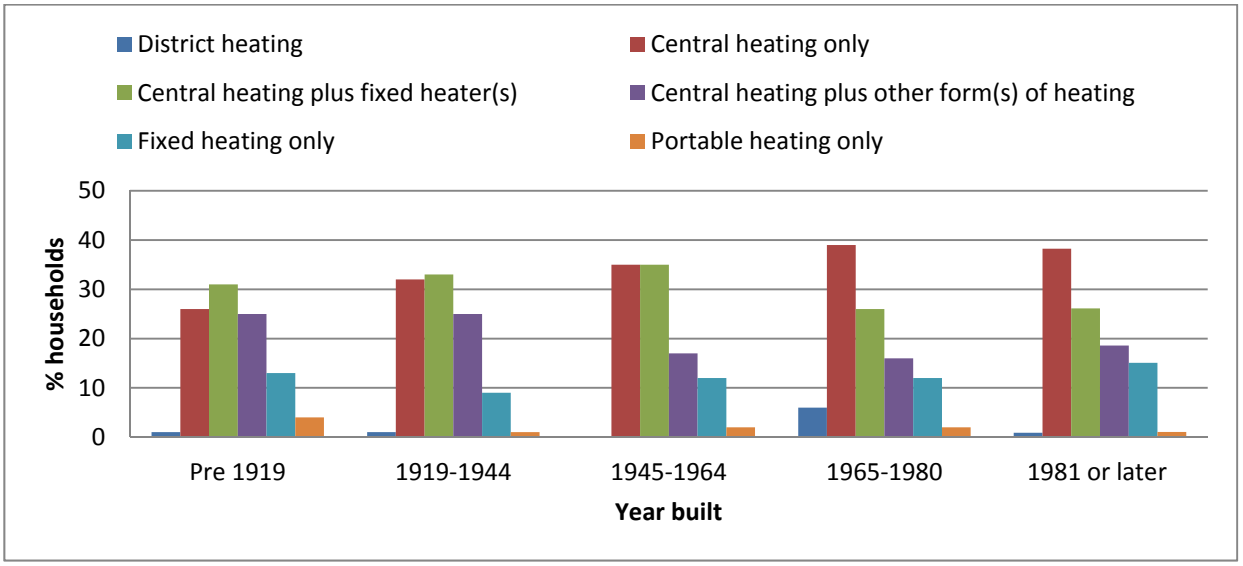
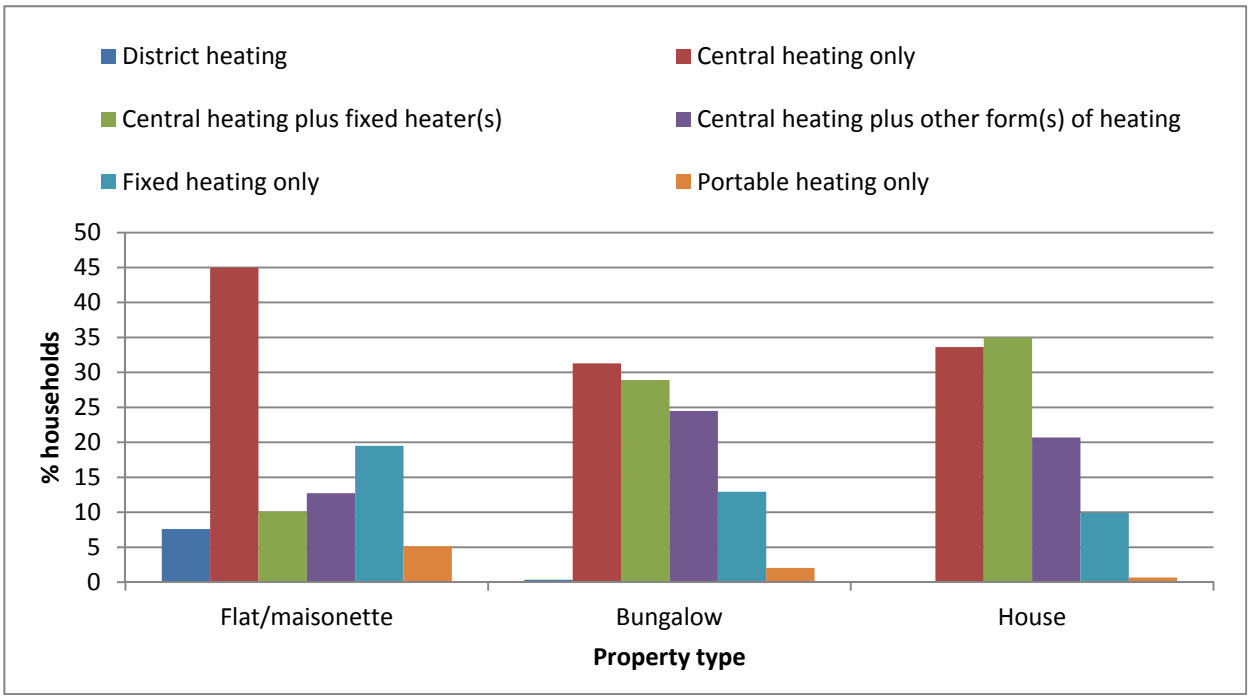


Figure 3.3 Percentage of respondents reporting each combination of means of heating, by dwelling type[15]



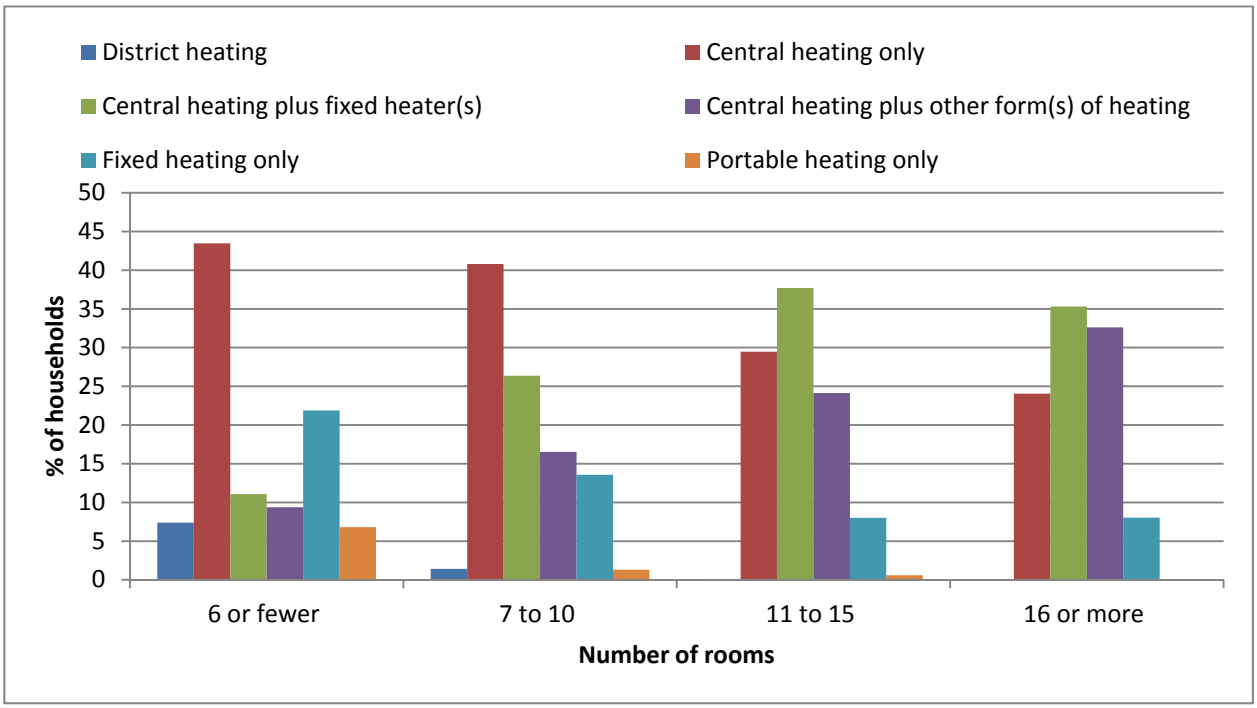
Clearly, some of the distinctions between flats/maisonettes and houses or bungalows will be related to the size of the property, with the larger properties in the sample likely to be houses or bungalows rather than flats or maisonettes. Heating smaller properties just with central heating alone may be relatively easy, but as homes increase in size the effectiveness of a single type of heating and the flexibility for space heating that this offers will often decrease. This expectation is supported by the pattern of combinations of means of heating seen in properties of different sizes in the sample. Figure 3.4 reveals that smaller properties are more likely to rely solely on central heating, or on individual heating fixed within the room, but as the

[14] Base: 2287 cases.

[15] Base: 2287 cases.

properties increase in size, the use of central heating alongside other types of heating increases. Additionally, district heating is primarily found in smaller properties.

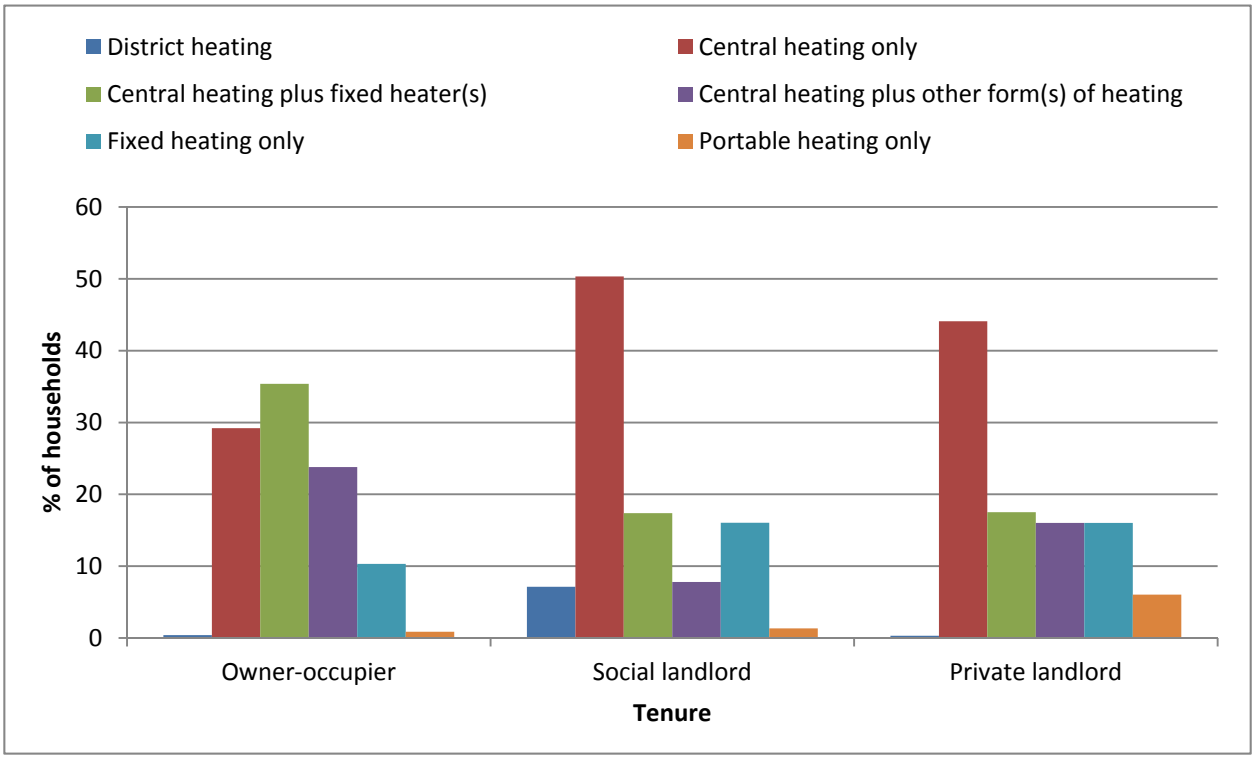
Figure 3.4 Percentage of respondents reporting each combination of means of heating, by number of rooms in the property[16]



Breaking down combinations of means of heating by tenure reveals a clear difference between the systems in homes that are owner-occupied and those that are rented, with some smaller differences also seen between homes rented from social landlords and those rented from private landlords (Figure 3.5). Homes that are owner-occupied tend to rely more on central heating, and have a greater proportion of additional use of other heating types alongside central heating. Homes rented from social landlords have the highest proportion of district heating or central heating only, and a correspondingly low proportion of central heating used with additional types of heating. Homes rented from private landlords are the most likely to rely solely on portable heating.

[16] Base: 2287 cases.

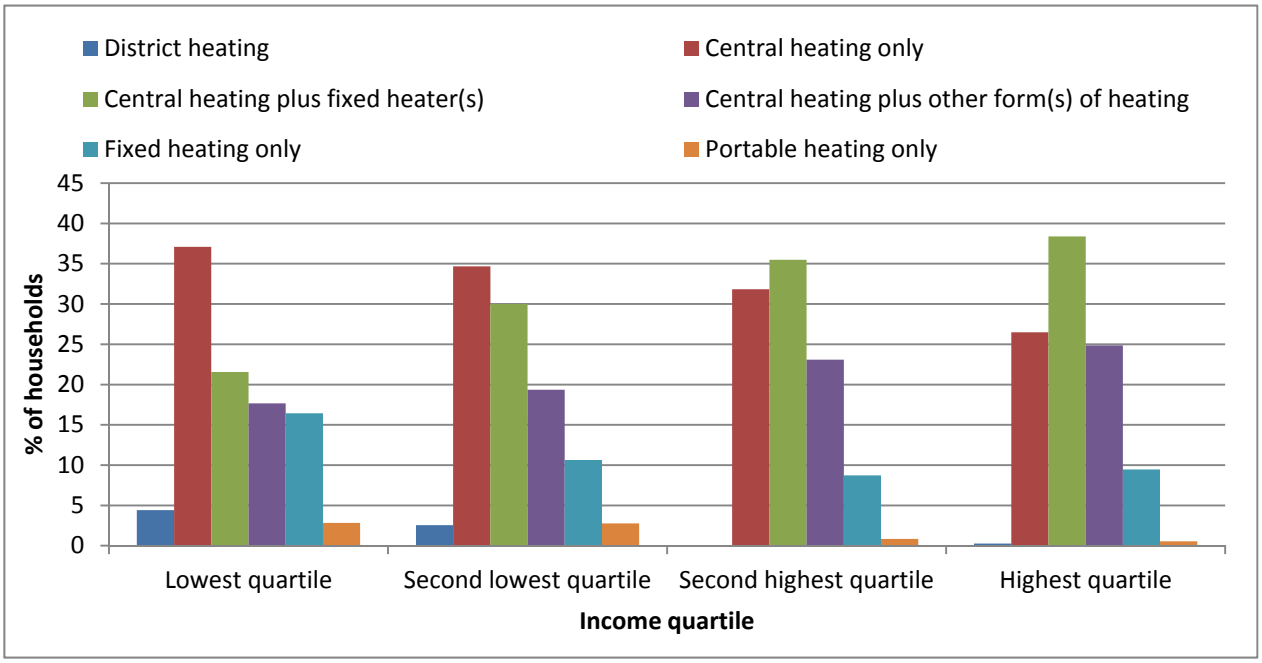
Figure 3.5 Percentage of respondents reporting each combination of means of heating, by tenure[17]



Tenure is likely to be strongly related in itself to a range of other characteristics that have been shown here to be associated with variations in heating systems. Flats are more likely to be rented than owner-occupied; larger homes are more likely to be owner-occupied than socially rented. Perhaps the clearest of these kinds of indicators is the effect of income. Breaking down the combinations of means of heating by income quartile (Figure 3.6) reveals that, as income increases, the reliance on single forms of heating decreases and the use of combinations of different heating types alongside central heating increases.

[17] Base: 2272 cases.

Figure 3.6 Percentage of respondents reporting each combination of means of heating, by income quartile[18]

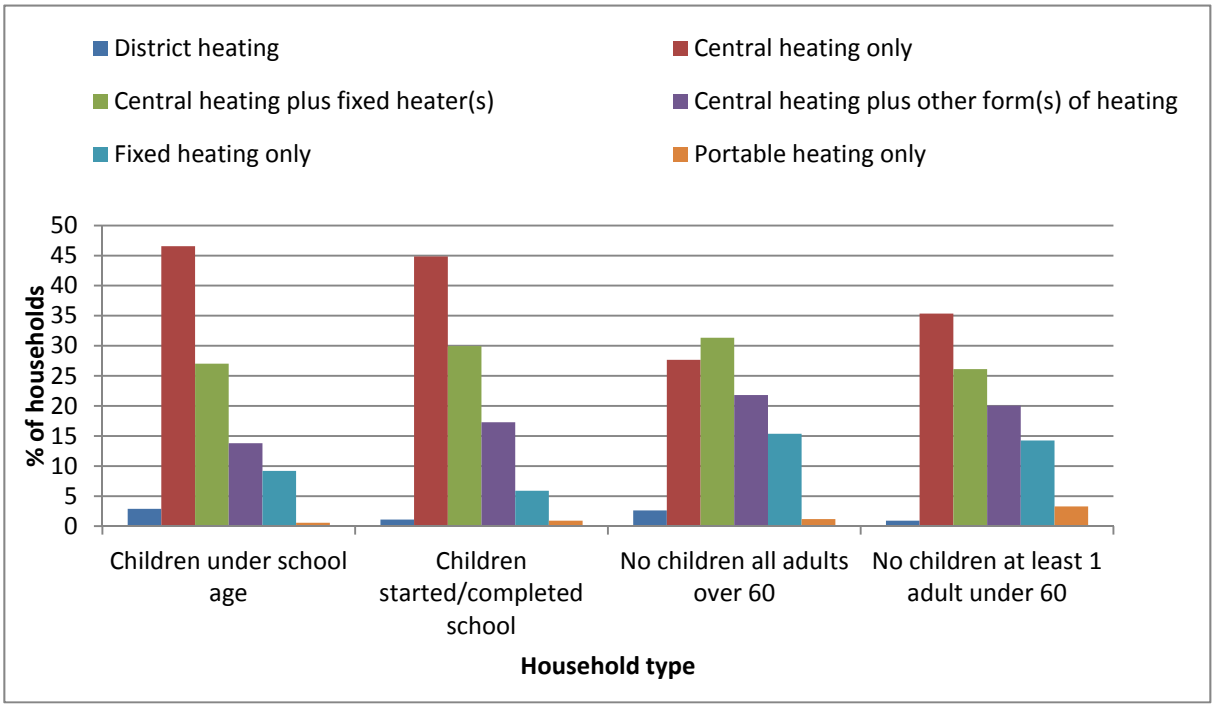


Finally, to understand a little more about the people occupying homes with different combinations of means of heating, Figure 3.7 breaks these down according to four household types: those with children under school age, those with children who have started or completed school, those with no children and all adults in the household aged over 60, and those with no children and at least one adult aged under 60. This reveals a similar pattern for the two groups containing households with children, dominated by central heating only, followed by other combinations involving central heating. The two groups containing only adults are the most likely to rely solely on heating that is fixed in the room, although central heating on its own or in combination still dominates within these groups. Households with no children and all adults aged over 60 tend to have the greatest reliance on combinations of central heating and other types of heating.

All of these patterns reflect other relationships with the property, which itself is related to the type of household: those with young children are likely to be of a lower income than older couples, and so are more likely to be in a smaller property, or renting, while those without children and a higher income are likely to be owner-occupiers. However, these patterns also reveal some of the constraints on the heating behaviours that people will perform in their home: if they are in a home that only has central heating, their ability to heat different spaces within the home may be much less flexible than if they were in a home with multiple means of heating available to them.

[18] Base: 1761 cases.

Figure 3.7 Percentage of respondents reporting each combination of means of heating, by household type[19]



3.3.5 Heating controls

There are two main aspects to the control of heating systems: the physical controls that are present on the systems themselves, and the way that householders use those controls to determine how they heat their home. The householders' interactions with systems are discussed later in this chapter; this section outlines the prevalence of different types of heating controls. Prevalence was primarily established through observations recorded by interviewers at the end of the interview, where the participant was willing for the interviewer to look around the home. Response options of 'Unsure' and 'Unable to check' were included as the observations relied on interviewers being able to observe systems and controls without needing to empty cupboards or climb into awkward spaces, and on interviewers recognising the type of system or control they were observing. These two response options have been amalgamated here into a single 'Unknown' response for analysis.

Interviewers recorded details of controls present on the heat source for central heating, where homes had this, plus any timers/programmers, room thermostats and thermostatic radiator valves (TRVs). Tables 3.5 and 3.6 present the observed prevalence of these control features.

On the central heating source (primarily a boiler, as shown in Table 3.4), about two-thirds of observed systems include some form of switch for controlling the item itself and the temperature of the water.

[19] Base: 2287 cases.

Table 3.5 Control features observed on central heating sources: % of cases[20]

Item	Present	Not present	Unknown
On/off switch on item itself	72	12	16
Switch/dial to set different water temperatures	67	19	14
Switch/dial to set different air temperatures	38	43	14

Table 3.6 reveals that most households (1351 of 1577) have a timer/programmer to control the heating, with digital models being most prevalent. Many of these have an 'extra time' option.

Table 3.6 Timer/programmers observed by interviewers

Item	Response	%	Base
Is there a timer/programmer	Present Not present Unknown	86 9 5	1577
How many are there?	1 2 3	98 2 *	1349
What type?	On/off switch only Digital Mechanical Unknown	5 63 29 3	1349
Does it also control the hot water?	Yes No Unknown	65 26 9	1349
Is there an extra time option?	Present Not present Unknown	59 18 24	1349
Is it visible in the room?	Yes No, enclosed in a cupboard Unknown	67 30 3	1349

Table 3.7 reports findings on observations of room thermostats, with 71% of homes having one and 6% more than one. About two-thirds of room thermostats are located in hallways or landings, with a further quarter located in living rooms. The figures on homes with more than one room thermostat suggest there may have been some confusion on the part of some interviewers, as it seems unlikely that one home would have five or more room thermostats. This may mean that some TRVs or thermostats on individual heaters have been counted as room thermostats in some cases.

Table 3.7 also shows whether there were TRVs in the homes; in 84% of cases where interviewers were able to observe the home, there were. This equates to 59% of all the homes that had central heating with radiators (some of the 41% remaining may also have had TRVs that the interviewers were unable to observe).

[20] Base: 1650 cases.

Table 3.7 Thermostats observed by interviewers

Item	Response	%	Base
Are there any room thermostats?	Yes in one room Yes in more than one room Not present Unknown	69 5 24 1	1474
Number of room thermostats if more than one	2 3 4 5 or more	40 13 7 36	73
Which rooms are room thermostats located in?	Living room Hallway/landing Bedroom Other	27 67 6 9	1095
Is the room thermostat mechanical or digital?	Mechanical Digital Unknown	63 35 3	1095
Is the room thermostat set in degrees or simple numbers?	Degrees Simple numbers Unknown	82 13 5	1095
Are there thermostatic radiator valves?	Yes No Unknown	84 13 2	1389

From these figures, the most common combinations of controls available for respondents to use with their central heating systems can be identified. Table 3.8 presents the combinations and their prevalence among the sample. This reveals that, of the cases where observations of the presence or absence of timer/programmers, room thermostats and thermostatic radiator valves were made, the majority (63%) had timer/programmers and both room thermostat(s) and thermostatic radiator valves. Only a small minority did not have a timer/programmer (8%) or only had a timer/programmer (3%).

Table 3.8 Prevalence of combinations of control systems for central heating[21]

Combination name	Description	%
Timer/programmer only	Timer/programmer only – no room thermostats or TRVs observed	3
Timer/programmer with room thermostat(s)	Timer/programmer plus room thermostat(s)	10
Timer/programmer with TRVs	Timer/programmer plus thermostatic radiator valves	16
Timer/programmer with both	Timer/programmer plus room thermostat(s) and thermostatic radiator valve(s)	63
Thermostat(s) only	Room thermostat(s) and/or TRV(s) but no timer/programmer	8

3.3.6 Use of rooms in the home

The size of the home, and in particular the number of rooms in the home, will clearly affect the use of heating in the home and the amount of energy used to heat it. Interviewers recorded the numbers of different types of rooms in the home, based on the use that occupants put the room to, rather than its designed purpose (e.g. a bedroom used as a study was recorded as a study). Table 3.9 presents the frequencies with which each main group of rooms was found in the sample. The mean number of rooms per home found in the

[21] Base: 994 cases.

sample was 10, including circulation spaces such as hallways and storage spaces; the mean number of day rooms and bedrooms combined was 4.

Table 3.9 Numbers of different types of rooms in the home: % of cases for frequency of each type[22]

Room type	0	1	2	3	4	5	6	7	8	9
Separate kitchen[23]	33	64	*	*	*	-	-	-	-	-
Combined kitchen[24]	63	35	1	*	-	-	-	-	-	*
Other kitchen-related[25]	67	88	4	*	-	*	-	-	-	-
Day rooms[26]	4	47	30	14	5	*	*	-	-	-
Bedrooms	*	12	31	40	13	4	-	*	-	-
Bathrooms/WCs	*	50	32	14	3	1	*	-	-	-
Gym / exercise / games	99	1	*	-	-	-	-	-	-	-
Circulation spaces[27]	5	28	52	15	1	*	-	-	-	-
Storage[28]	24	65	9	1	*	*	-	-	-	-
Outbuildings / conservatories	95	5	*	*	-	-	-	-	-	-

Respondents were asked to describe how selected types of room (day rooms, bedrooms, gym/exercise/games rooms, conservatories and heated outbuildings) are used. Very few rooms are regarded as 'not used' by householders, and in most homes there are no or very few rooms that are 'rarely used' (see Table 3.10).

Table 3.10 Numbers of rooms (selected types) put to different uses: % of cases for frequency of each type[29]

	Number of rooms of each type											
Use of room	0	1	2	3	4	5	6	7	8	9	10	11
General use	*	2	22	28	22	13	7	3	1	*	*	*
Rarely used	53	27	14	4	1	*	-	-	-	-	-	-
Not used	96	3	1	*	-	*	-	-	-	-	-	-

Further analysis of the relationship between the stated use of selected rooms and the total number of such rooms in the home found a strong linear relationship between the two (see Figure 3.8). The number of rooms in general use in the home is strongly predicted by the number of rooms in the home. In other words, people generally use the space they have, and have few rooms that they perceive to be rarely used or unused in their home. This, of course, may reflect that people tend to choose homes that provide the space they need. However, it also suggests that heating strategies focusing on reducing heating in rarely used or unused rooms may not have a large impact on heat energy demand except in the largest homes, where there is increasing divergence between the number of rooms and the number that are in general use.

It is also the largest homes where zonal controls would most easily be introduced because they are the most likely to have existing central heating (see Figure 3.9). Homes with central heating may also be more likely to heat all rooms. The largest homes are almost exclusively owner-occupied. In smaller homes, zonal control is therefore likely to be more attractive as a means of dealing with the different times when each room is used and possibly the different individuals using the rooms and the different activities carried out.

[22] Base: 2287 cases.

[23] Not used as a dining room but could have a breakfast bar.

[24] Kitchen diner or open plan kitchen / living / dining area.

[25] Pantry/larder or utility room.

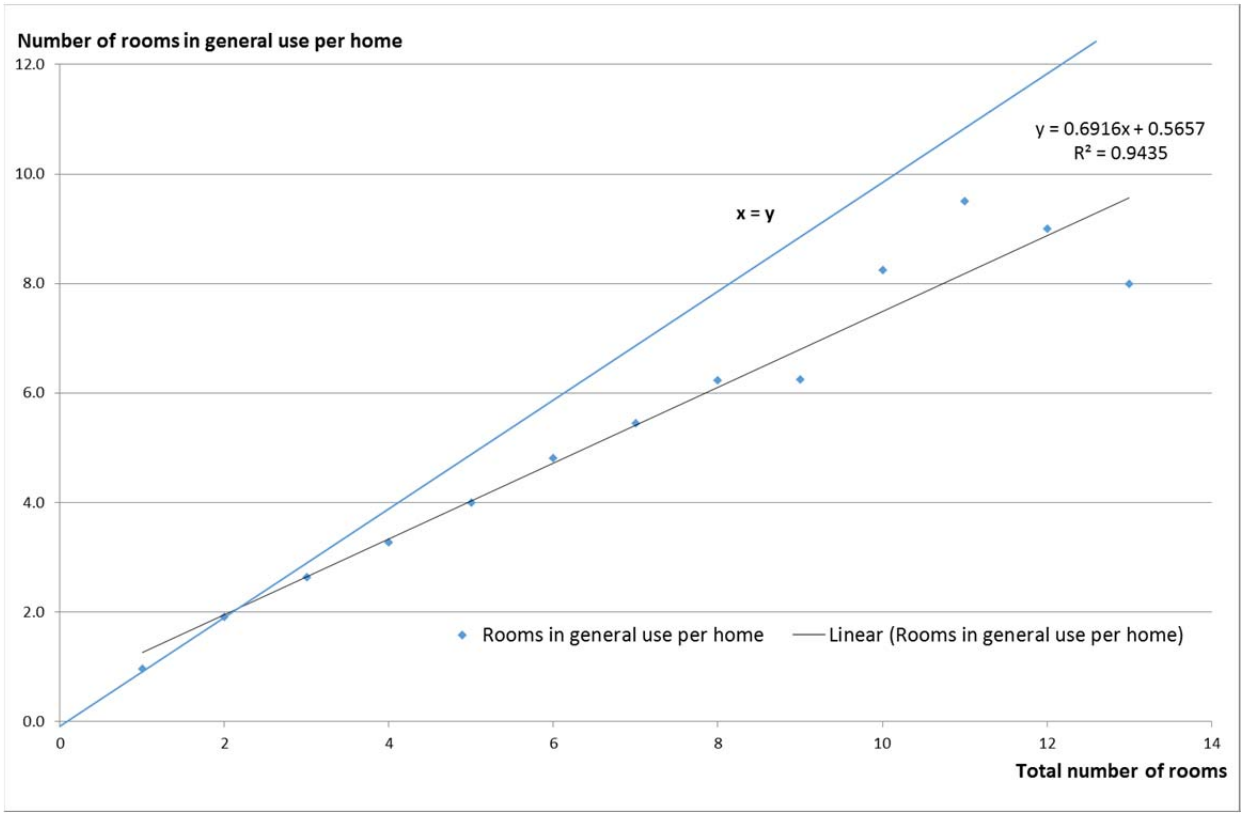
[26] Living room / dining room / study / studio / home office / bedsit room.

[27] Hall / landing / porch (not open to the outside).

[28] Cellar, loft or other storage room.

[29] Base: 2287 cases.

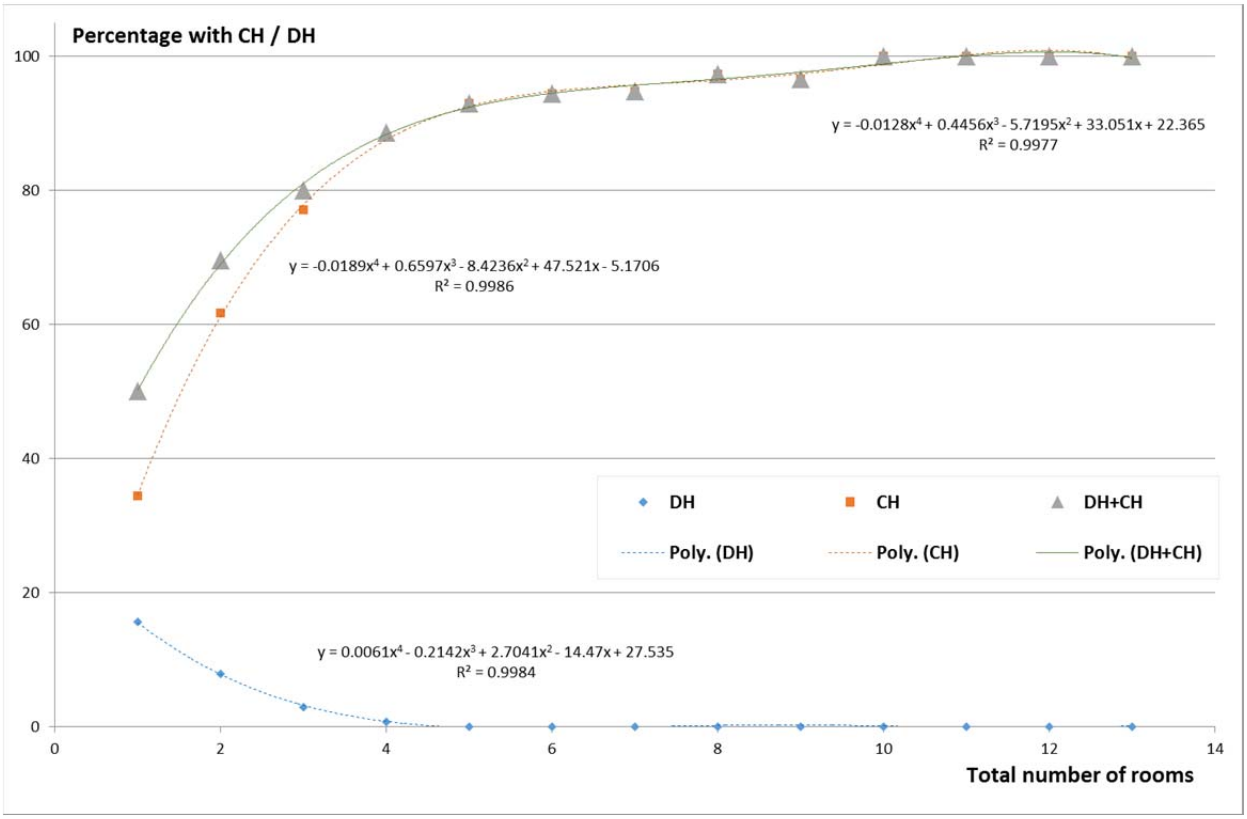
Figure 3.8 Relationship between number of selected rooms and the use of rooms[30]



[30] Question on total number of rooms: "*Looking at this list, could you indicate how many of each of these kinds of room you have as part of your home? Think about the main way you use the room rather than what it might have been designed for."* Answer selected from list of rooms.

Question on use of rooms (asked for habitable rooms selected in the previous question): "*Which of the following best describes how that room is used?*" Answer options: "*1. Occupied by someone in the household at least some of the time, most days/ 2. Occupied by someone in the household less often / 3. Rarely or never occupied by someone in the household/ 4. Used mainly for/by pets/ 5. Used mainly by someone who is away from home a lot of the time / 6. Used mainly for guests/ 7. Used mainly for storage/ 8. Not used at all/ 9. Other*".

Figure 3.9 Relationship between number of selected rooms and the presence of central or district heating[31]



Respondents were asked whether they heat only some of the rooms in their home as part of their normal strategy for keeping warm. In combination with the stated use of the rooms, as presented in Table 3.10 above, responses to this question were used to identify the proportion of cases where unused or rarely used rooms were heated. Table 3.11 reveals that, of the 4% of respondents who reported having unused rooms, about two-thirds did not report heating only some of the rooms in their home (representing 64 cases). While 46% of respondents reported having rarely used rooms in their home, only 11% reported that they heated only some of the rooms in their home. This suggests that 35% of cases (around 800 households) may be heating rooms that are rarely used.

[31] Question on total number of rooms: "*Looking at this list, could you indicate how many of each of these kinds of room you have as part of your home? Think about the main way you use the room rather than what it might have been designed for.*" Answer selected from list of rooms.

Question on heating type: "*I would now like to ask some questions about heating your home and keeping warm. Looking at this card, please tell me which types of heating you have anywhere in your home, including any that you have but do not actually use.*" Answer selected from list of heating types.

Question on main heating: "*And what do you think of as your main way of heating the home?*" Answer selected from previously indicated heating types.

Table 3.11 Heating state of unused and rarely used rooms (%)[32]

State of use	Number of rooms	Heated (%)	Unheated (%)	Base
Unused rooms	No unused rooms	78	18	2287
	1 unused room	2	1	
	More than 1 unused room	1	*	
Rarely used rooms	No rarely used rooms	46	8	2287
	1 rarely used room	20	6	
	More than 1 rarely used room	15	5	

3.4 What do people do to keep warm?

3.4.1 Introduction

This section describes the prevalence and combinations of the various means that people use to keep warm at home in the UK. It examines whether these means always keep people warm enough, and identifies relationships with characteristics of the heating system, property and household. Variations in the use of heating according to time of year, time of day and occupancy of the home are examined, and common strategies adopted to control the heating are identified. Finally, it examines the effect on heating behaviour of a range of different circumstances that the household may face.

3.4.2 Common strategies

Figure 3.10 shows the prevalence of the various ways that people keep warm at home on a typical winter's day – not in especially cold weather. There is a wide range of methods (a mean of 5.2 per respondent) and each one could itself encompass considerable diversity. Figure 3.11 shows the additional methods to keep warm that respondents report using if the usual methods are not sufficient. There is again considerable diversity and a mean of 2.7 methods are reported per respondent.

The usual methods of keeping warm.

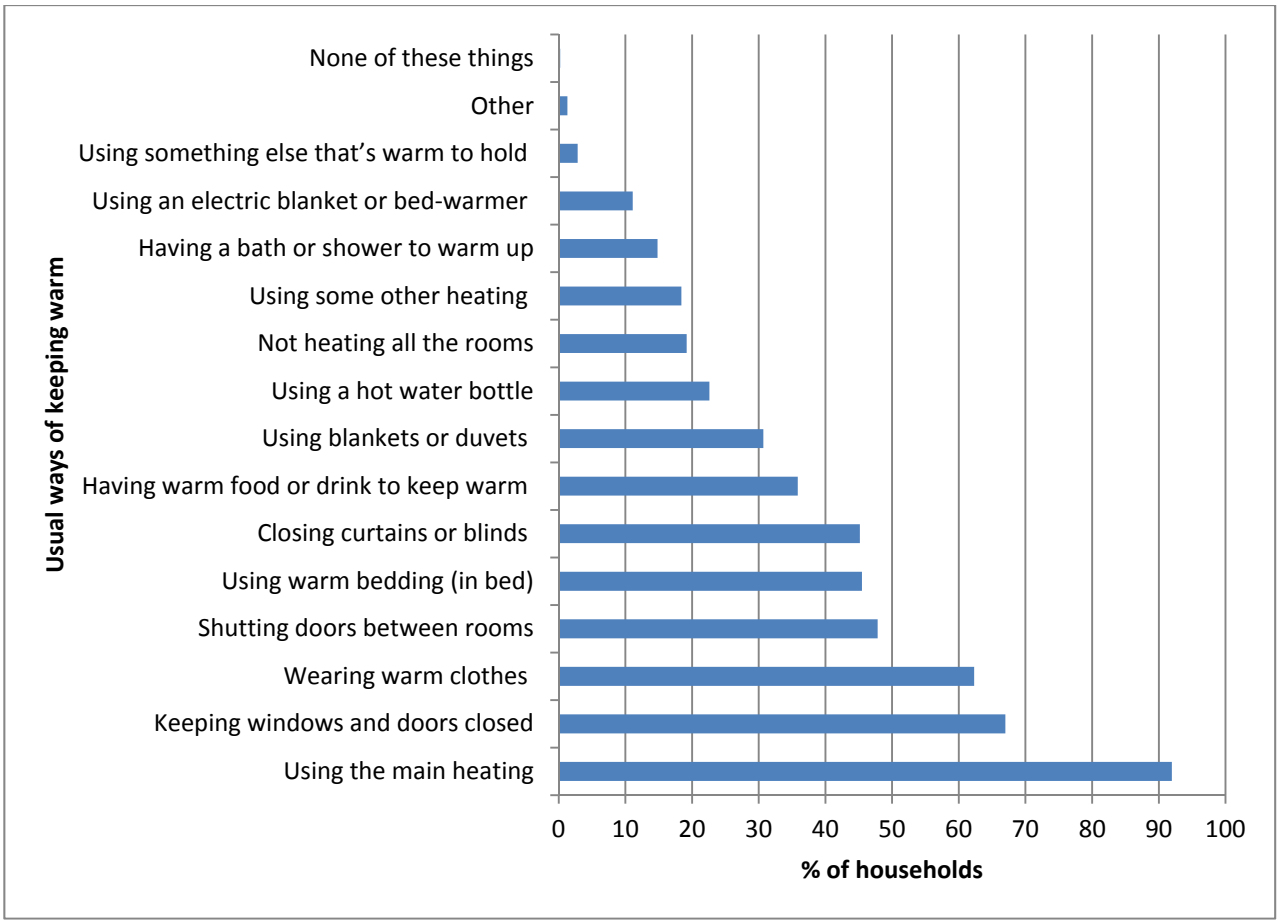
- Unsurprisingly, the main heating is used in most cases, with around one in five using some other form of heating instead of, or in addition to, the main heating.
- Around two-thirds close external windows and doors (specifically to keep warm) but under half manage heat loss by closing curtains, blinds or internal doors. Only 19% use the alternative of not heating all rooms but 14% combine this with closing internal doors.
- Insulating the person is a common strategy, with wearing warm clothes the most frequently reported example (62%), followed by using warm bedding in bed (45%) and – perhaps most interesting – using bedding when not in bed (31%).
- Directly warming the person is reported less often than other strategies but more often than might have been expected, and with a range of specific approaches: using warm food or drink (45%); using a hot water bottle (23%) or something else warm to hold (3%); or having a bath or shower to warm up (15%).

[32] Question on total number of rooms: "*Looking at this list, could you indicate how many of each of these kinds of room you have as part of your home? Think about the main way you use the room rather than what it might have been designed for.*" Answer selected from list of rooms.

Question on use of rooms (asked for habitable rooms selected in the previous question): "*Which of the following best describes how that room is used?*" Answer options: "*1. Occupied by someone in the household at least some of the time, most days/ 2. Occupied by someone in the household less often / 3.Rarely or never occupied by someone in the household/ 4. Used mainly for/by pets/ 5. Used mainly by someone who is away from home a lot of the time / 6. Used mainly for guests/ 7. Used mainly for storage/ 8. Not used at all/ 9. Other*".

Question on heating of rooms: "*For each of the rooms I mention, please tell me which option on this card applies.*" Answer options: "*(Room) has heating and we do tend to use the heating in winter/ (Room) has heating but we do not tend to use the heating in winter/ (Room) has no heating*".

Figure 3.10 Percentage of respondents reporting each usual method of keeping warm[33]



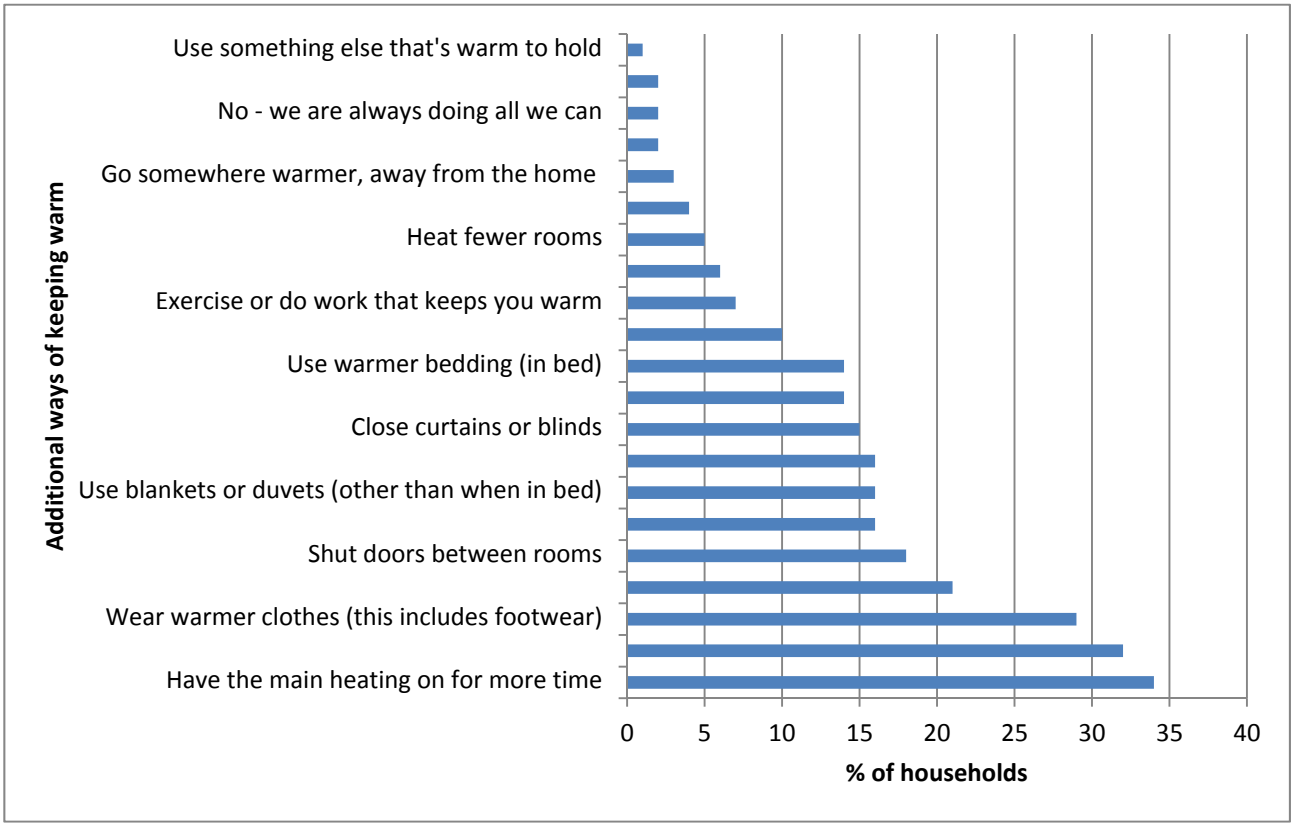
The additional methods of keeping warm.

- Only 21% say they do not need to do anything extra because the usual methods of keeping warm are always enough. A further 2% say they are always doing all they can, without this necessarily always being enough.
- The most frequently reported approach is to use more heating: around one-third have the main heating on for more time and/or turn up the thermostat while around one-sixth use more of some other heating.
- Better insulating the person is the next most frequently reported approach: wearing warmer clothes (29%), or using warmer bedding in bed (14%) or when not in bed (16%).
- In contrast with the usual means of keeping warm, there is approximate parity between closing external windows and doors (16%), closing internal doors (18%) and closing curtains or blinds (15%).
- While 2% heat more rooms, 5% heat fewer rooms. This represents a small overall proportion of households but appears to signal a difference between advance (heat rooms when they need heating) and retreat (heat as many rooms as can be afforded but perhaps maintain comfort in the rooms that are still heated). Income does not have an observable relationship with heating more or fewer rooms, but there is a slight trend towards performing these behaviours more in homes with greater numbers of rooms (although the small number of households involved makes it difficult to draw firm conclusions from this). Of course, homes with greater numbers of rooms provide more opportunities to practice such behaviours.
- A greater diversity of approaches to directly heating the person emerge in the additional methods than in the usual methods of keeping warm: using warm food or drink (14%); using a hot water bottle (10%) or something else warm to hold (1%); exercising or working (9%); having a bath or shower to warm up (6%); or using an electric blanket or bed warmer (4%).

[33] Base: 2313 cases.

- In 3% of cases, the respondent reports going somewhere warmer, away from the home, rather than trying to keep warm at home.

Figure 3.11 Percentage of respondents reporting each additional method of keeping warm[34]



To facilitate further analysis, the methods of keeping warm were further categorised, as in Table 3.12. The combinations of things that people do were then represented as combinations of these categories, as in Table 3.13. In arriving at these combinations, we have treated "Other" heating as being *de facto* the main heating if it is the only heating being used. This could arise for example, if a respondent says that central heating is the main heating, meaning the main system in the home, but actually uses some other form of heating as first choice. In some cases, "Retain" and "Person" are treated as interchangeable because they are both ways of keeping the person warm as distinct from keeping the room warm.

The combinations of methods usually used to keep warm.

- In around four-fifths of cases, one form of heating is being used, but in most cases with some supplementary method.
- A further 14% use two forms of heating, again with some supplementary method.
- Only 13% use just one form of heating and no supplementary method.
- The most frequently reported approach is one form of heating, controlling where the heat goes plus insulating and/or heating the person (54%).
- More surprising is that 5% are not using any heating.

The combinations of additional methods used to keep warm.

- In contrast to the usual methods, approaches other than room heating now dominate, with 30% using only non-heating methods and a further 30% combining heating with non-heating methods.
- Those using non-heating methods or doing nothing extra account for just over half the respondents.

[34] Base: 2313 cases.

Table 3.12 Categories of methods of keeping warm

Category	Includes
M: Use **main heating**	Use main heating
O: Use **other heating**	Use other heating
C: **Control** where heat goes	Keep windows & ext. doors closed Shut doors between rooms Not heat all rooms Heat all rooms Close curtains or blinds
R: **Retain** own warmth	Wear warm clothes Use warm bedding (in bed) Use blankets or duvets (not in bed)
P: Heating the **person**	Warm food or drink to keep warm Bath or shower to warm up Use hot water bottle Use something else warm to hold Use electric blanket or bed warmer

Of course, the available additional methods will depend on what is usually already being done. The combinations of usual and additional methods (see Table 3.14) are therefore important to understand. The most striking point about Table 3.14 is that the type of additional method varies little with the usual means, as shown by the narrow range of figures in each row of the table. Put another way, whatever the household is usually doing to keep warm in winter, when they need to do something additional, it is as likely to be more of the same as it is to be something different: the additional methods are not predicted by the usual methods.

Table 3.13 Combinations of methods of keeping warm

Combination (see Table 3.12 for key)	Label	% usual[35]	% additional[36]
One form of heating (M or O) only	H	13	13
One form of heating plus C	HC	8	4
One form of heating plus R and/or P	HRP	6	11
One form of heating plus C plus either R or P	HCR/P	19	4
One form of heating plus C and R and P	HCRP	35	4
Two forms of heating plus one or two of C, R and P	2HCRP	6	5
Two forms of heating plus C and R and P	All	9	2
No heating, some combination of C, R and P	CRP	5	30
Always warm	No need	-	21
Can't do more	None	-	2

[35] Base: 2287 cases.

[36] Base: 2287 cases.

Table 3.14 Percentage of respondents using each additional combination of methods, given each combination of usual methods of keeping warm[37]

Additional methods	Usual methods								Range
	H	HC	HRP	HCR/P	HCRP	2HCRP	All	CRP	
Base	288	170	148	444	797	130	196	108	
H	9	10	9	10	10	9	10	9	1.0
HC	11	11	11	11	10	11	11	11	0.4
HRP	10	10	10	10	10	10	10	9	0.6
HCR/P	11	11	11	11	10	11	11	11	0.5
HCRP	11	11	11	11	10	11	11	11	0.6
2HCRP	11	11	11	11	11	10	10	11	1.5
All	11	11	11	11	11	10	10	11	0.7
CRP	8	7	7	7	8	9	9	7	2.2
No need	8	8	9	9	9	9	9	10	1.7
None	11	11	11	11	11	11	11	11	0.4

3.4.3 Do these actions always keep people warm enough?

Following the question asking them to identify the methods that they usually use to keep warm, respondents were asked “When you are doing that on a typical winter’s day, does it always keep you (and your household) warm enough?” While 72% of respondents agree that those typical actions ‘always’ keep them warm, 23% report that these actions only ‘sometimes’ keep them warm enough, and a further 4% report that these actions ‘rarely’ or ‘never’ keep them warm enough. A final 1% reported that this varies between household members. Further analysis of responses to this question is based on recoding the responses into ‘Always enough’ and ‘Not always enough’.

Responses to this question were examined in the light of the combinations of methods that people usually adopt to keep warm (Table 3.15). These figures reveal that most people using most combinations do usually find that these methods keep them warm enough. Those who are least likely to report ‘always’ feeling warm enough are those using every method available to them (All, 61%). This is logical, as people who frequently feel cold are likely to look for additional ways to keep warm. However, those who are most likely to report ‘always’ feeling warm enough also adopt a lot of different methods to keep warm, using more than one form of heating as well as one or two methods from the Control, Retain and Person groups (2HCRP, 83%). Since they have stopped just short of doing everything possible, this may be a sign that they have built up a strategy that does always kep them warm. Using one form of heating and controlling where that heat goes is also reported to be a successful method for keeping warm (HC, 82%), while those who use no heating at all are only slightly less likely to report that they ‘always’ feel warm enough (CRP, 69%).

[37] Refer to Table 3.13 for combination labels.

Table 3.15 Percentage of respondents who are always warm enough, using combinations of methods of keeping warm[38]

Usual methods[39]	% for each combination of methods	
	Always warm enough	Not always warm enough
H	79	21
HC	82	18
HRP	74	26
HCR/P	77	23
HCRP	69	31
2HCRP	83	17
All	61	39
CRP	69	31

Greater variation in the proportions of people reporting that they are 'always' warm enough is seen when examining this alongside the combinations of heating type used in the home (Table 3.16). Those with district heating overwhelmingly report 'always' being warm enough (95%), while those who use portable heating (44%) or heating that is fixed in the room (64%) are least likely to report 'always' being warm enough. Of the dominant heating form, central heating, the combination of central heating and heating that is fixed in the room is most likely to keep people warm enough (80%).

Table 3.16 Percentage of respondents who are always warm enough, using different combinations of heating type[40]

Heating type	% in each heating type	
	Always warm enough	Not always warm enough
District heating	95	5
Central heating only	71	29
Central heating and fixed	80	20
Central heating and other	70	30
Fixed in the room	64	36
Portable heating	44	56

As might be expected, the age of the property also has a relationship with how likely people are to report that they are 'always' warm enough. Table 3.17 reveals that people living in older properties are less likely to report 'always' feeling warm enough, with the proportion who are warm enough rising as properties become more recent.

Table 3.17 Percentage of respondents who are always warm enough by age of property[41]

Age of property	% in each heating type	
	Always warm enough	Not always warm enough
Pre-1964	69	31
1965-2001	76	24
2002 or later	85	15

[38] Base: 2287 cases.

[39] Refer to Table 3.13 for combination labels.

[40] Base: 2287 cases.

[41] Base: 2287 cases.

Perhaps counter-intuitively, there is a positive relationship between the number of rooms in the property and the proportion of respondents who report 'always' feeling warm enough: as the size of the home increases, so too does feeling warm enough (Table 3.18). While larger homes may be larger spaces to heat, suggesting they should be more difficult, they are also more likely to have central heating plus other types of heating, the dominant heating type offering success in keeping occupants warm. Additionally, larger homes are more likely to be owner-occupied and occupied by households with a higher income (Tables 3.19 and 3.20 reveal that both of these characteristics are related to higher levels of reporting 'always' feeling warm enough).

Table 3.18 Percentage of respondents who are always warm enough by number of rooms in property[42]

	% in each heating type	
Number of rooms	Always warm enough	Not always warm enough
6 or fewer	66	34
7 – 10	71	29
11 – 15	74	26
16 or more	80	20

Table 3.19 Percentage of respondents who are always warm enough by tenure[43]

	% in each heating type	
Tenure	Always warm enough	Not always warm enough
Owner occupier	78	22
Renter or other	63	37

Table 3.20 Percentage of respondents who are always warm enough by income quartile[44]

	% in each heating type	
Income quartile	Always warm enough	Not always warm enough
Lowest	65	35
Second lowest	74	26
Second highest	78	22
Highest	79	21

Against this background, the figures for each household type (Table 3.21) reveal that households made up entirely of adults aged over sixty are most likely to report 'always' feeling warm enough (80%). This group has already been shown to be most likely to use a combination of central heating and other types of heating, which also return the highest levels of reports of 'always' feeling warm (80% for central heating and heating fixed in the room). The figures for households with pre-school children are closest to the overall average for the sample as a whole; it is households with children who have started or completed school who are least likely to report 'always' feeling warm (67%), although this is very similar to the figure for households with no children and at least one adult aged under 60 (68%).

[42] Base: 2287 cases.

[43] Base: 2286 cases.

[44] Base: 1742 cases.

Table 3.21 Percentage of respondents who are always warm enough by household type[45]

Household type	% in each heating type	
	Always warm enough	Not always warm enough
Children under school age	73	27
Children started/completed school	67	33
No children all adults over 60	80	20
No children at least 1 adult under 60	68	32

In the section of the questionnaire that asked about cooling (discussed in detail in Chapter 4), respondents were asked what they did to avoid overheating in winter: 37% of respondents do carry out actions to avoid overheating; this indicates that, for 63% of respondents, overheating in winter was not a problem. Analysing this alongside the question asking whether people 'always' feel warm enough in winter revealed an important finding (see Table 3.22). Of those who do always feel warm enough, a large majority sometimes overheat in whereas, for those who do not always feel warm enough in winter, similar numbers do and do not overheat in winter. This suggests some kind of conflict between ability to keep warm and ability to avoid overheating in winter.

Table 3.22 Percentage of respondents who are always warm enough by overheating and cooling[46]

	Always warm enough	Not always warm enough	Base
Sometimes overheat in winter	49	14	2287
Do not overheat in winter	23	13	

3.4.4 Variation in heating with time of year and time of day

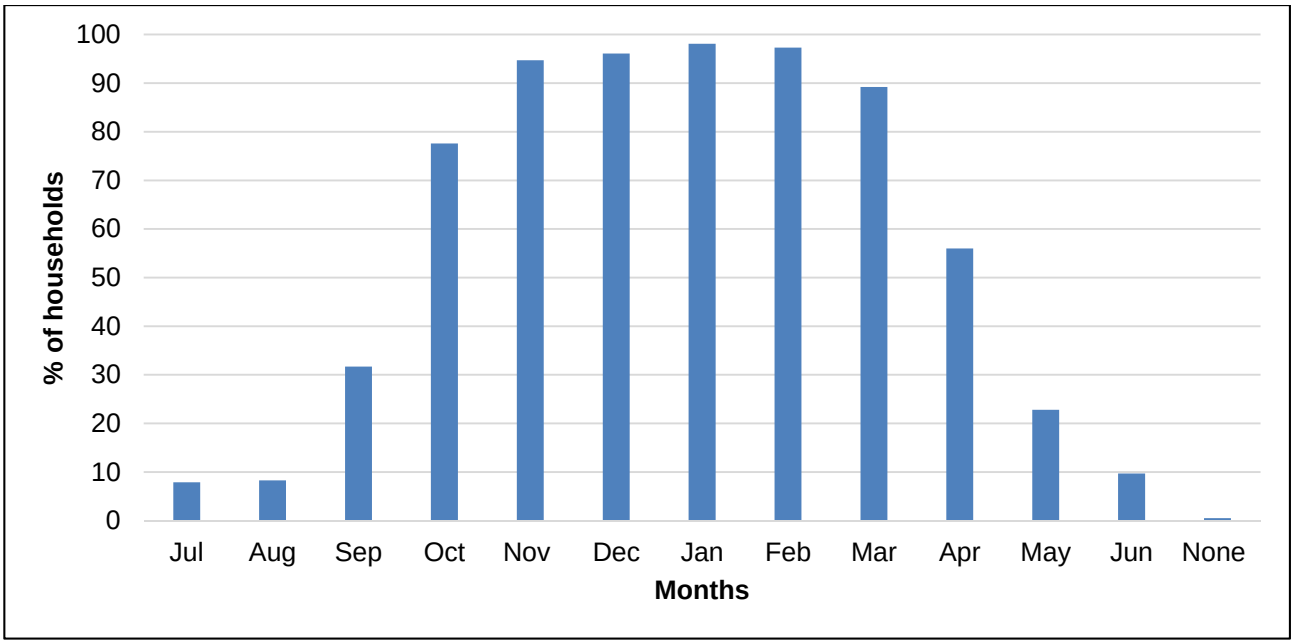
Figure 3.12 shows the months of the year when respondents report having their heating on. These reports do not rely on respondents having accurate memories of exactly when they turn heating on or off (daily or annually) – only that they are aware of the months in which heating is sometimes used. This should generally be reliable although it could depend to some extent on how routine their behaviour is, and whether the respondent is the person who is at home at the time and/or who operates the controls.

From November to February, almost all respondents are using the heating. More surprisingly, 8% are still using the heating for at least part of July and August. The increase in percentage using heating between August and November is slightly steeper than the decline from February to July. This perhaps arises from people being more aware of getting cold at some point during autumn than they are of the opportunity to be warm without the heating on as spring progresses. This would indicate an opportunity to reduce heating energy demand by using feedback that signals to the household that the home would be warm enough without having the heating on.

[45] Base: 2287 cases.

[46] Base: 2287 cases.

Figure 3.12 Percentage of respondents reporting heating during each month[47]



Of those using the heating all year:

- 54% (92 households) are households of 'no children and all adults aged over 60';
- 24% (40 households) are childless households with at least one adult aged under 60.;
- 25% (43 households) report that they, or someone in the household, have a disability which affects how warm or cool they keep the home or the amount of hot water they require.

Among those who heat at some point during the summer months (July and August) but not all year:

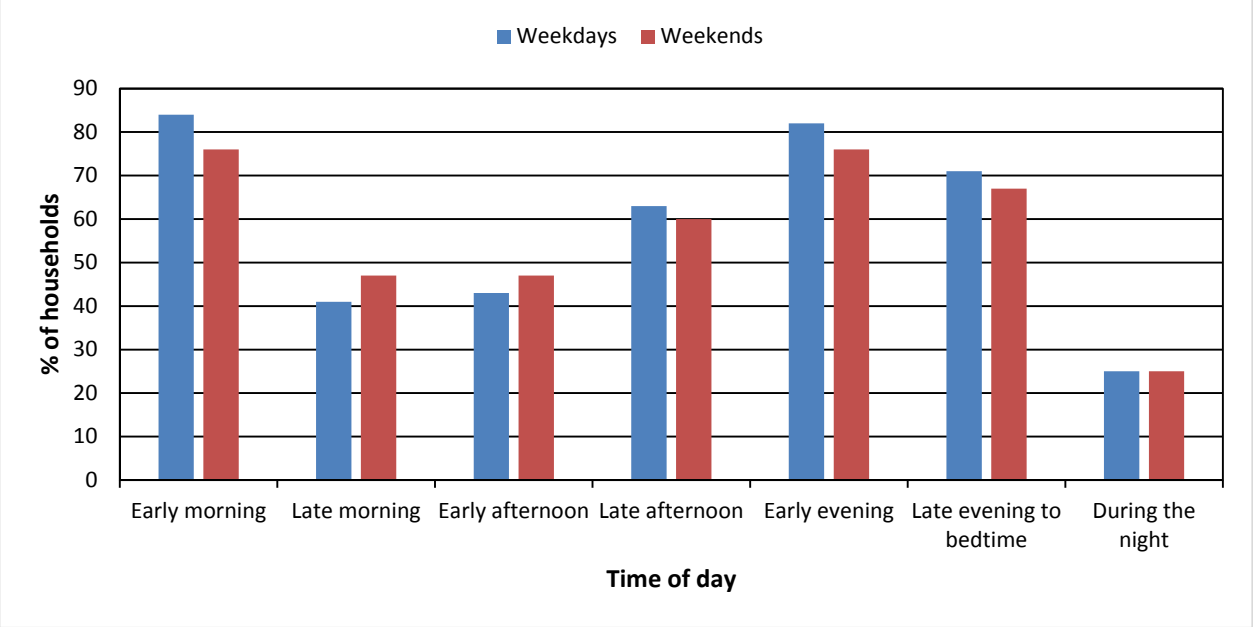
- 45% (58 households) are households of 'no children and all adults aged over 60';
- 26% (33 households) are found in both childless households with at least one adult under 60 and households with school-aged children;
- 32% (43 households) report that they have a disability affecting how warm or cool they keep the home or the amount of hot water they require.

Out of the whole sample, 20% of respondents (462 cases) reported that, during the months when they use their heating, the heating is on at all times, including overnight and when there is nobody at home. The majority of this group of respondents (60%) report that they do this because they would be too cold otherwise, while 35% give convenience as their motivation, and 27% base this behaviour on the belief that having the heating on all the time will cost less or will use less energy. This behaviour is not accounted for by absence of timing controls: a timer/programmer was observed in 80% of homes where respondents reported that the heating is on at all times, compared to 87% where respondents reported that the heating was not on all of the time.

Figure 3.13 shows the times of day when respondents report usually having their heating on, during weekdays and at weekends. As expected, the peak heating periods are early morning and early evening but a quarter of homes are also heated at night. The heating is on all the time in 20% of cases. Weekdays and weekends follow a generally similar pattern and this is likely to arise from some combination of the need for heating being similar and households not varying the timer settings. Where there is a difference, heating is more likely to be in use during the day at weekends than on weekdays and this would be consistent with the greater likelihood of someone being at home during the day at weekends. More surprising is the slightly lower percentage of homes heated at other times of day at weekends. This may relate to some combination of getting up later, being out of the house (e.g. socialising in the evening) and the extra heating during the day reducing the need for heating at other times.

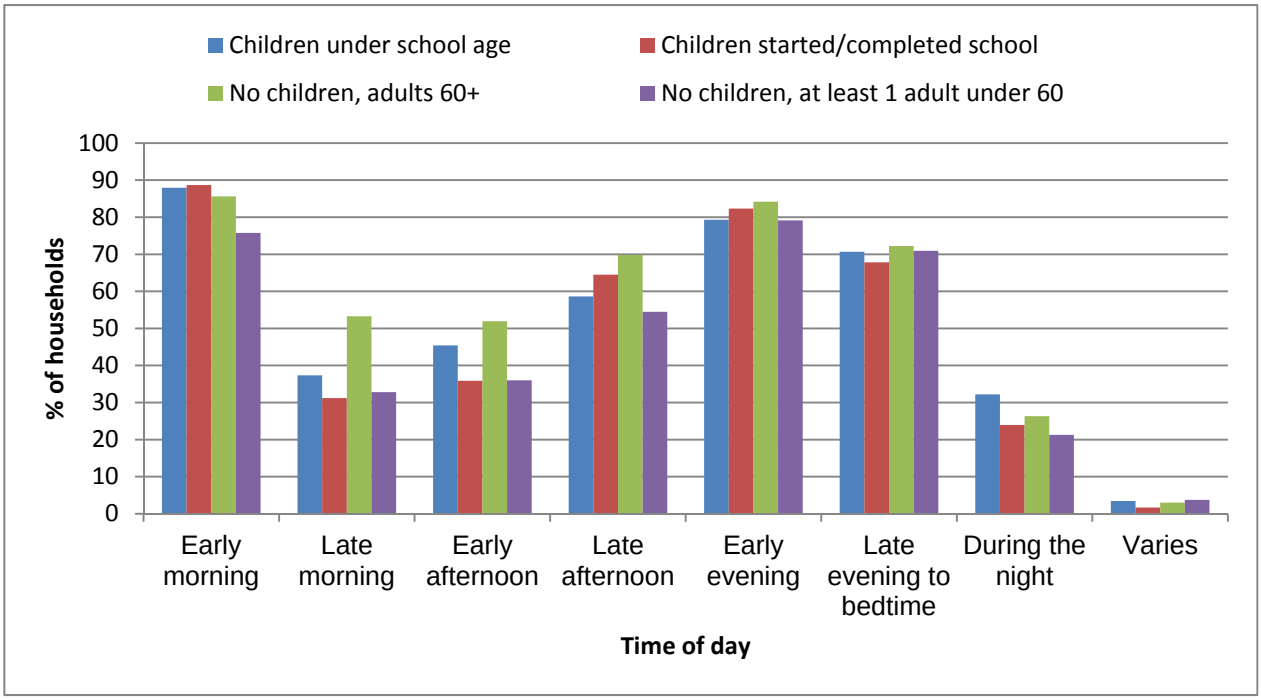
[47] Base: 2287 cases.

Figure 3.13 Percentage of respondents reporting heating on at each time of day[48]



To explore this further, heating patterns were broken down by the four household types (Figure 3.14). The overall pattern is very similar across all household types, but as expected there are slight variations, with greater levels of daytime heating among households made up entirely of those aged over sixty and households with pre-school children. These households also have slightly lower levels of early morning and evening heating than other household types, perhaps reflecting that greater levels of heating during the day leave less of a requirement for heating at other times.

Figure 3.14 Percentage of households with heating on during weekdays by type of household[49]



[48] Base: 2287 cases.

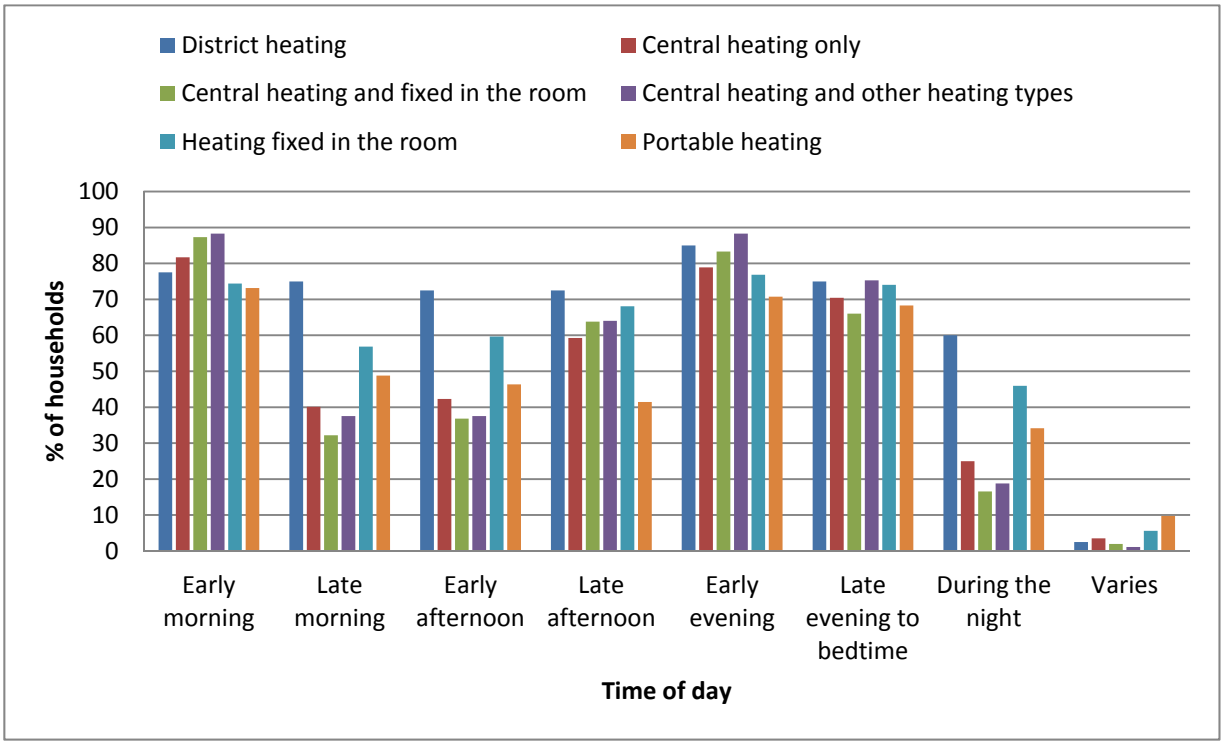
[49] Base: 2287 cases.

The household type reflects the influence of the people within the home, but the types of system available to the household are also an important influence on how people use their heating. This is illustrated when the heating patterns for different heating systems are examined.

Figure 3.15 presents the weekday heating pattern for each of the six most common combinations of heating system. A comparison between those whose main heating type is district heating and all of those with central heating as their main heating type reveals distinct differences. While those with central heating conform to the pattern of early morning and evening heating already seen, the district heating pattern reveals less pronounced differences across times of day, including much higher levels of overnight heating.

The pattern seen for central heating is dominant because central heating is so widespread, with 74% of households having some combination of central heating. However, examination of the patterns for those households with individual heating fixed in the room as their main heating type and those with portable heating as their main type reveals a similar pattern of more early morning and evening heating and less daytime heating. As fixed and portable heaters are more likely to be individually controlled and so turned on and off as required, this suggests that the common pattern fits most effectively with the times when households need their heating to be on. Dissatisfaction with the lack of control over district heating (as revealed in the literature review and qualitative elements of this project) may stem from the failure of many district heating systems to provide this pattern of heating. This suggests that future design solutions should enable households to achieve this heating pattern easily.

Figure 3.15 Percentage of households with heating on during weekdays by type of heating system[50]



3.4.5 Variation in heating with occupancy of the home

Occupancy is based on respondents' reports of when someone in the household is always or usually at home, when someone is rarely or never at home, or when there is sometimes someone at home or it is too variable to say. Responses to these questions were collected in a self-completion questionnaire, and not every household completed this (1658 of the 2287 respondents completed at least some of the occupancy questions, although there is further variation in the numbers responding for each timeslot asked about).

[50] Base: 2287 cases.

To present an overview of the general occupancy patterns on weekdays and at weekends, Figure 3.16 compares the percentages of those responding that someone in the household is always or usually at home in each timeslot on weekdays and weekends. This reveals high levels of occupancy of the home, with similar proportions in most timeslots on weekdays and weekends. The largest differences between weekdays and weekends are seen in slightly greater daytime occupancy at weekends than during the week, as might be expected. There is also a slight tendency for higher occupancy during weekday evenings than on weekend evenings, again as might be expected. Given the overall similarity between weekday and weekend occupancy patterns, the following analysis focuses on weekday patterns.

Figure 3.16 Percentages of households reporting that someone is usually or always home on weekdays and at weekends[51]

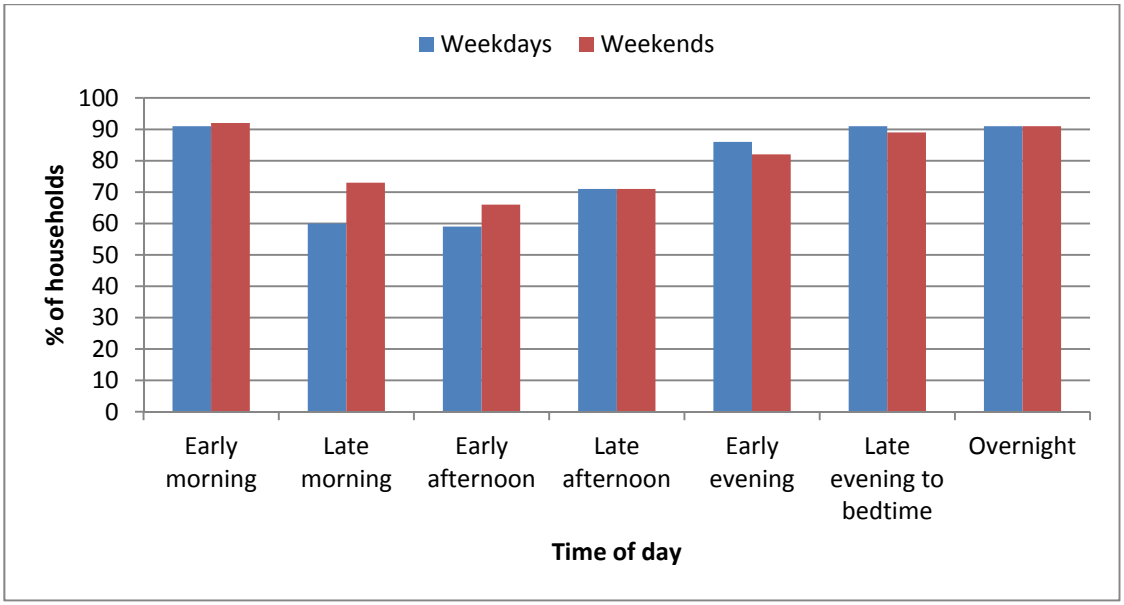
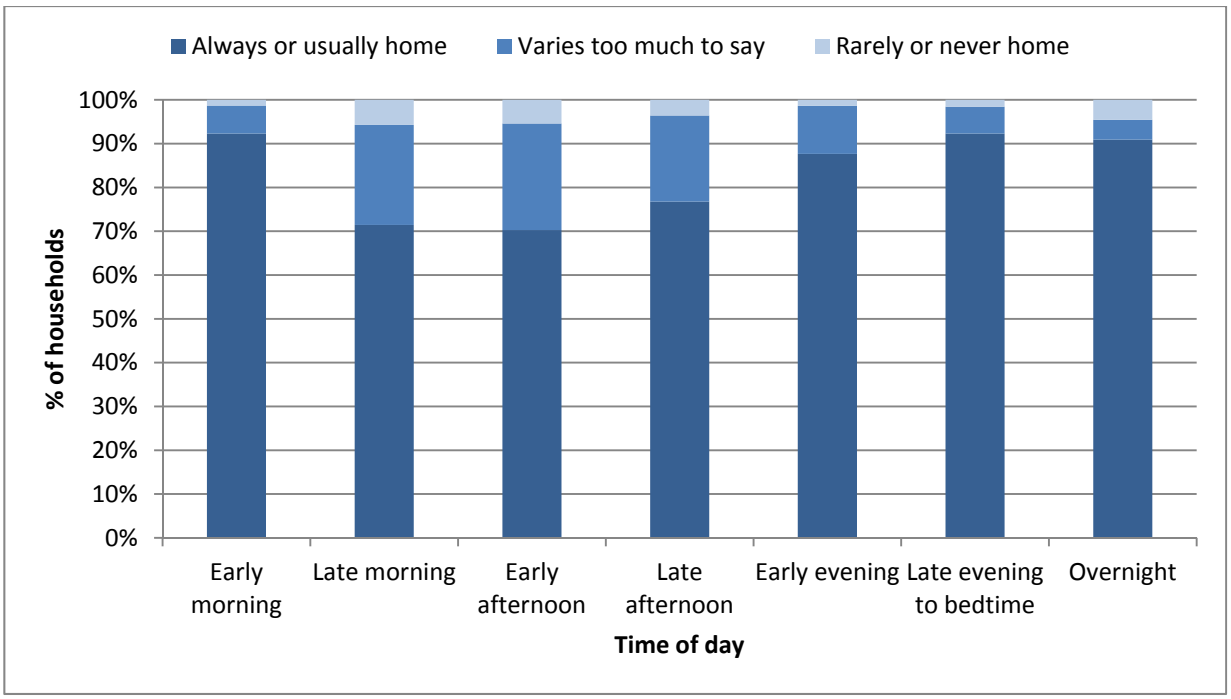


Figure 3.17 compares when respondents reported that their heating is turned on with the patterns of occupancy of the home. This reveals that there are actually few times reported when there is rarely or never somebody at home but the heating is on (a maximum of 2% of households at any time of day). The proportion of times when there is sometimes someone in or when it is too variable to say, but the heating is turned on, is also relatively small, rising to a maximum of 11% in late afternoon.

[51] Base for weekdays: Early morning 1658; Late morning 1519; Early afternoon 1522; Late afternoon 1552; Early evening 1598; Late evening to bedtime 1598; Overnight 1562. Base for weekends: Early morning 1658; Late morning 1567; Early afternoon 1562; Late afternoon 1571; Early evening 1614; Late evening to bedtime 1609; Overnight 1567.

Figure 3.17 Percentage of households with heating on during weekdays when someone is at home ("Always/usually", "Varies too much to say", or "Rarely/never")



3.4.6 Control of heating

The ways in which respondents describe controlling the temperature have been broken down in two ways, as shown in Table 3.23: manual vs thermostat control and centrally vs room-by room control. 'Manual control' includes manually turning the heating on and off, adjusting individual heat sources, and opening or closing windows or doors. 'Thermostat control' includes using a single thermostat in one room, other thermostats in individual rooms, thermostatic valves on radiators, or changing the temperature setting on the boiler itself. 'Centrally' includes the use of a single thermostat in one room, or changing the temperature setting on the boiler itself, while room-by-room includes manually turning the heating on and off, using thermostatic valves on individual radiators, using room thermostats in individual rooms, adjusting individual heat sources (e.g. using switches on heaters or manual valves on radiators), and opening or closing windows or doors.

Of those respondents who reported that they did not control the temperature, 73% saw no need to change the temperature, 22% did not believe they had the means to control it and 6% believed it would increase energy use. The ways in which respondents describe controlling the timing of the heating have been broken down in terms of whether the control is manual or uses timing/programming controls (see Table 3.24). It is clear that there are many combinations of approaches, even at this high level of description. To facilitate further analysis, control strategies were categorised as shown in Table 3.25. These categories have been created by logical examination of the combinations of control of timing and temperature. Where a combination was insufficiently prevalent to form a useful category on its own, we merged it with the most similar combination(s) to form a category.

Table 3.23 Percentage of respondents using each approach to controlling the temperature[52]

Manual vs thermostat control				
		Thermostat		
		Yes	No	Total
Manual	Yes	18	22	40
	No	50	10	60
	Total	68	32	100

Central vs room-by room control				
		Room-by-room		
		Yes	No	Total
Central	Yes	26	27	53
	No	36	10	46
	Total	62	37	99

Table 3.24 Percentage of respondents using each approach to controlling the timing of heating[53]

Manual vs timer control				
		Timer		
		Yes	No	Total
Manual	Yes	18	28	46
	No	31	1	32
	Total	49	29	78

Table 3.25 Categories of approach to controlling temperature and the timing of heating and the percentage in each category[54]

Short description	Long description	Label	%
Manual temperature, manual time	Manual control only of both temperature and timing	Temp M / Time M	13
Active temperature, active time	Both manual and thermostat control of temperature Both manual and timer/programmer control of timing	Temp A / Time A	14
Active temperature, set and forget time	Both manual and thermostat control of temperature Only timer/programmer control of timing	Temp A / Time SF	6
Set and forget temperature, set and forget time	Only thermostat control of temperature Only timer/programmer control of timing	Temp SF / Time SF	23
Set and forget temperature, active time	Only thermostat control of temperature Both manual and timer/programmer control of timing	Temp SF / Time A	18
No control temperature, any of time	Unable to or do not control temperature Use any method to control timing	Temp No / Time Any	10
Active temperature, always time	Both manual and thermostat control of temperature Heating that is always switched on	Temp A / Time All	7
Set and forget temperature, always time	Only thermostat control of temperature Heating that is always switched on	Temp SF / Time All	10

The balance of categories of control varies markedly with type of heating system. Figure 3.18 shows this in relation to the categories of heating system described in Table 3.3. The three profiles where central heating is used are relatively similar, although active control and “set and forget” increase and manual control decreases as other forms of heating come into play.

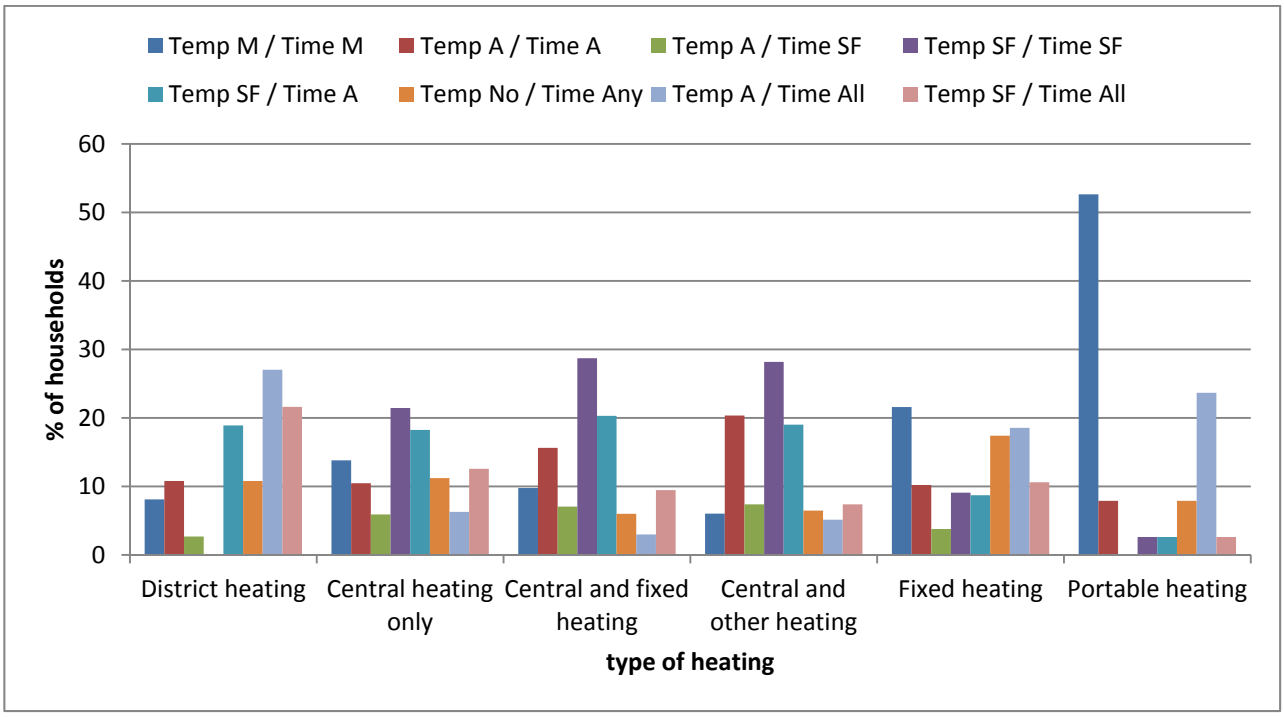
[52] Base: 2314 cases.

[53] Base: 2314 cases.

[54] Base: 2233 cases.

The profiles are markedly different for the other three types of heating. With district heating, active control of timing increases and complete “set and forget” disappears. When fixed heaters are used, manual control increases and it dominates when portable heaters are used (the opposite of the effect when fixed or portable heaters are used in combination with central heating).

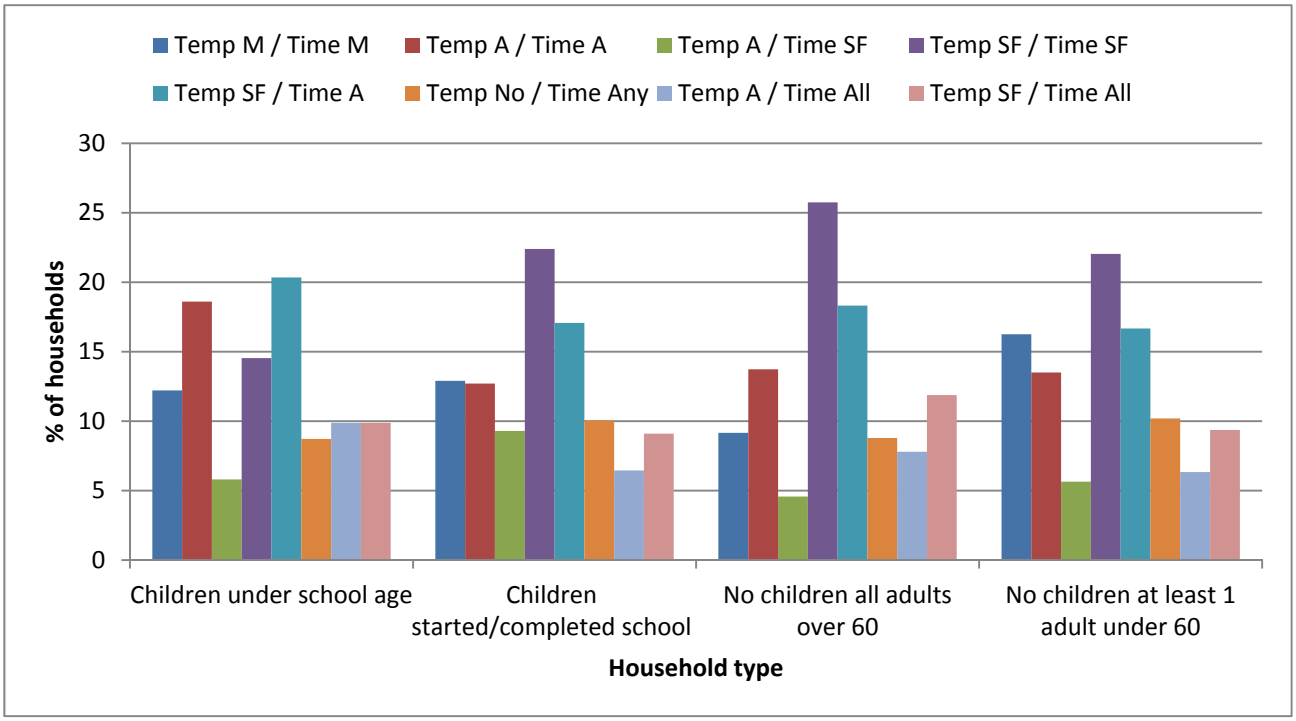
Figure 3.18 Percentage of respondents in each control category for each heating system type[55]



This effect of heating type sets a background against which any effects of household demographics need to be seen, effectively constraining the possibilities. Hence, as shown in Figure 3.19, there is relatively little variation among the four household types. Manual control is greatest in younger households without children and least in older households without children. Complete “set and forget” is greatest in older households without children and least in households with preschool children, where active control (particularly of timing) is most prevalent.

[55] Base:2233 cases.

Figure 3.19 Percentage of respondents in each control category for each household type[56]



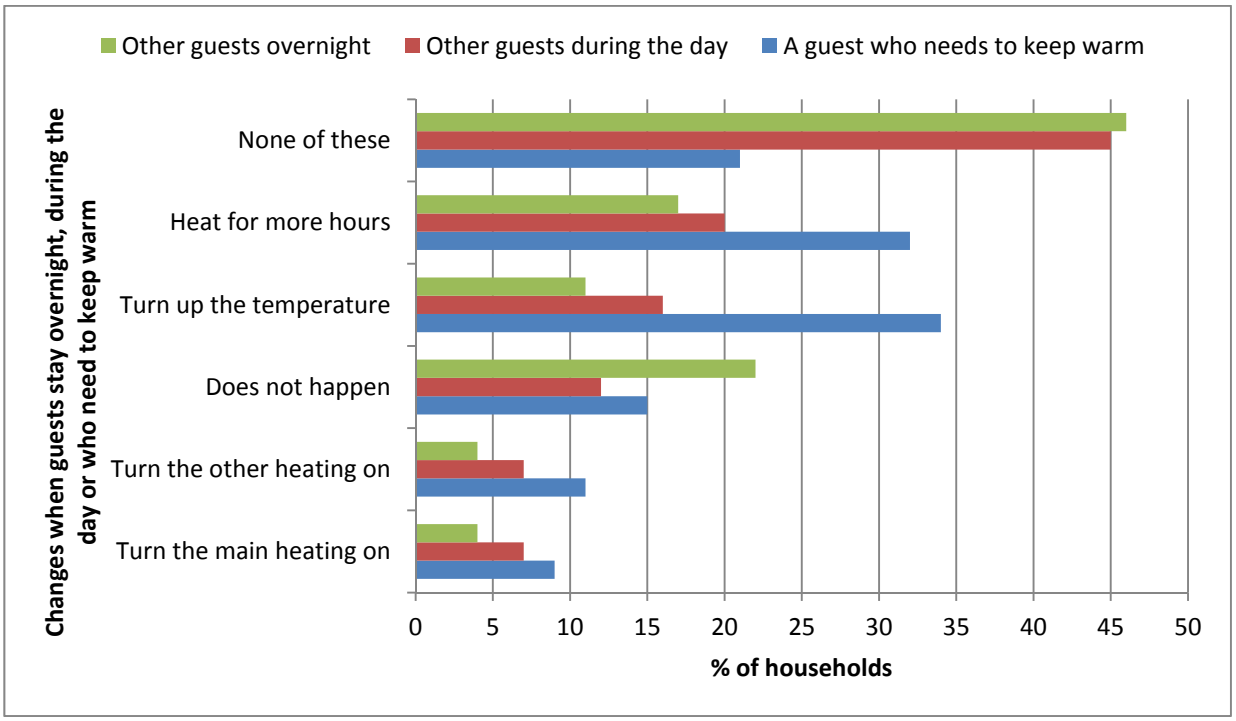
3.4.7 Circumstances when households change what they do

The circumstances under which households change something about how they heat the home are varied but not entirely surprising. The reason most frequently given was it being cold outside (91%), followed by variations in the householders themselves or visitors being at home (76% and 73% respectively). Only 64% reported changing something when they are away from home, which suggests significant potential for reducing energy demand. A similar percentage (62%) change what they do when the heating is not working, which seems a low percentage but may be partly due to the respondent or interviewer missing the response option “This does not happen”.

Variation in what households do when they have visitors is worth discussing in greater detail; the specific changes made are shown in Figure 3.20. It makes little difference whether the visitors are present during the day or overnight: adjusting for those who do not have visitors in the way described, over half of respondents would do nothing different; around one in five would heat for more hours and/or turn up the temperature. In contrast, if there is a visitor who has a particular need to keep warm (e.g. babies, the elderly or those who feel the cold), around three-quarters would do something different.

[56] Base: 2233 cases.

Figure 3.20 Percentage of respondents reporting each change in heating when there are visitors during the day, overnight or having particular needs to keep warm[57]



3.4.8 Maintenance preferences

Respondents were asked to state, if the long-term costs (over many years) were similar, whether they would prefer their heating system to be serviced, maintained and repaired for a fixed annual fee, or to be responsible themselves for arranging the servicing, maintenance and repair of the heating system as and when it is needed. Of the respondents who answered the question (2204 cases), 60% expressed a preference for paying a fixed annual fee.

Analysis of how these preferences break down across characteristics of the household found a slight tendency for households with pre-school children to prefer to pay an annual fee (68%). Likewise, tenants of social landlords prefer to pay an annual fee (66%), perhaps reflecting their familiarity with this kind of arrangement in their current property. Generally, however, preferences for these two options did not seem to be related to characteristics of the household, nor did they relate to the individual respondent's role in managing energy accounts or the use of energy in the home.

Preferences are, however, strongly influenced by the type of heating system currently used in the home. Table 3.26 reveals that, while all combinations of central heating systems result in responses of 61-63% in favour of a fixed annual fee, responses for other types of heating system are more varied. Those with district heating were most likely to favour an annual fee, again perhaps reflecting that a similar arrangement may already be in place in their current property. Those with portable heating systems were least likely to favour these types of service, perhaps reflecting that such a service would not be particularly appropriate for their kind of heating. Responses from those with heating fixed in the room was more mixed, perhaps reflecting that some fixed systems (such as storage heaters or gas fires) might be perceived as requiring regular servicing, while other fixed systems, such as electric fires, might not be seen in the same way.

[57] Base: 2278 cases.

Table 3.26 Percentages of maintenance preferences by combination of heating system[58]

Type of heating system	% in each heating type	
	Fixed annual fee	Responsible themselves
District heating	74	26
Central heating only	63	37
Central and fixed heating	63	37
Central and other heating	61	39
Heating fixed in the room	44	56
Portable heating	39	61

3.5 The use of heating and dimensions of heating needs

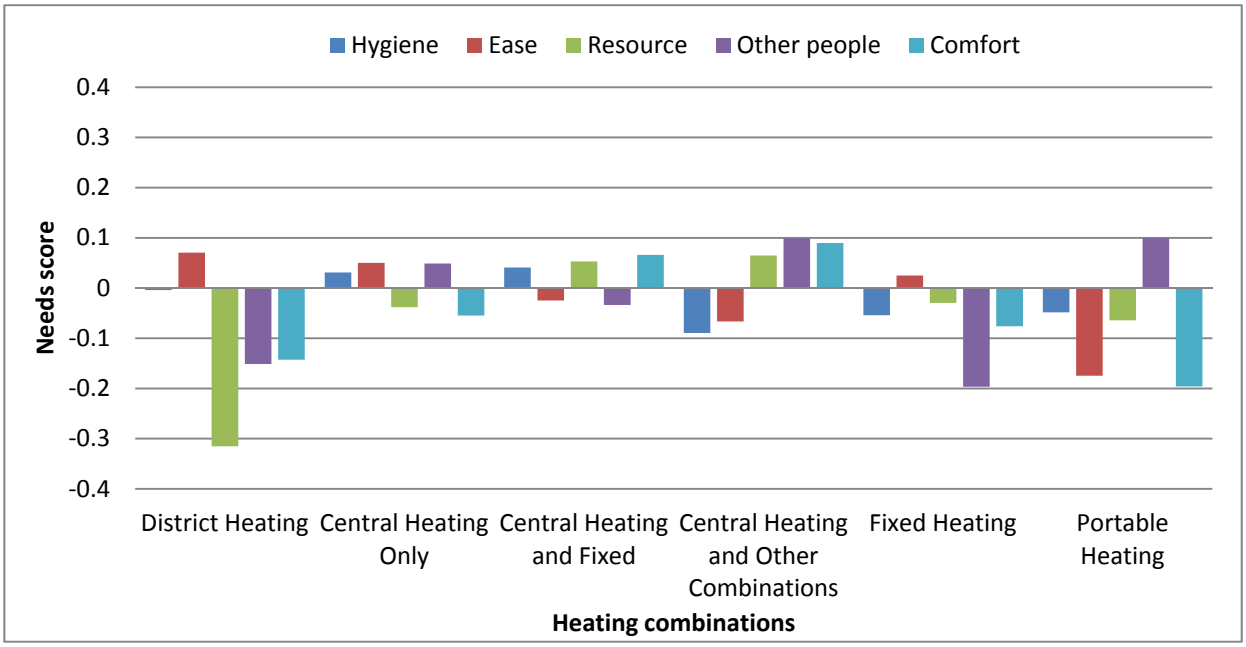
The segmentation analysis presented in Chapter 2 of this report identified five dimensions of need related to heating. These five dimensions, *Hygiene*, *Ease*, *Resource*, *Other people*, and *Comfort*, identify areas of particular emphasis for the respondents, which can be compared across groups of respondents. In this section, aspects of heating already discussed in this chapter are examined in the light of the dimensions of need.

The analysis begins by examining the heating system and its use. Figure 3.21 presents scores across each of the five dimensions for the six combinations of heating systems identified in this chapter. As might have been expected, the profile of heating dimensions for the three combinations of central heating have greater similarities with each other than with the other heating types. While there are some differences, particularly around the emphasis placed on *Other people* and on *Comfort*, these differences are small.

Those respondents with district heating placed the least emphasis on *Resource*, and low emphasis on both *Other people* and *Comfort*, perhaps reflecting that heat tends to be available all the time through a system that they have little control over. Interestingly, those with portable heating also place little emphasis on *Comfort*, despite analysis earlier in this chapter revealing that people with portable heating are the least likely to report that they usually feel warm enough. This can be explained logically if (a) people who prioritise comfort do not use portable heating and/or (b) people with portable heating have had to learn to limit comfort. Those using fixed heating place little emphasis on *Other people*, whereas the opposite is true of those using portable heating (reflecting that 56% of households with portable heating are single-person households).

[58] Base: 2204 cases.

Figure 3.21 Dimensions of heating need for combinations of heating type



Examining the dimensions of heating need for the combinations of methods people usually adopt to keep warm (Figure 3.22) reveals a range of differences in emphasis, although many of them are quite small. The dimension with the highest level of emphasis in any group is *Resource*, which is particularly important to the three combinations involving the widest range of measures: HCRP (heating, controlling where the heat goes, retaining heat, and heating the person), All (both types of heating plus controlling and retaining heat and heating the person) and 2HCRP (both types of heating plus two of controlling where the heat goes, retaining the heat and heating the person). This suggests that these respondents are conscious of their use of resources as they actively control the heating and their own warmth. These groups also place a slightly lesser emphasis on *Comfort*.

The groups with the least diversity of methods to keep warm (HRP: using heating, retaining the heat and heating the person; H: using heating only; and CRP: using methods other than heating) tend to emphasise *Ease*, which may either reflect that they are acting in the manner that they find easiest or that they would prefer their methods of keeping warm to include greater *Ease*. They also emphasise *Comfort* the least of all of the groups, particularly the CRP group who do not use any form of heating.

Figure 3.22 Dimensions of heating needs for combinations of methods usually used to keep warm

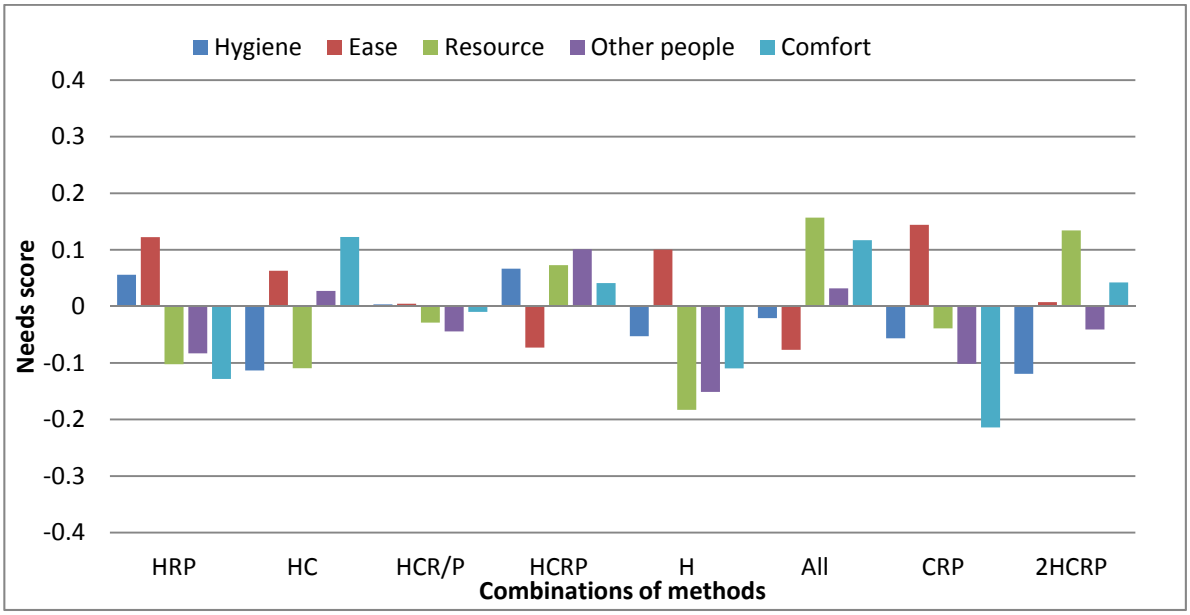
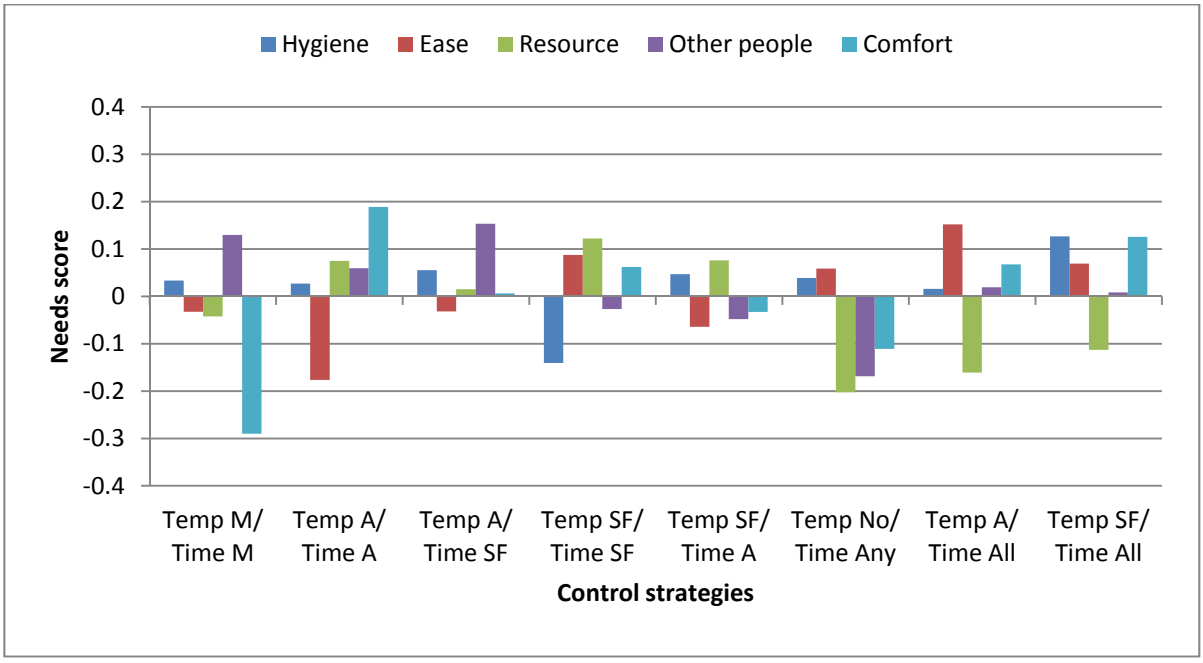


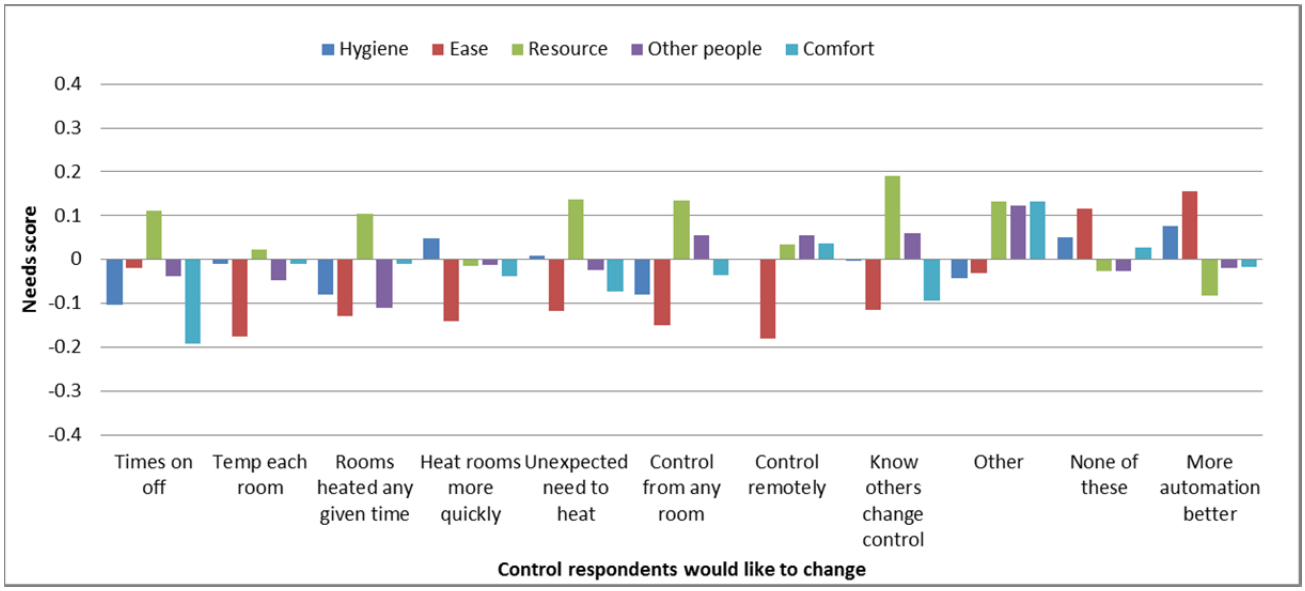
Figure 3.23 presents dimensions of heating need for different strategies used to control the heating. This reveals a distinct difference between the dimensions emphasised by the two groups who adopt strategies requiring the most interaction with their systems. The group who control both the temperature and the timing of their heating manually (Temp M / Time M) do not emphasise *Comfort* highly at all, while those who control both the temperature and the timing using a combination of manual and 'set and forget' controls (Temp A / Time A) emphasise *Comfort* the most out of all of the dimensions but place less emphasis on *Ease*. Those who do not control temperature at all (Temp no / Time any) and those who have their heating on all the time (Temp A / Time All and Temp SF / Time All) place the least emphasis on *Resource* but tend to emphasise *Ease*. The two most common types of control strategy adopted, Temp SF / Time SF and Temp SF / Time A, present the smallest range of values of dimensions, but tend to slightly emphasise *Resource* over other dimensions.

Figure 3.23 Dimensions of heating needs for strategies used to control heating



The final analysis using dimensions of heating needs examines people's preferences for changing aspects of their heating controls (Figure 3.24). *Resource* is the dimension most emphasised for any of the options, and particularly relates to options regarding the times people heat, being able to respond to an unexpected need to heat, and being aware of others changing control settings. *Ease* is emphasised by those who would prefer greater automation or who indicated no preference for any of the suggested changes. This perhaps reflects a perception that greater control will make things more complicated.

Figure 3.24 Dimensions of heating needs for aspects of heating controls respondents would like to change



4 Findings: needs and behaviours related to space cooling

4.1 Key findings

1. Only about 2% of households use air conditioning (including use of heat pumps for cooling). The actions that households do take to keep cool can be targeted either at the indoor environment or at the self. Those targeted at the environment involve strategies to control/limit heat gain (turning the heating down/off or creating shade) or remove heat (e.g. increasing natural ventilation by opening windows or doors, or using mechanical ventilation or cooling systems). Those targeted at the self involve insulation (e.g. using lighter clothing or bedding), cooling the body (e.g. from inside through a drink or outside through a fan or shower) or a change of location, either within the home or by leaving the home.
2. In winter, about two-thirds of households do not always keep cool enough by what they usually do and therefore do one or more things extra in order not to overheat in winter. This indicates potential for improved control of heating systems with the dual aim of improving comfort and reducing energy demand, through eliminating overheating.
3. The main combinations of methods that households use to avoid overheating in winter involve turning the heating down or off (in four-fifths of cases), most often in a combination involving natural ventilation. This leaves one in five who do something else in preference to turning the heating down or off (again, most often in a combination involving natural ventilation).
4. The need to act to avoid overheating in winter is greater in households that are larger (until the number gets to five or more), owner-occupiers or have higher incomes, and in homes that are newer or have double, triple or secondary glazing, or that have central heating or (especially) district heating. But the dominant factor appears to be the age of the household members, with older households being more likely to say that it would not get too warm in winter.
5. In summer, fewer than one in ten do not need to do anything specifically to keep cool but about three-quarters do successfully keep cool all the time. Strategies in summer cover a similar range to those used in winter but are dominated by natural ventilation – used alone in 61% of households and with other methods in 32%. Over half the sample use light clothing or bedding, or cool the body directly. About one-third circulate air within the building or change location.
6. Fewer (about a quarter) use shading, and the shading is in the most effective location (on the outside of the windows) in only 4% of the sample. External shading can be very effective and there is clearly potential for greater application in Britain, perhaps supported by smart control systems.
7. The factors that affect whether something needs to be done to keep cool in summer are similar to those that affect the need to do something to avoid overheating in winter and, if anything, more dominated by the age of household members.
8. About two-thirds of households sometimes keep windows closed when they would like to open them for cooling, for a range of reasons – most frequently security or noise. These barriers do not explain the age effect noted above but they do need to be addressed if smart cooling is to be achieved. One implication is that it should be possible to open windows without compromising risks related to security, safety of children, noise, pests and outdoor air pollution.
9. Besides the obvious situation when the weather is particularly hot, the main driver for households to change what they do to keep cool is when someone at home is unwell (which prompts change in one-sixth of households), especially if there are children in the household. All other options, such as when there are visitors, are chosen by less than 10% of households. In addition, 23% change their behaviour in none of the listed circumstances. Older household are least likely to change what they do.
10. Those who say it would not get too warm in summer are less likely to express most heat energy needs – unsurprising as this indicates that their needs are met, with the exception of *Ease*. However there is little difference between those who always keep cool enough and those who only sometimes do so.

4.2 Introduction

This chapter examines the methods that households use to avoid overheating in winter and to keep cool in summer, variation in the use of these methods (or not needing to do anything specifically to keep cool), whether households do keep cool and the circumstance in which they change what they do to keep cool.

4.3 Households' strategies to keep cool in summer and winter

4.3.1 Households in Britain do not rely on cooling systems

The vast majority of households in Britain do not rely on mechanical cooling or ventilation systems to avoid overheating in winter or keep cool in summer. Mechanical cooling and mechanical ventilation systems were available as response options for various questions in relation to overheating in winter and cooling in summer (see Section 4.4). Only 4% of households in Britain have systems for cooling. Of these, 46 households sometimes use air conditioning, 21 households sometimes use mechanical ventilation and only 4 households sometimes use heat pumps for cooling. Of the households using air conditioning, 19 use air conditioning that is portable but vented to the outside and 13 use air conditioning that is portable but vented inside the home. Hiring of air conditioning units is very rare: 0.24% of all households do this on a typical summer day and 0.6% when their usual ways of staying cool are not enough.

4.3.2 What households do to avoid overheating in winter

Along with design for heating, it is important to take into account the need to avoid being too warm. While overheating in winter does not affect all households in Britain, strategies may be sub-optimal from a perspective of comfort and energy use. Overheating might be avoided by the same means as smart heating solutions: well controlled heating systems that the users understand how to operate. But smart energy solutions aimed at heating also need to be designed to avoid causing problems for cooling (e.g. by insulating in a way that reduces thermal mass). We therefore explored how households avoid getting too warm in winter, whether this is a problem and, if this is the case, whether certain groups are particularly affected.

Respondents were asked: *"I would now like to ask some questions about the ways you and your household keep yourselves and your home cool or avoid overheating the home. Please tell me which of these things, if any, you or your household sometimes do to avoid getting too warm in winter."* Respondents could select as many options as they liked with the exception of those who said it would not get too warm in winter, which was an exclusive category.

As Table 4.1 shows, households' strategies to stay cool can be conceptualised at a range of levels of description, moving from detailed individual strategies to more abstract groupings. At the highest level, there are two groups of respondents, those that keep cool enough by what they usually do, without any additional conscious actions or out of necessity. The other group includes those households that sometimes do one or more things extra in order not to overheat in winter. These additional actions might or might not be sufficient to keep cool. These actions can be either targeted at the indoor environment or targeted at the self. Those targeted at the environment involve strategies to control/limit heat gain (i.e. turning the heating off or creating shade) or remove heat (e.g. increasing natural ventilation or using mechanical ventilation or cooling systems). Those targeted at the self involve measures of insulation (e.g. changing clothing or using lighter bedding), cooling the body (e.g. from inside through a drink or outside through a fan or shower) or a change of location, either within the home or by leaving the home. Table 4.2 shows strategies grouped, based on levels 3 and 4 in Table 4.1.

On average, respondents picked 2.3 options and, as Table 4.1 shows, 37% of respondents said their household would not get too warm in winter. While these households do not need to do anything specifically to avoid overheating, this does not mean that they are doing nothing. It is just that whatever they do normally (to heat the home or for other reasons) is sufficient to not overheat. Conversely, those 63% of households that need to do something specific to avoid overheating should not be interpreted as though they actually get too warm, indeed while this survey does not allow us to answer this question: they might all succeed in avoiding overheating in winter through the strategies they adopt. However, the fact that 63% of households need to do something specific to avoid overheating even in winter indicates existing potential for improved

control of heating systems with the dual aim of improving comfort and reducing energy demand, through eliminating overheating.

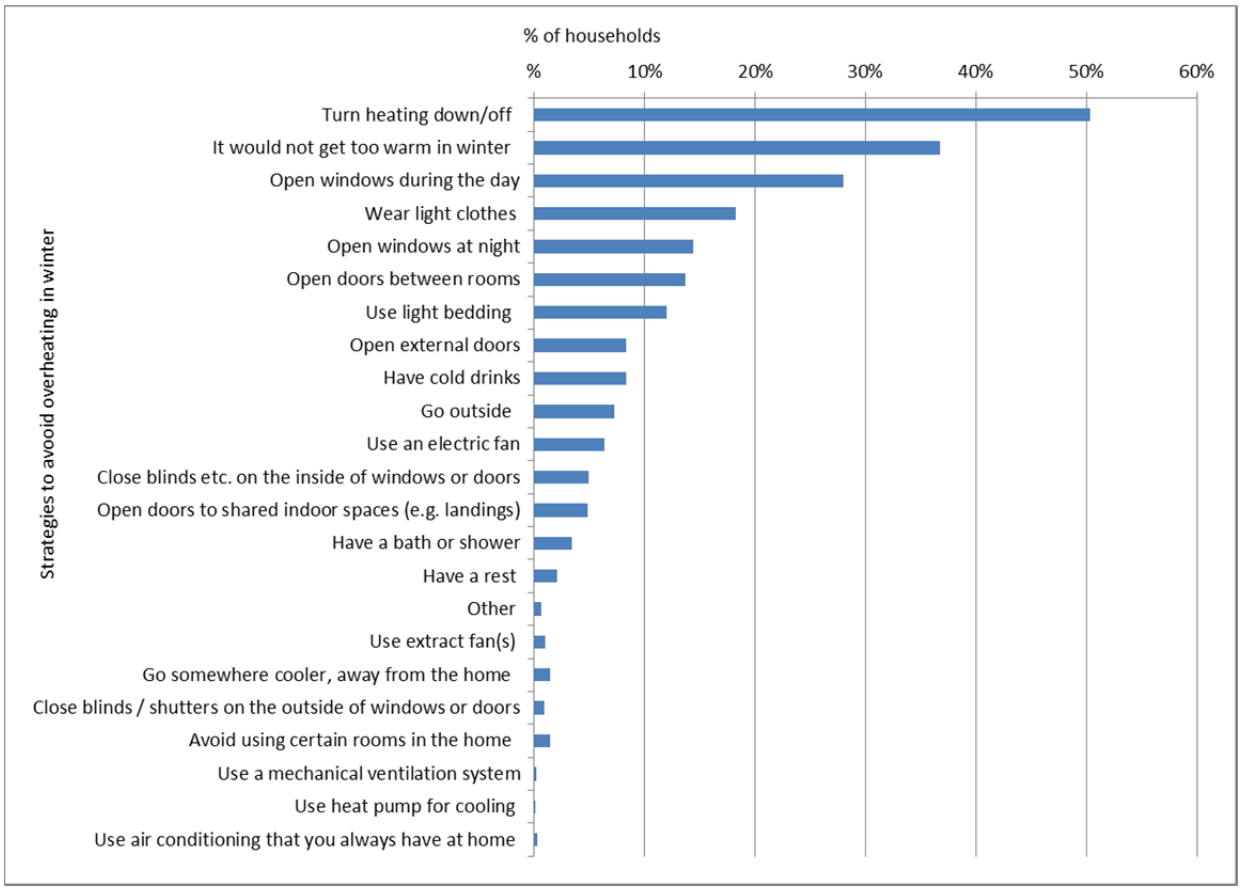
As Table 4.2 shows, the single most prevalent strategy to avoid overheating is to reduce heat input: 50% of households turn the heating down or off. Another 34% of households use methods of natural ventilation to avoid overheating, such as opening windows or external doors. The third most prevalent group of strategies, used by roughly one-fifth of households, is to change clothing and/or use lighter bedding. Least prevalent and only used by less than 1% of households are methods of mechanical cooling, including air conditioning and use of heat pumps for cooling.

Table 4.1 Strategies to avoid getting too warm in winter

Level 1	Level 2	Level 3	Level 4	Level 5	%
Would not get too warm (i.e. keeping cool but not by any conscious action)					37
Do something to avoid getting too warm (therefore mostly don't get too warm)	Environment-focused	Control heat gain	Turn heating down or off		50
			Shading	Internal	5
				External	1
		Remove heat	Natural ventilation	Windows (day)	28
				Windows (night)	14
				External doors	8
			Mechanical ventilation	Extract only	1
				Supply & extract	*
				Supply & extract + heat recovery	*
			Air circulation within building	Internal doors	14
				Doors to shared parts	5
			Air conditioning	Hired	*
				Present in the home	*
				Heat pump	*
	Self-focused	Insulation	Clothing		18
			Bedding		12
		Cooling	Fan		6
			Drink		8
			Bath / shower		3
			Rest		2
		Change location	Indoors		1
			Outdoors		7
			Away from home		1

Base: all (2287).

Figure 4.1 Non-grouped strategies to avoid overheating in winter



Base: all (2287).

Table 4.2 Grouped strategies to avoid getting too warm in winter

Strategy (grouped)	Percentage
Reduce heat input	50
Natural ventilation	34
Clothing & bedding	21
Circulate air within building	15
Cooling the body	13
Choice of location	8
Shading	5
Mechanical ventilation	1
Mechanical cooling	*
Base	*2287*

Base: all.

Views of overheating in winter and the strategies used to deal with it vary by both household and property characteristics. Generally, older households are less concerned with overheating in winter. While 40% of households with all members over 60 stated that it would not get too warm in winter, this was the case for only 28% of households with children under school age, 35% for households with children in or having completed school and 37% for households with no children and at least one adult under 60. Consequently, younger households are more likely to engage in strategies to keep cool.

Single-person households and households with five people or more are less likely to overheat than other households. While 42% of single-person households and 40% of households with 5 or more people agree it would not get too warm in winter, this is only the case for 30% of households with 3 people. Overall, increasing household size relates to increased likelihood to overheat, a trend that reverses for the largest households (with 5 or more members). While this trend likely reflects the finding that younger households with children (which tend to be the bigger households) are more likely to overheat, this cannot explain why households with 5 or more members are again less likely to overheat as compared to medium-sized households.

It may be that, in larger households, there is a greater likelihood of somebody being at home during the day, and therefore being able to have windows open. However, the percentage saying it would not get too warm in winter varies little with whether there is usually somebody at home during the day (and the same is true of being able to keep cool in summer).

Those in the lowest income quartile are more likely to say it would not get too warm in winter (41% compared to 34% in the middle income quartiles and 26% in the highest quartile). Consequently, those in the highest quartile are more likely to engage in cooling strategies in the winter such as turning the heating down or off (63%), opening windows during the day to keep cool (32%), opening windows at night to keep cool (21%), wearing light clothes (27%) and using light bedding (21%). Similarly, those that rent are less likely to do something to avoid getting too warm in winter: 42% renting from a social landlord say it would not get too warm in winter and 41% renting from a private landlord, as compared with only 34% who own their home.

Households living in properties built pre-1919 are most likely to say it would not get too warm in winter (45%) and households living in the newest properties (built 2002 or later) are least likely (26%). Consequently, those households in properties built 2002 or later are most likely to engage in strategies such as turning the heating down/off (61%), opening windows during the day to keep cool (40%), wearing light clothes (28%) or using light bedding (19%). This might partly be explained by the fact that properties built pre-1919 generally have the lowest level of insulation, combined with the greatest capacity to absorb heat in the fabric. Similarly, those properties with single glazing are more likely to say it would not get too warm in winter as compared to those with double, triple or secondary glazing (43% and 36% respectively).

There is no clear overall trend by dwelling type with 39% of households in flats saying it would not get too warm in winter as compared to 38% in bungalows and 36% in houses. This might be surprising as we could suspect overheating to be bigger problems in smaller flats rather than in houses. However, ventilation may also be greater in flats on upper storeys, or security may be less of a barrier to opening windows.

Whether households do something to avoid getting too warm in winter also varies by their main heating system and the level of control households have over their heating: 35% of those households who identify central heating as their main heating type state that it would not get too warm in winter, while only 23% with district heating say so. Of those households who identify portable heat sources as their main heating, 68% say it would never get too warm in winter and of those households that have their main heating fixed in individual rooms, 45% say it would never get too warm in winter. Those households with individual fixed or portable heaters may not overheat because people engage with these more, switching them on when needed and switching them off if they get warm enough. Also, homes without central heating tend to be smaller, older homes.

Control of heating is a potential factor here as households with central heating may have more control over when the heating comes on/off and can set the temperature, but are more likely to heat all rooms. Interestingly, however, those households that say they do not do anything to control the temperature of their home (e.g. by manually turning the heating on or off or by use of a thermostat) are also less likely to overheat: 50% in this category say it would not get too warm in winter as compared with only 35% of those who do in some way control the temperature of their home when the heating is on. It might be that people do nothing to control their heating because they do not overheat and therefore do not see a need to control. Many of those who do not control the temperature of their home do not know how to control the temperature; possibly these households do not know how to control the temperature because they do not feel the need to control.

Table 4.3 shows the main combinations of methods that households use to avoid overheating in winter. In four-fifths of cases, the strategy involves turning the heating down or off, most often in a combination

involving natural ventilation. This leaves one in five who do something else in preference to turning the heating down or off (again, most often in a combination involving natural ventilation).

Table 4.3 Combined strategies to avoid getting too warm in winter

Combined strategies	Number	Percentage	
Reduce heat input only	424	29	80
Reduce heat input plus natural ventilation, with or without anything else	554	39	
Reduce heat input plus anything other than natural ventilation	173	12	
Do not reduce heat input; natural ventilation, with or without anything else	224	16	20
Do not reduce heat input; anything other than natural ventilation	63	4	
Total	1438	100	

Base: those who do anything to avoid overheating in winter.

4.3.3 What households do to keep cool in summer

Overheating in summer is expected to be a bigger issue than overheating in winter. Respondents were therefore also asked "*please say which of these things, if any, you or your household sometimes do to avoid getting too warm on a typical summer day (not when there is a heat wave)?"* Again, respondents could select as many options as they liked with the exception of those who say it would not get too warm in summer, which was an exclusive category. On average respondents picked 5.6 options.

Again, as Table 4.3 shows, households' strategies to stay cool in summer can be conceptualised at a range of levels of description, moving from detailed individual strategies to more abstract groupings. Unsurprisingly, things look different in summer as compared to winter with only 9% of households stating that it would not get too warm on a typical summer day. As shown in Table 4.4, amongst those 91% who feel it can get too warm in summer, the most prevalent group of strategies for cooling is a form of natural ventilation, e.g. opening windows or external doors: 84% of all households adopt at least one of these measures sometimes. As the second most prevalent group of cooling measures, 60% of households change clothing or bedding to keep cool and 60% reduce heat input (e.g. turn heating down or off).

Fewer (about a quarter) use shading, and the shading is in the most effective location (on the outside of the windows) in only 4% of the sample. External shading can be very effective and there is clearly potential for greater application in Britain, perhaps supported by smart control systems. There is also greater potential for use of night ventilation.

Table 4.4 Strategies to avoid getting too warm in summer

Level 1	Level 2	Level 3	Level 4	Level 5	%
Would not get too warm (i.e. keeping cool but not by any conscious action)					9
Do something to avoid getting too warm (with either success or failure)	Environment-focused	Control heat gain	Turn heating down or off		60
			Shading	Internal	25
				External	4
		Remove heat	Natural ventilation	Windows (day)	79
				Windows (night)	53
				External doors	40
			Mechanical ventilation	Extract only	4
				Supply & extract	1
				Supply & extract + heat recovery	
			Air circulation within building	Internal doors	35
				Doors to shared parts	13
			Air conditioning	Hired	*
				Present in the home	2
				Heat pump	*
	Self-focused	Insulation	Clothing		53
			Bedding		48
		Cooling	Fan		29
			Drink		39
			Bath / shower		18
			Rest		8
		Change location	Indoors		6
			Outdoors		29
			Away from home		5

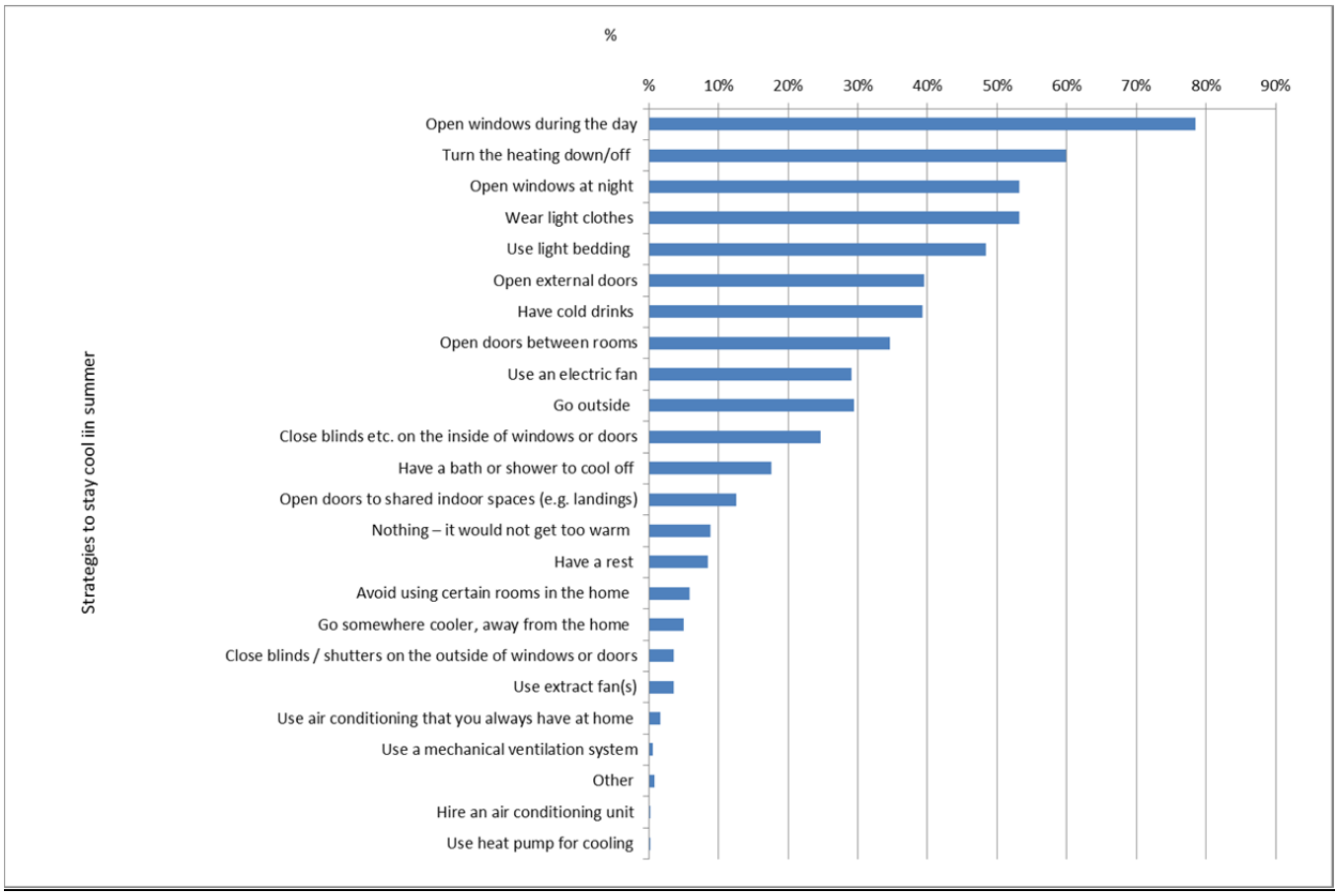
Base: all excluding those who did not live in their property last summer (2106).

Table 4.5 Grouped strategies to keep cool in summer

Strategy (grouped)	% of households
Natural ventilation	84
Clothing & bedding	60
Reduce heat input	60
Cooling the body	55
Circulate air within building	36
Choice of location	33
Shading	26
Mechanical ventilation	4
Mechanical cooling	2
Base	*2106*

Base: all excluding those who did not live in their property last summer.

Figure Error! No text of specified style in document. Single strategies to avoid overheating in summer



Base: all excluding those who did not live in their property last summer (2106).

With regard to variation in both household and property characteristics, the situation is similar to overheating in winter. Households with small children are least likely, and the oldest households are most likely, not to get too warm in summer: only 5% of those households with children under school age as compared to 10% of the oldest households (with all household members over 60) state it would not get too warm in summer.

As in winter, both the smallest (single-person) households and the largest (five or more people) are most likely to state it would not get too warm in summer (10%). Again, this means that there seems to be a trend with increasing household size relating to increased likelihood to get too warm in summer, which reverses when households have five or more members.

There are clear trends with regard to household income, with those in the lowest income quartile twice as likely to say it would not get too warm in summer (12%) as compared to those in middle or highest quartiles (both 6%) and being correspondingly less likely to engage in behaviours to stay cool. Likely reflecting this finding, those households renting from social landlords are more likely to say it would not get too warm in summer (12%) as compared to both those renting from private landlord as well as those owning (both 8%).

There is no clear trend with regard to the extent of overheating in households in flats, bungalows or houses generally but those living in a house adopt a wider range of strategies. As in winter, those in properties built pre-1919 are most likely to say it would not get too warm (15% agree that it would not get too warm as compared to 9% overall).

Table 4.6 shows the combinations of things that households do to keep cool in summer. While it appears that many do not reduce heat input, in most cases this is because the heating is not used in summer. Taking this into account, it is clear that strategies are dominated by natural ventilation – used alone in 61% of households and with other methods in 32%.

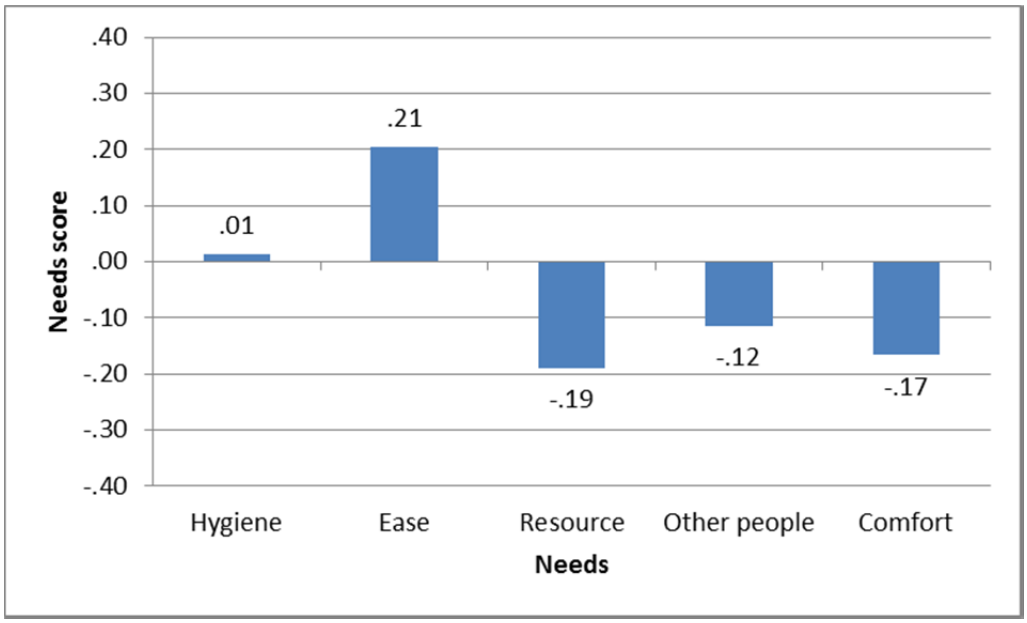
Table 4.6 Combined strategies to staying cool in summer

Combined strategies	Number	%	
Reduce heat input only	42	2	2
Reduce heat input plus natural ventilation, with or without anything else	1166	61	92
Do not reduce heat input; natural ventilation, with or without anything else	609	32	
Reduce heat input plus anything other than natural ventilation	54	3	5
Do not reduce heat input; anything other than natural ventilation	49	3	
Total	1920	100	100

Base: those who do anything to keep cool in summer.

As Figure 4.3 shows, those who say it would not get too warm in summer are less likely to express most needs – unsurprising as this indicates that their needs are met. The noticeable exception to this is *Ease*, possibly because *Ease* contains needs such as 'keeping to everyday routines', and 'doing what's easiest', which arguably become more important as other needs such as *Comfort* are satisfied. However, it should be remembered that these dimensions are based on needs related to heating the home.

Figure 4.3 Needs by whether it would not get too warm in summer



Base: all excluding those who did not live in their property last summer (2106).

4.4 How effective are strategies for cooling and when do they change?

4.4.1 Do households manage to keep cool enough in summer?

We were interested in whether households' current strategies to keep cool in summer are sufficient. We therefore asked all households except those who had indicated that it never gets too warm in summer *"When you are doing this on a typical summer day, does this always keep you {and everyone in your household} cool enough?"* Table 4.6 shows that the strategies of keeping cool on a typical summer day, as listed in the previous section, are successful for most households. If we combine the responses to this question with respondents who indicated it does would not get too warm in summer, there are two groups who always keep cool in summer: those who do not need to do anything specific and those who do need to do something and it does succeed. These two groups, 9% and 64% of all households respectively, together make up 73% of the sample. A further 25% of all households manage to sometimes keep cool enough with the strategies they usually use. Only 2% say their usual strategies rarely or never keep them cool enough.

Table 4.7 Keeping cool enough (all households)

When you are doing this on a typical summer day, does this always keep you {and everyone in your household} cool enough?		
	%	%
Yes - no special effort	9	73
Extra effort, always cool enough	64	
Extra effort, sometimes cool enough	25	27
Extra effort, rarely or never cool enough	2	
Base	*2106*	*2099*

Base: all excluding those who did not live in their property last summer.

While generally an encouraging finding, being able to keep cool enough varies by type of household and property (see Table 4.8). Most clearly, it emerges that cooling is more of a problem for younger households and for those households occupying flats rather than houses or bungalows (which are likely to include some

of the same households). Indeed, older households (those with no children and all adults over 60), are more likely to say:

- it would not get too warm in winter (Section 4.3.2);
- it would not get too warm in summer (Section 4.3.4);
- their cooling strategies in summer were always successful (Table 4.7).

However, based on this survey, it remains unclear whether this represents a cohort or an age effect. This means, the data from this survey cannot establish whether the generation that is now over 60 is less concerned about warm weather due to factors that specifically affected this generation, such as having lived through a certain time period or having had the same life experiences, or whether people, as they get older, become generally less concerned about overheating.

Table 4.8 Keeping cool enough by household composition, dwelling type and household size

Combination	Yes – always (%)	Yes – sometimes (%)	No – rarely or never (%)	*Base*
Total	**73**	**25**	**2**	***2099***
Household with children under school age	67	29	5	*147*
Household with children started or completed school	70	28	2	*498*
Households with no children and at least one adult under 60	69	29	2	*649*
Households with no children and all adults over 60	78	20	2	*805*
Flat/Maisonette	67	31	2	*407*
Bungalow	74	23	3	*280*
House	74	24	2	*1402*
Single-person household	76	23	2	*577*
2 Household members	74	23	2	*729*
3 Household members	65	33	2	*319*
4 Household members	73	25	2	*296*
5 or more Household members	68	29	3	*177*
Own	74	25	1	*1411*
Social landlord	71	26	3	*410*
Private landlord	68	29	4	*244*

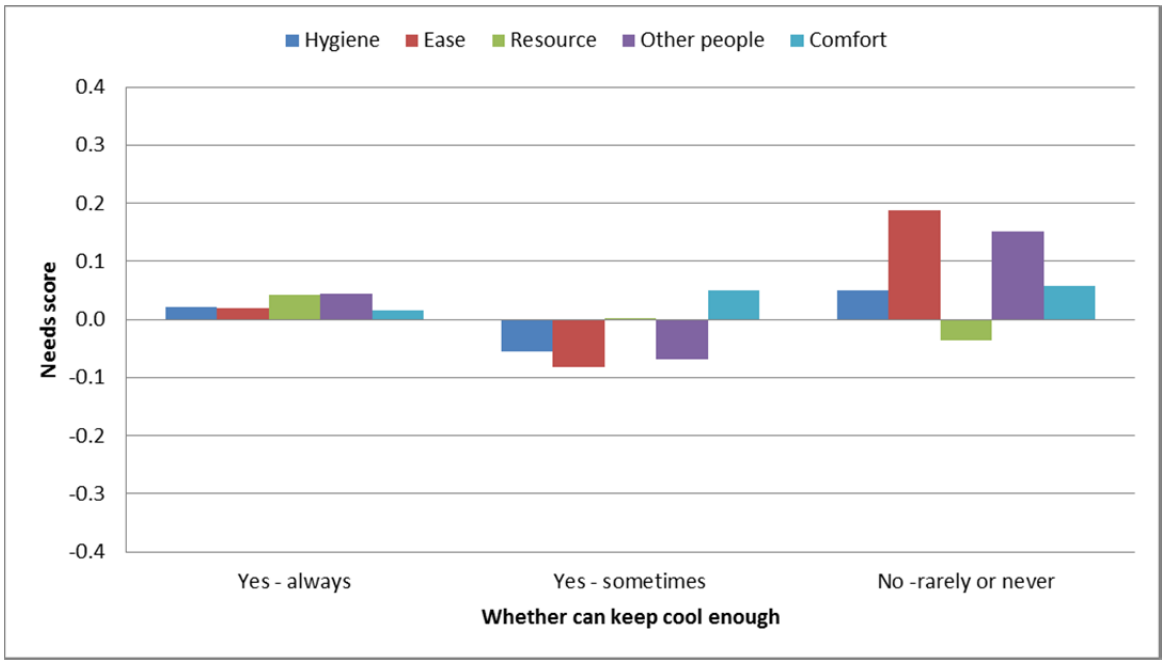
Base: all excluding those who did not live in their property last summer.

As Table 4.8 shows, there is no clear trend concerning how size of the household correlates with being able to stay cool enough in summer but generally smaller households are more likely to always keep cool enough (76% of single-person households) and those with three members in the household are least likely (65%). Also, 74% of owners always keep cool enough, as compared with only 68% of renters from a private landlord. Both these findings likely reflect the earlier finding related to household composition, with larger households and those renting more likely to be young families.

Those in a flat or maisonette are less likely (67%) to always keep cool enough than those in a bungalow or house (both 74%). There are no clear trends by income or age of property, except that those in the oldest and the newest properties are most likely to always be cool enough (both 78%).

As Figure 4.4 shows, those who rarely or never are cool enough are more likely to express most needs – possibly because their needs are not met. However, it needs to be noted that the number of those who said rarely or never is quite low (42).

Figure 4.4 Needs by being able to stay cool enough in summer



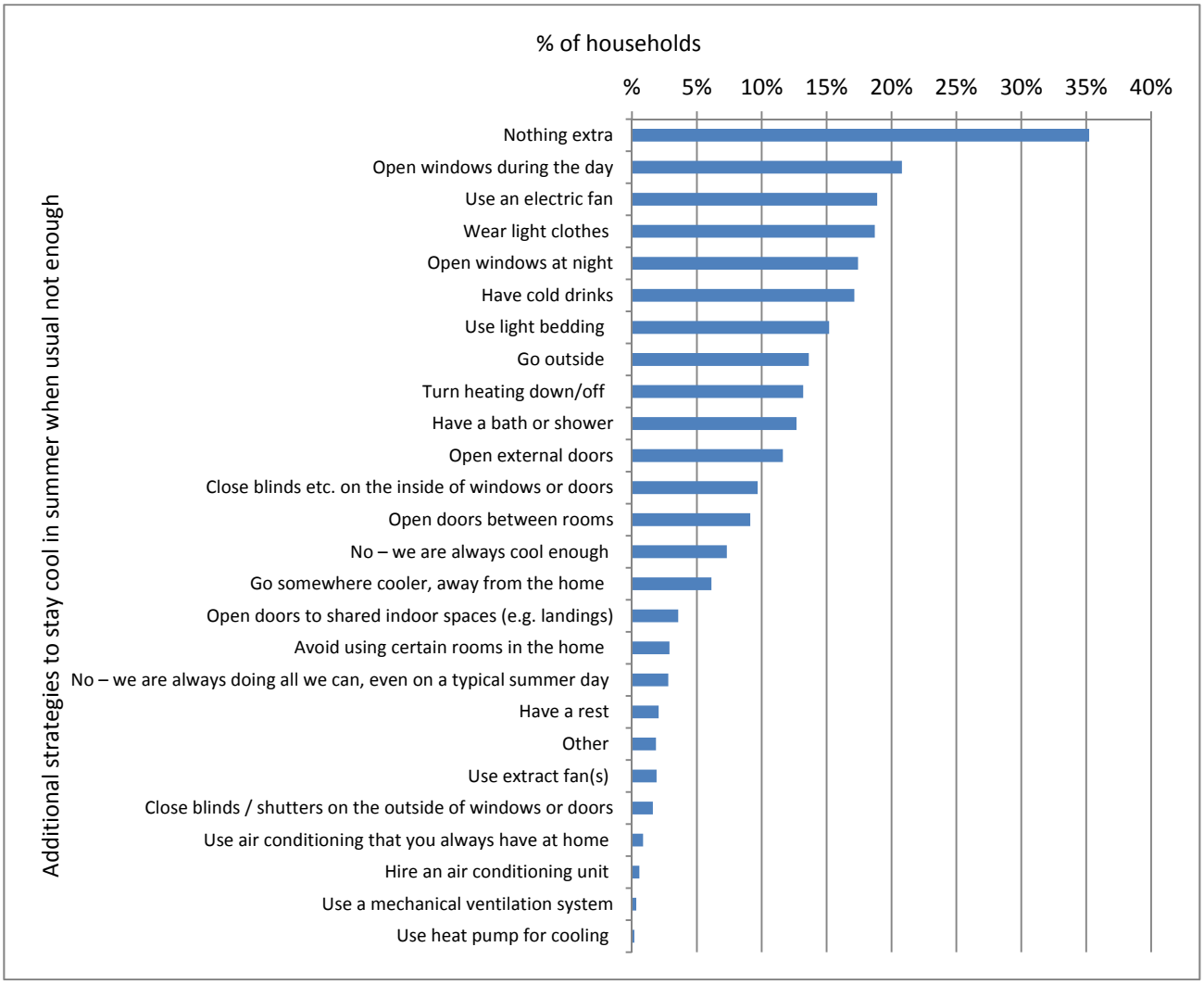
Base: all excluding those who did not live in their property last summer (2099).

4.4.2 Which additional strategies do households use to keep cool in summer

In light of the fact that roughly one-third of households only sometimes stay cool enough with their usual strategies, the question emerges as to what else households do to keep cool when their usual ways of cooling are not enough (for example on really hot days). Respondents – again excluding those who had said it never gets too warm in summer – were therefore asked *"Are there any things on this list that you and your household} do when your usual ways of keeping cool in summer are not enough (for example, on really hot days)?"* As Figure 4.5 shows, while 7% of households would always be cool enough and another 35% of households report doing nothing extra (even when they might not be cool enough), more than half of households use additional strategies and on average they do 2.4 extra things when their usual ways of keeping cool in summer are not enough.

There is no overriding strategy that households adopt when their usual ways of keeping cool are not enough; most options are undertaken by less than 20% of households with the most prevalent one being opening windows during the day (21% of households) – see Figure 4.5.

Figure 4.5 Additional strategies when usual ways to keep cool are not enough



Base: all those that indicated that it can get too warm in the summer (1914).

Again, older households are slightly less likely to do anything extra, with 38% of households where all members are over 60 doing nothing extra as compared to 35% overall. While this does not imply that older households are less likely to overheat, 8% of households where all members are over 60, 6% of households with no children and at least one adult under 60 and 7% of those households with children say they are always cool enough.

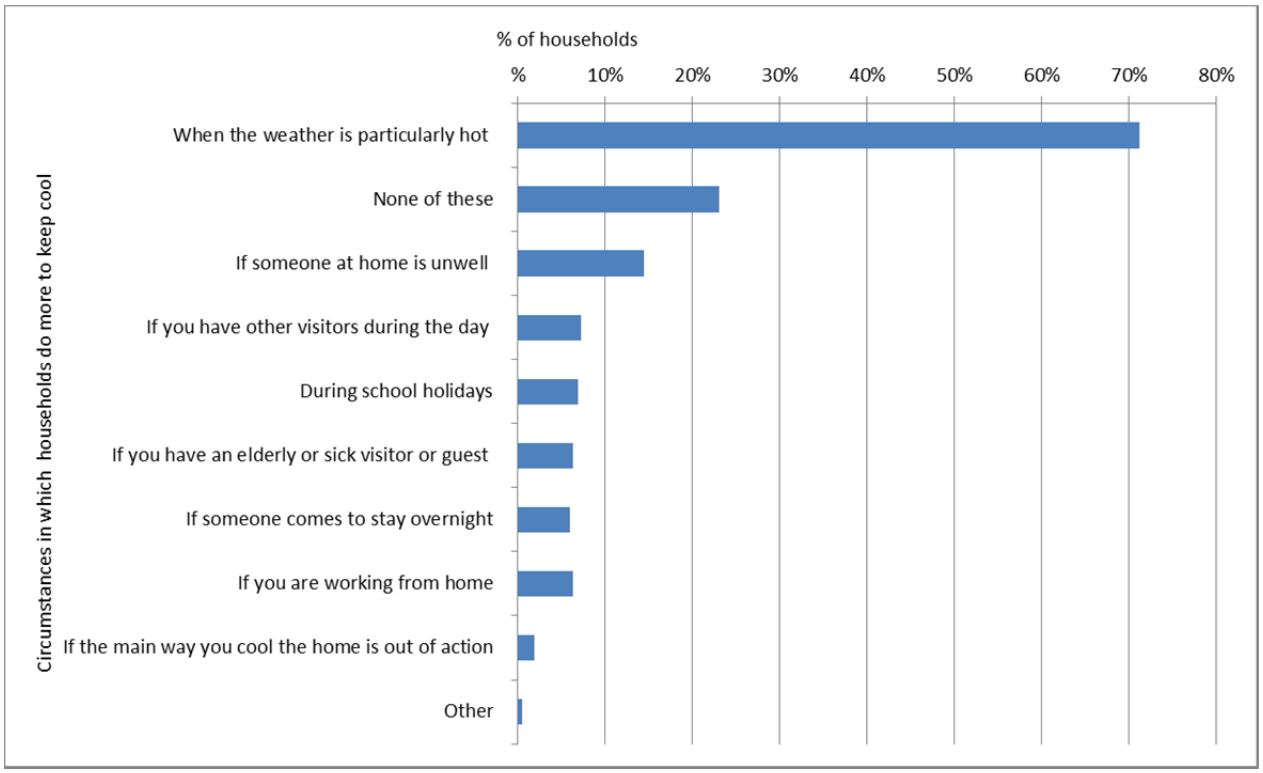
Those who own or rent from a social landlord are more likely to do nothing extra (36%) than those who rent from a private landlord (29%). Unsurprisingly, there is no clear overall trend and relatively little variation with age, dwelling type, age of property or household income.

4.4.3 Circumstances in which households do more to keep cool in summer

There is evidence from the qualitative research that households change their behaviour in certain circumstances, for instance when the weather is particularly hot, when they have guests or when someone at home is unwell. To explore whether this is the case and which households are most likely to change their behaviours in which circumstances, respondents were asked "*In which of these circumstances, if any, do you do more to keep cool at home in summer?*" Again, respondents could select as many circumstances as they wanted to and on average they picked 1.4 scenarios in which they do more to keep cool at home. The response options and percentage of households giving each response are shown in Figure 4.6.The weather being particularly hot is the main reason households do more in summer with the majority (71%) choosing

this option. The next most frequently selected option (15% of households) is when someone at home is unwell. All other options were chosen by less than 10% of households. In addition, 23% change their behaviour in none of the listed circumstances.

Figure 4.6 Circumstances in which households do more to keep cool



Base: all excluding those who did not live in their property last summer (2101).

Generally, older households are less likely to change their behaviour, with 28% of households with all members over 60 saying they would not change their behaviour in any of these circumstances. This is the case for only 16% of those households with young children and 19% of those with children of school age or older. More specifically, households with children are more likely to do something extra when someone at home is unwell: 20% of those with children under school age and 21% of those with children started or completed school, compared to 10% of the oldest households (al over 60) and 13% of those households with no children and at least one adult under 60. Unsurprisingly, those households with children who started or completed school are most affected by school holiday with 22% doing something different during school holidays.

There is no large variation by income, but those in highest income quartile are much more likely to change their behaviour when someone is working from home (18% as compared to 6% in lowest quartile), which likely reflects that people in this quartile are generally more likely to work from home. There is no overall trend or large variation by dwelling type, age of property or tenure.

Generally, besides the obvious situation when the weather is particularly hot, the main driver for households to change what they do to keep cool is when someone at home is unwell, especially if there are children in the household. It is not necessarily the children who are unwell but it is a reasonable assumption that it is sometimes them.

4.5 The property as a system for cooling

4.5.1 Introduction

When discussing what households do to avoid overheating in winter and summer (Section 4.3), it emerged that – besides a range of other strategies outlined in more detail in Sections 4.3 and 4.4 – households use the home itself, e.g. windows and doors, as key elements for purposes of cooling. As shown in Tables 4.4 and 4.5, in the summer, the most prevalent group of strategies (which 84% of households said they sometimes do for cooling) is a form of natural ventilation, e.g. opening windows during the day (79%) or at night (53%) or opening internal and external doors (40% and 35% respectively) – see Table 4.9. As we saw in Figure 4.1, the single most prevalent strategy to avoid overheating in winter is (unsurprisingly) to turn the heating down or off (50%) but second was opening windows during the day, which 28% of households do.

Table 4.9 Strategies using physical aspect of the property to keep cool in summer and winter

Strategies using physical aspect of the property to keep cool	Summer	Winter
	% of households	% of households
Open windows during the day	79	28
Open windows at night	53	14
Open external doors	40	8
Open doors between rooms	35	14
Go outside	29	7
Close blinds etc. on the inside of windows or doors	25	5
Open doors to shared indoor spaces (e.g. landings)	13	5
Avoid using certain rooms in the home	6	1
Go somewhere cooler, away from the home	5	1
Close blinds / shutters on the outside of windows or doors	4	1
Base	*2106*	*2287*

Base: all (winter) and all excluding those who did not live in their property last summer (summer).

4.5.2 Use of windows and doors to keep cool

Those particular methods that use physical aspects of the property as a system for cooling are summarised in Table 4.8, with the percentage of all households using them in winter and summer. As opening windows and doors is a key strategy for cooling homes, respondents were specifically asked *"For which of these reasons do you sometimes open a window at home?"* Almost all households open windows and in most cases, they do so mainly for fresh air (85%) and to keep cool (79%), while 44% of households open windows to let out smoke or smells and 38% to sleep better or to avoid condensation.

Generally, older households (those where all household members are above 60) are less likely than other households to open windows for most of the reasons provided in the answer options. Households with higher income are more likely to open windows than those in the lowest income quartile. This is the case, for instance, with regard to opening windows to keep cool (85% in highest quartile and 75% in lowest quartile), to let out smoke or smells (55% and 37% respectively), to avoid condensation (46% and 33% respectively) or to sleep better (48% and 31% respectively). Those who own are more likely to open windows to stay cool (82%) or to sleep better (44%) than those that rent from a private landlord (70% to keep cool and 26% to sleep better) or a social landlord (78% to keep cool, 28% to sleep better). This could in principle be because of the dwelling, the household or perhaps where they live (urban/rural or different neighbourhoods).

Unsurprisingly, those households that sometimes get too warm in winter are more likely to open windows than those who do not (83% as compared to 74%) and the trend is even more pronounced for summer, where 85% of those that do at times get too warm open windows to keep cool as compared to only 50% of those that say it would not get too warm.

There are no clear trends by age or type of property except that those in a flat/maisonette are less likely to open windows in order to sleep better (28%) as compared to those in a Bungalow (33%) or house (42%). This might reflect the fact that flats are located more in urban areas which tend to be noisier. In general, those who have part or their entire home on the ground floor are not less likely to open windows than those that do not live on the ground floor.

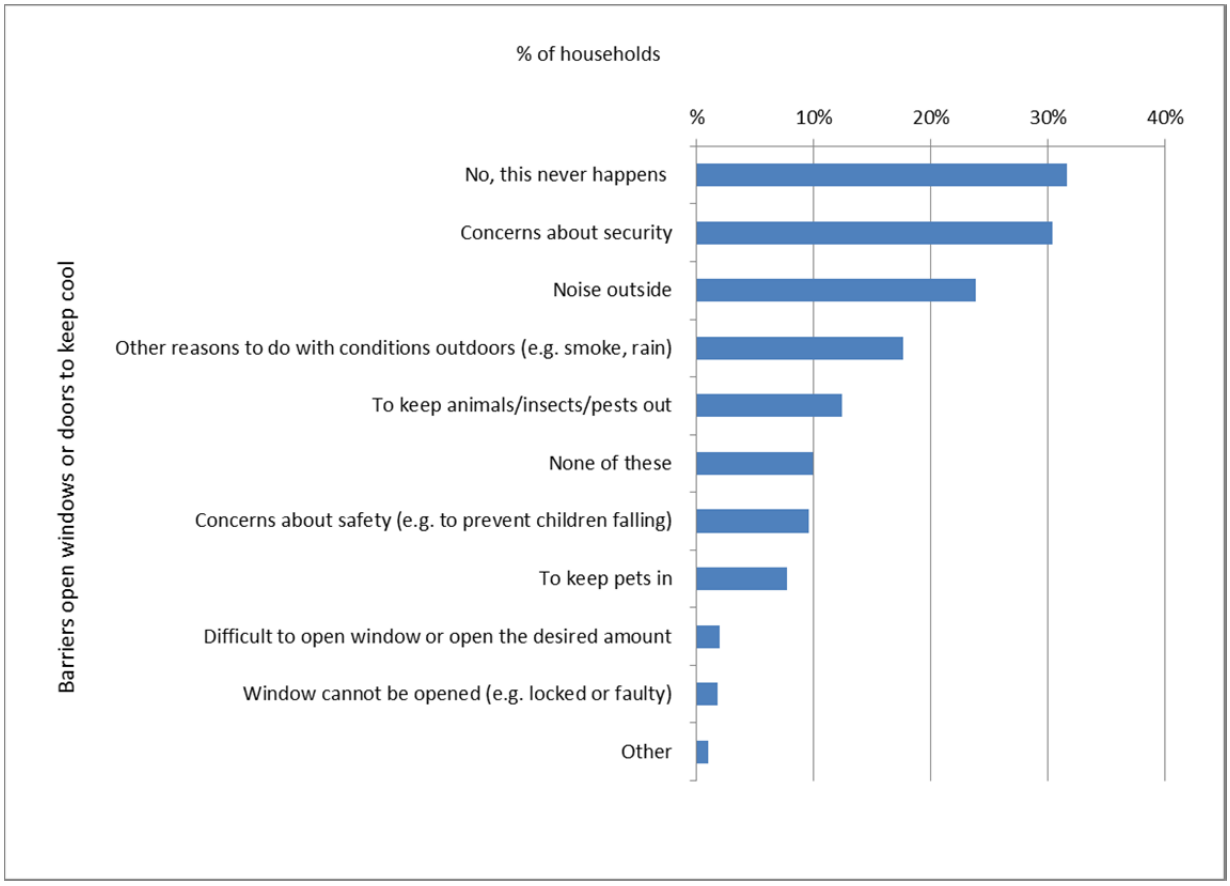
4.5.3 Barriers to using windows and doors to keep cool

There might be times that people would like to open windows as a strategy to cool their home but are unable to do so for a range of reasons. This survey wanted to find out to what extent this was a problem for households, which households were most affected and for which reasons. Respondents were asked *"Are there ever times when you would like to open a window or door to keep cool, but you don't do it for one of these reasons?"* and could choose multiple answers from a list of reasons as well as indicating any other reasons. As Figure 4.7 shows, 32% of respondents stated that this never happens, implying that for a majority there are times when they would like to open a window as a strategy to keep cool, but they do not do it for one or more reasons. Amongst the reasons for not opening windows or doors to keep cool, concerns about security are most prevalent and have influenced 30%. Outside noise has prevented about 24% from opening windows to keep cool and other reasons to do with conditions outdoors (e.g. smoke, odours, wind, rain) have prevented 18% from doing so.

While the oldest households – those with no children and all adults over 60 – are slightly more likely than other households to indicate that they never face any barriers to opening windows, there is no general difference between households with or without children. The exception to this is concerns about safety (e.g. to prevent children falling out), where those households with young children are – unsurprisingly - much more likely to agree that this has sometimes prevented them from opening windows (27% as compared to households without children where only 4% and 5% give this reason in households aged under or over 60 respectively). Those in the lowest income quartile are less likely to face barriers to opening windows – 35% indicate they can always open windows when they want to as compared to 25% in the highest income quartile. The main differences here are due to noise or other reasons to do with conditions outdoors (e.g. smoke, odours, wind, rain) and to keep pets in (6 percentage points difference between lowest and highest quartile for each of them). There is no difference in concerns about security on the other hand among the income quartiles (30% or 31% for all quartiles).

Those living in a flat do not generally face more barriers to opening windows (31% say this never happens) than those in houses or bungalows (32% and 33% respectively) but are more likely to not open windows due to noise outside. On the other hand, those in a bungalow are more likely to not open windows due to concerns about security (37%) than those in flats (29%) or houses (29%). This likely reflects that bungalows are single-storey, meaning all their windows are at ground floor level. Those renting are slightly more likely to be able to open windows for cooling when they want to do so (36% of those with a private landlord indicate they never face barriers as compared to 30% of households who own their property). There is no clear trend by age of property.

Figure 4.7 Barriers to opening windows



Base: all (2285).

5 Findings: needs and behaviours related to heating water and using hot water

5.1 Key findings

1. Across the whole sample, 54% of households have a combi boiler, 34% a standard boiler with a storage tank/cylinder and 15% an immersion heater.
2. The relative prevalence of combi and standard boilers varies with a range of household and dwelling characteristics in a way that can be accounted for by a combination of factors. Combi boilers need less space and provide better for households that are unpredictable as to when someone will be at home or need hot water. Standard boilers can more easily service multiple hot water outlets and maintain a satisfactory flow rate. So the tendency is to provide standard boilers for larger homes but combi boilers for larger households: a clear conflict in choice of system.
3. In properties built up to 1980, combi boilers are the most prevalent system, whereas standard boilers are more prevalent in later homes. This suggests that older properties have replaced previous systems with newer systems, while properties built more recently still have the systems that were initially in the property when they were built.
4. For the majority of respondents, the hot water system operates in the background of their everyday lives, either because they have hot water on demand or available all of the time, or, when looked at by how they control temperature, because they have set the temperature and paid no further attention to it, or because they have no control over how their temperature is set.
5. However a substantial minority, actively engage with their system although with variable frequency. These households are more prevalent among owner-occupiers, households with higher income, and households without children – especially those without school-age children. These findings most likely relate to a combination of having access to controls and controlling differently with the controls they have.
6. Comparing needs dimensions across households, according to how they control the timing of hot water, the strongest effect is that households with water “Available all the time” emphasise *Ease* and are less concerned about *Resource*. Households that “Set and forget” the water temperature place more emphasis on *Hygiene*, *Ease* and *Comfort*, and less emphasis on *Other people*, but with little overall variation. Those classified as “Active control” of temperature put more emphasis on *Resource*, *Other people* and *Comfort* than on *Hygiene* and *Ease*. The “No control” of temperature households place little emphasis on *Resource* and *Comfort*; this emphasis may have resulted in this group not seeking out means to control the temperature, or the emphasis could be as a result of the system they have or resignation to the situation they find themselves in.
7. The ways in which households use hot water are many but factor analysis revealed five factors, which can be used to characterise households to describe their water use.
8. Households use showers more often than baths in both winter and summer, and more baths and showers in summer than in winter. Households are more likely to use showers in the morning (or both the morning and the evening) and baths in the evening.
9. Households without children are more likely to have showers in the morning than households with children, while households with children are more likely to have baths in the evening. The percentage of households that have showers in the morning decreases with increasing household size, whereas the percentage that have showers in the evening varies little and the percentage having showers both morning and evening increases with household size. There is a similar pattern for baths

11. About two-thirds of households say they never use hot water away from home (other than when away for a night or more). However, 21% say that they use showers elsewhere and 6% that they use baths. The reasons most often given are to get clean after activities and because it is more convenient, rather than to save money or energy.
12. A majority of households do not vary how long they have hot water on for. Some increase the hours of heating when they have visitors. Some decrease when they are away from their home but this is not universal.
13. Households tend to have at least two ways of drying their clothes; about two-thirds dry their clothes outdoors, other common methods being in a tumble drier, using radiators and drying clothes somewhere else around their home. This has implications for heating the home (with a requirement for both warmth and good ventilation) and the particular means of heating the home (with a requirement for localised heat sources such as radiators). Flexibility around heating the home might be increased by providing secure, covered outdoor drying areas.

5.2 Introduction

This chapter examines the prevalence of different hot water systems, how these vary with household and dwelling characteristics, strategies for the control of hot water timing and temperature, specific problems with hot water, uses of hot water (particularly for baths and showers), uses of hot water away from the home, and the circumstances in which households vary the hours for which they heat water.

5.3 Hot water systems

This section presents findings on the prevalence and distribution of systems for heating water across households in Britain. It begins with an analysis of what systems households have and which systems households use as their main way of heating water. It then looks at the distribution of these systems across different types of properties and by different household characteristics.

5.3.1 Prevalence of systems

Respondents were asked which systems they had available to them in their household to heat water and, if they selected more than one option, which one they use as their main way of heating water. Across the whole sample, 54% of households had a combi boiler, 34% a standard boiler with a storage tank/cylinder and 15% an immersion heater.[59] Less prevalent systems included 2% of households with district heating, 1% with instant hot water taps and 1% with solar thermal water heating. The mean selection of options for this question was 1.1 which suggests that households tend to have only a single system available to them to heat water.

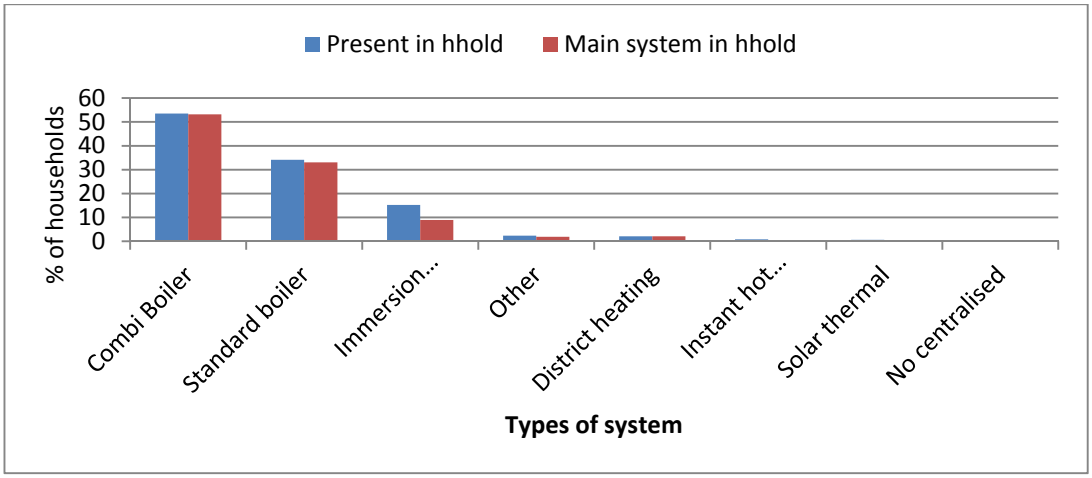
Interviewers observed hot water cylinders in 754 homes (13% in bathrooms, 19% in bedrooms, 46% in a hall, corridor or landing, 9% in a kitchen and 14% in other locations in the home). In these households they observed 86% with timing controls for their boilers. Of the households with timing controls, 98% had a single timing control and 2% with two timing controls. Finally, they also observed 58% with insulation moulded onto the tank, 23% with insulation fitted onto the tank, 13% with insulation factory sealed and 4% with no insulation.

As Figure 5.1 shows, the majority (86%) identified either combi boilers or standard boilers as both a system in their household and as their main system for heating water. Therefore, the following analysis will focus on these two systems. In comparing the two types of boiler, it should be kept in mind that the combi boilers may

[59] This may underestimate the true number of immersion heaters. Standard boilers are often combined with an immersion heater as backup but respondents were probably not all aware of whether this was the case in their home and interviewers were not expected to try to make the necessary technical observations.

have been installed more recently than standard boilers. One consequence of this could be a greater likelihood that they were installed by the current household, who therefore could have more awareness of how to operate them.

Figure 5.1 Available systems in the household and main system for heating water



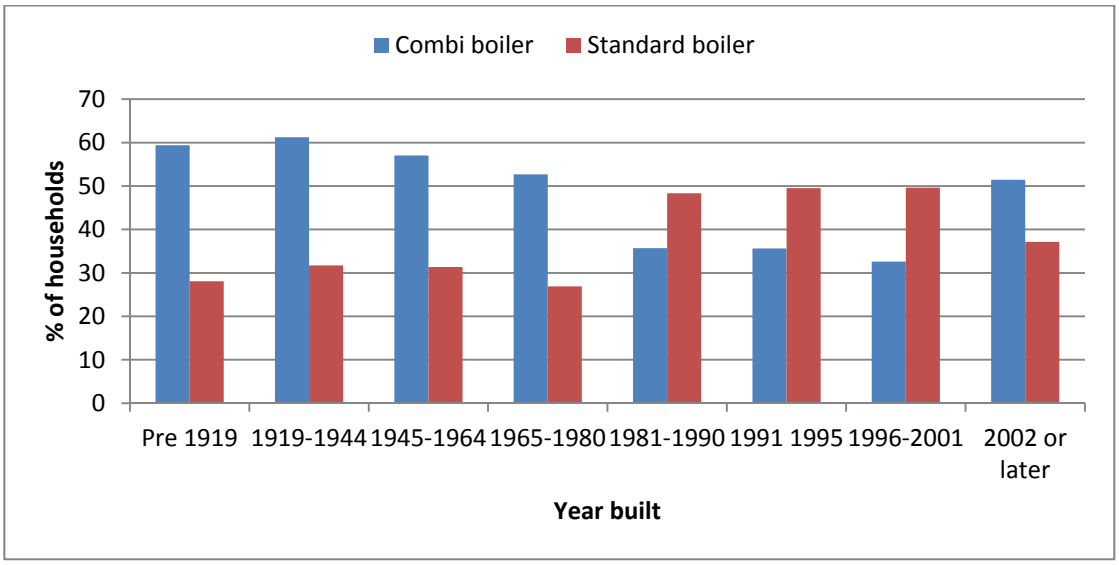
Base: all those who have systems (2490) and all those with a main system (2284).

5.3.2 Characteristics of the property

This section looks at how the two main systems for heating are distributed across different property types.

Figure 5.2 shows that, in properties built up to 1980, combi boilers are the most prevalent system. However, in properties built between 1981 and 1990, 48% of households have standard boilers as their main system, compared to 18% of households with a combi boiler, a level that is maintained although not significantly increased through the periods 1991 and 1995 and 1996 and 2001. This should not have resulted directly from a change in regulations but suggests that older properties have replaced previous systems with newer systems, while properties built more recently still have the systems that were initially in the property when they were built.

Figure 5.2 Property age by main system



Base: all those with a main system (2284).

Table 5.1 shows that the overall greater prevalence of combi boilers is repeated in the figures for each property type. However, while a similar percentage of each property type have combi boilers, standard

boilers are less prevalent in flats or maisonettes in comparison to bungalows or houses. This could be explained because a standard boiler requires space in the property to fit a cylinder, making it less suitable for a flat. In contrast, a standard boiler can more easily service multiple hot water outlets and maintain a satisfactory flow rate; it can therefore be favoured in larger homes.

Table 5.1 Type of property by main hot water system

Type of Property	% with each system		Base
	Combi boiler	Standard boiler	
Flat/maisonette	55	17	484
Bungalow	52	35	293
House	53	38	1497
Total	53	33	2284

The effect of size of home can also be seen in Table 5.2 where 15% of properties with 6 or fewer rooms feature standard boilers, increasing to 53% in the largest homes. It is also noticeable that flats and the smallest homes are the least likely to have a boiler at all. The net effect is that the percentage of homes with a standard boiler increases markedly with size of home but the percentage with a combi boiler decreases only slightly, except for the drop to 40% in the largest homes.

Table 5.2 Number of rooms in the property by main system

Property rooms	% with each system		Base
	Combi boiler	Standard boiler	
6 or fewer rooms	54	15	349
7-10 rooms	57	28	909
11-15 rooms	51	42	848
16+ rooms	40	53	178
Total	53	33	2284

In summary, this analysis suggests that, while combi boilers are the most prevalent system for heating water across households in Britain, there is some variation in the distribution of combi boilers and standard boilers when looked at by the characteristics of a property. Standard boilers are more prevalent in homes built after 1981, in larger homes, and in houses and bungalows.

5.3.3 Characteristics and attitudes of the household

This section looks at the characteristics of the household, beginning with tenure. As Table 5.3 shows, standard boilers are most prevalent in owner-occupied homes and least in the social rental sector, with privately rented homes being intermediate. The prevalence of combi boilers follows the opposite pattern but with much less variation (a difference of only 5% between owner occupiers and social renters, in contrast to the 20% difference for standard boilers).

Table 5.3 Tenure type by main system

Tenure type	% with each system		Base
	Combi boiler	Standard boiler	
Own	51	39	1463
Social landlord	57	19	447
Private landlord	55	27	333
Total	53	33	2284

Furthermore, as Table 5.4 shows, households of three or more people are more likely to have a combi boiler than households of fewer people. In comparison, standard boilers are least prevalent in single-person households but there is otherwise no consistent trend across household sizes. These findings may reflect a dual effect of standard boilers being favoured for larger homes but combi boilers being more convenient for larger households, because hot water is always available.

Table 5.4 Number of people in the household by main system

Number of people in the household	% with each system		Base
	Combi boiler	Standard boiler	
1	49	28	621
2	50	37	795
3	58	32	344
4	58	35	324
5 or more	62	31	199
Total	53	33	2284

Larger households tend to be those with children, so a similar effect of household size can be seen when looking at household types. As Table 5.5 shows, households with children are more likely than households without children to have a combi boiler, while households with no children and all adults over 60 are more likely than other types of households to have a standard boiler. This may explain why households of more than three people are more likely to have a combi boiler, suggesting it might be more closely linked with households with children than the number of people in a property. There is also possibly an effect of predictability of being at home. The older households are most likely to have a standard boiler and least likely to have a combi. Combi boilers are most prevalent in households with children, particularly where the children are old enough to have started school.

Table 5.5 Type of household by main system

Type of hhold	% with each system		Base
	Combi boiler	Standard boiler	
Household with children under school age	57	30	174
Household with children started or completed school	63	32	536
Households with no children and all adults over 60	46	37	828
Households with no children and at least one adult under 60	53	30	746
Total	53	33	2284

Table 5.6 shows that the prevalence of combi boilers varies little between income quartiles, except that it is lowest in the highest quartile. The prevalence of standard boilers increases with income. This pattern could reflect the housing of those in each quartile, with more wealthy people tending to live in larger homes and in houses. For example, 80% of those in the highest quartile live in houses.

Table 5.6 Income quartile by main system

Income quartile	% with each system		Base
	Combi boiler	Standard boiler	
Lowest quartile	53	26	566
2nd lowest	54	32	465
2nd highest	53	38	353
Highest quartile	47	47	355
Total	53	33	2284

Finally, respondents were asked to choose three from a series of 10 statements that they felt reflected their feelings about their home. Table 5.7 shows, for each type of boiler, the percentage of responses represented by each option. The figures are mostly similar for the two types of boiler but those with a standard boiler are more likely to think of their home as a place to relax and socialise with their family.

Table 5.7 Feelings about home by main hot water system

Feelings about the home	% of responses		Total
	Combi boiler	Standard boiler	
A place to relax on my own	33	33	32
A place to relax and socialise with my family	57	64	57
A place to sleep and to store my belongings	39	34	38
A place to raise a family	34	33	31
A place where my family can live in the long term	29	28	28
A place to relax and socialise with my friends	20	23	21
A place to take pride in	19	20	20
A shelter from the weather	19	21	21
A long-term investment	19	21	19
A place to work	4	5	4
None of these	1	1	1
Bases (number of respondents)	1215	754	2286

5.4 Control of hot water

The previous section looked at the prevalence of different types of hot water systems in households, showing that combi boilers and standard boilers were the most prevalent types of system. It also showed how these systems were distributed across different groups. This section looks at how households control when hot water is available and establishes three types of control over the timing of hot water. It then looks at how households control the temperature of their hot water and again establishes three types of control for temperature. It uses the types developed from the way households control timing and temperature – two distinct parameters that are also generally controlled through different devices – to look at how these vary among groups of homes and households.

5.4.1 Timing of hot water availability

Respondents were asked "*Is hot water available all the time in your home or do you do any of these things to control when hot water is available?"* to help understand how households control hot water. Households

whose main system was a combi boiler or instant hot water tap were excluded from this question because these systems are designed to produce hot water on demand, rather than create a store of hot water. As Table 5.8 shows, 50% of respondents asked the question said that hot water is available at times when they set the controls for it, 16% said that they turn the water heating on and off as needed,13% said that they use boost buttons to increase the time their hot water is on, and 30% said that hot water is available all the time.

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Table 5.8 Availability and use of controls

Controls	%
Hot water is available at times when I/we set the controls for it	50
I/we sometimes use a boost button on the timer to get extra water heating	13
I/we turn the water heating on and off as needed	16
Other	3
Hot water is available all the time (this response was exclusive – it could not be combined with other responses)	30
Responses	1189

Respondents who said that they controlled when their hot water is on in some form were asked follow-up questions to establish the frequency with which they used their controls. Only those who said that hot water is available at times when they set the controls for it were offered the option of 'Never' when asked how often they use their controls. Table 5.9 shows that 43% of these households never used their controls, suggesting that while they, or someone else, may have set the times or controls for when hot water is available, they have never used the controls since. A further 29% said they used their controls at least once per week and 28% less than once per week. Overall, out of the 529 households that have hot water at times when they have set the controls for it, 61% never change the controls, 39% do so less than once per week and only 40% do so at least once per week.

Table 5.9 Availability and use of controls

Frequency	%
Never	43
Less than once per week	28
At least once per week	29
Total	745

How all respondents use their controls can be categorised into three different types of control, as shown in Tables 5.10 and 5.11.

Table 5.10 Control types

	Type		
	On demand	Available all of the time	Controlled
How the household controls their system	*Respondents whose main system for heating water is a combi boiler or instant hot water tap*	*Respondents who said that hot water is available all of the time, in the absence of an "on demand" system*	*Respondents who control when hot water is available either through timers, boost buttons or manually*

Base: those with either a combi boiler or controls for hot water 2263.

Table 5.11 Availability and use of controls

Control types	%
On demand	54
Available all of the time	14
Controlled	32
Base	2263

Overall this analysis suggests that the majority of respondents' hot water systems operate in the 'background' of their everyday lives, either because they produce hot water on demand or hot water is available all of the time. There is however a substantial minority – 32% – who actively engage with their system although the frequency with which they engage with their system can vary, as noted above. If households with a combi boiler as their main system are excluded from the analysis, so that the "On demand" category is removed, 30% of households can be classified as having hot water "Available all of the time" and 68% as "Controlled".

5.4.2 Controlling water temperature

An alternative set of types was developed using respondents' answers to the question "*How, if at all, do you or your household control the temperature of water from your hot taps?"* This question was asked of all respondents and therefore gives an indication of how those who have a combi boiler or instant hot water tap control hot water, alongside households with other systems.

As Table 5.12 shows, when asked this question, 33% of respondents said that the hot water was set up once and they have left it like that, 22% said that they change the temperature directly on their boiler, 21% that they are not able to control the temperature of their hot water and 16% that they are able to control their hot water, but do not do this. As with the previous questions on how respondents control when hot water is available, the majority of respondents, 49%, either do not use their temperature controls or, having set them up once, do not use them afterwards.

Table 5.12 Control of hot water temperature

Statements	%
Not able to control the temperature of our mains hot water	21
Able to control the temperature of our mains hot water but don't do this	16
The hot water was set up once and we just leave it like that	33
We change the temperature of our hot water on the boiler	22
We change the temperature of our hot water on the hot water cylinder/tank	4
We set the temperature on a point-of-use water heater	2
We get someone else to do it	1
Other	2
Base	2284

As Table 5.13 shows, based on how households control the temperature of water, we can categorise respondents into three temperature control types: "Set and forget", "Active control" and "No control".

Table 5.13 Three types of temperature control and the percentage of households in each type

	Type		
	Set and forget	Active control	No control
How the household controls the water temperature	*We are able to control the temperature of our mains hot water but don't do this* *The hot water was set up once and we just leave it like that*	*We change the temperature of our hot water on the boiler* *We change the temperature of our hot water on the hot water cylinder/tank* *We set the temperature on a point-of-use water heater*	*We are not able to control the temperature of our mains hot water* *We get someone else to do it*
%	48	26	22

Base = 2287.

The 48% "Set and forget" is comparable to the 54% of respondents who were categorised as having water on demand, and the 26% "Active control" is comparable to the 32% categorised as controllers of water timing, leaving 22% with no control over temperature and 14% with hot water available all of the time. Overall the findings on control suggest that – whether looking at how households control when hot water is available or the temperature of hot water – for the majority of respondents their system operates in the background of their everyday lives, either because they have hot water on demand or available all of the time, or, when looked at by how they control temperature, because they have set and forgotten about it, or because they have no control over how their temperature is set. However, in each case, about one quarter of respondents are actively controlling when hot water is available or the temperature of their hot water, although only 3% are doing this once per week or more often. This raises the question of the role of both the dwelling and household characteristics of these two groups, which is addressed in the next section.

Removing those who say they have no control over the temperature of their hot water shows that 62% of respondents can be categorised as "Set and forget", while 34% can be categorised as "Active control". This suggests that households are less likely to use their temperature controls than their timing controls.

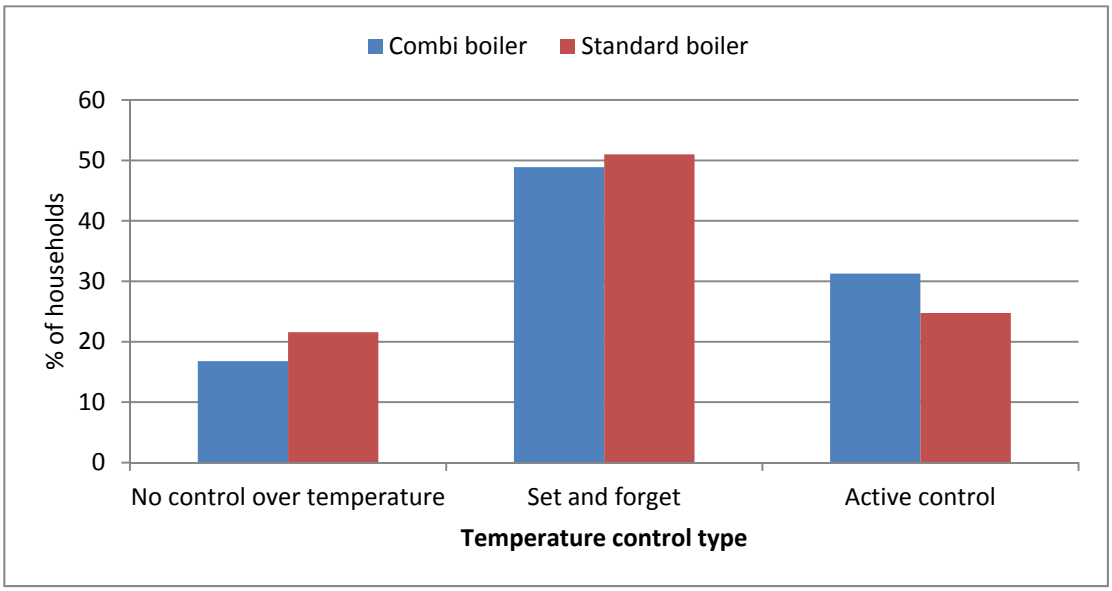
5.4.3 Control types, property types and household characteristics

Having categorised two groups of control types in the previous section, this section looks at how these types vary across different property types and household characteristics.

When looked at by timing control type, 72% of households with standard boilers were categorised as controllers while 27% were categorised as having water on demand. As combi boiler users were categorised into their own type when looked at by how they control the timing of their hot water, when looked at by main system, they were 100% 'On demand'.

As Figure 5.4 shows, in households with combi boilers, 49% can be classified as set and forget for control of temperature, 31% active controllers and 17% as having no control over the temperature. In households with standard boilers as their main system, 51% can be classified as set and forget, 25% as active controllers and 22% as having no control over temperature. This suggests that while both systems are likely to include a majority of set and forget types, those with combi boilers are more likely to be active controllers than to have no control over the temperature of the water, while those with boilers are almost as likely to be either active controllers or to have no control (because there are no controls or because they are not aware that they have controls) over the temperature of the water.

Figure 5.4 Temperature control types by main system



Base: all those with a main system (2284).

When looked at by timing control types (Table 5.14), 57% of those with social landlords, 56% of those with private landlord and 52% of owner occupiers can be categorised as having water 'on demand', mirroring the percentages with combi boilers as reported in Section 5.3. Overall, the type of timing control varies little with tenure.

Table 5.14 Control of hot water types by tenure

	% of each tenure exhibiting each control type			
Types	Own	Social landlord	Private landlord	Total
On demand	52	57	56	54
Available all of the time	13	16	13	14
Controlled	34	26	29	32
Bases	1447	447	328	2263

In contrast, Table 5.15 shows that, when looked at by temperature control types, owner occupiers are much less likely than renters to report having no control, and more likely to be "Set and forget" or "Active control" types. Compared with private renters, social renters are more likely to be "Active control" types. A distinction can be drawn mainly between owner occupiers and both types of renters.

Table 5.15 Control of hot water temperature types by tenure

	% of each tenure exhibiting each control type			
Types	Own	Social landlord	Private landlord	Total
No control over temperature	17	31	33	22
Set and forget	51	45	38	48
Active control	29	20	25	26
Bases	1447	447	328	2263

When looked at by income quartiles (Table 5.16) control over timing and active control of temperature both increase with income. In contrast, on-demand hot water and lack of control over water temperature both decrease with increasing income. There is relatively little variation with income in the percentage having hot water on all the time or adopting a "Set and forget" approach to temperature. These findings may be partly explained by the higher income groups having more access to controls (as distinct from controlling their systems differently with the controls they have). Excluding homes with combi boilers, interviewers observed 48% of households in the lowest quartile with a water heating timer/programmer compared to 58% in households in the highest quartile. In addition, interviewers observed accessible thermostats in 38% of households in the lowest quartile compared to 55% in the highest quartile.

Table 5.16 Control of hot water types and temperature types by income quartiles

	% of each income quartile exhibiting each control type				
Control types	Lowest quartile	2nd lowest	2nd highest	Highest quartile	Total
On demand	54	55	53	47	54
Available all of the time	16	12	14	12	14
Controlled	29	32	32	41	32
Bases	561	460	352	353	2263
No control over temperature	26	21	19	18	22
Set and forget	48	46	46	47	48
Active control	23	29	31	33	26
Bases	566	467	353	356	2287

As Table 5.17 shows, when looked at by timing control type, households with children – especially those with school-age children – are more likely to have hot water on demand, less likely to have hot water constantly available (from storage) and slightly less likely to control when hot water is available. Among households without children, the older adults are less likely to have hot water on demand, more likely to have it available all the time but also more likely to control the timing.

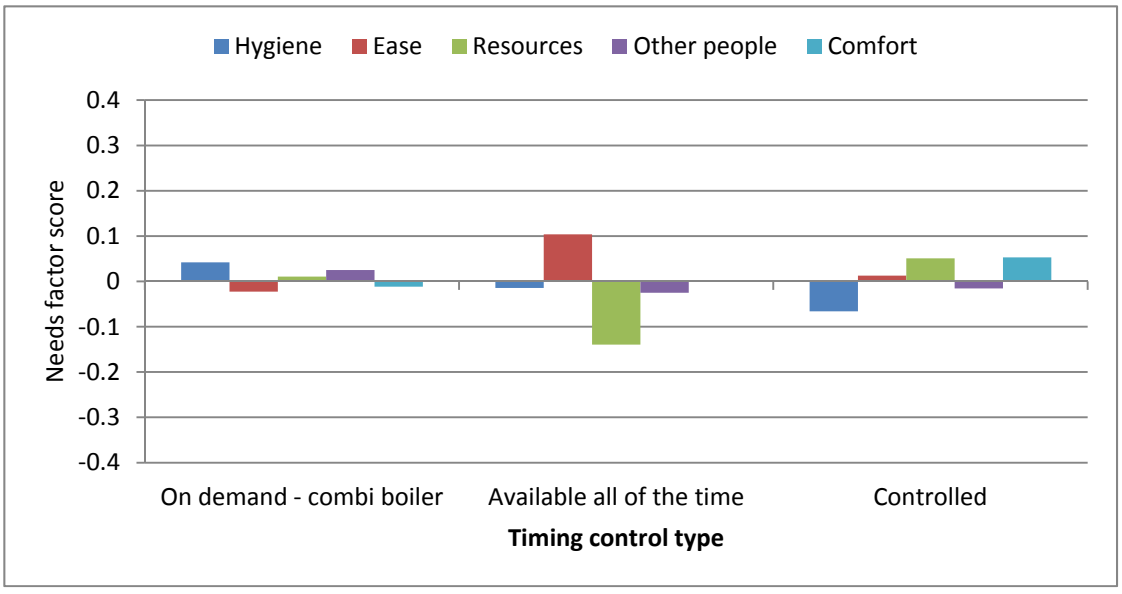
Households with preschool children are more likely than other households to report no control over temperature and least likely to report active control, again reflecting a "hands-off" approach. There is less variation among the other household types but the older household types are the most likely to "set and forget".

Table 5.17 Control of hot water types and temperature types by household type

	% of each income quartile exhibiting each control type				
Control types	Household with children under school age	Household with children started or completed school	Households with no children and all adults over 60	Households with no children and at least one adult under 60	Total
On demand	58	63	47	54	54
Available all of the time	11	8	17	14	14
Controlled	29	28	35	30	32
Bases	171	536	817	739	2263
No control over temperature	30	20	21	24	22
Set and forget	47	46	52	45	48
Active control	20	31	25	27	26
Bases	174	538	828	747	2287

Comparing the control types by the distribution of needs dimensions (as described in Chapter 2) shows that those categorised as having hot water on demand on average place more emphasis on *Hygiene* but with little overall variation (see Figure 5.5). Those classified as 'controllers' on average place less emphasis on *Hygiene*, and more emphasis on *Resource* and *Comfort*, but again with little overall variation. The strongest effect is that those with hot water available all the time emphasise *Ease* and are less concerned about *Resource*.

Figure 5.5 Needs factors by timing control type

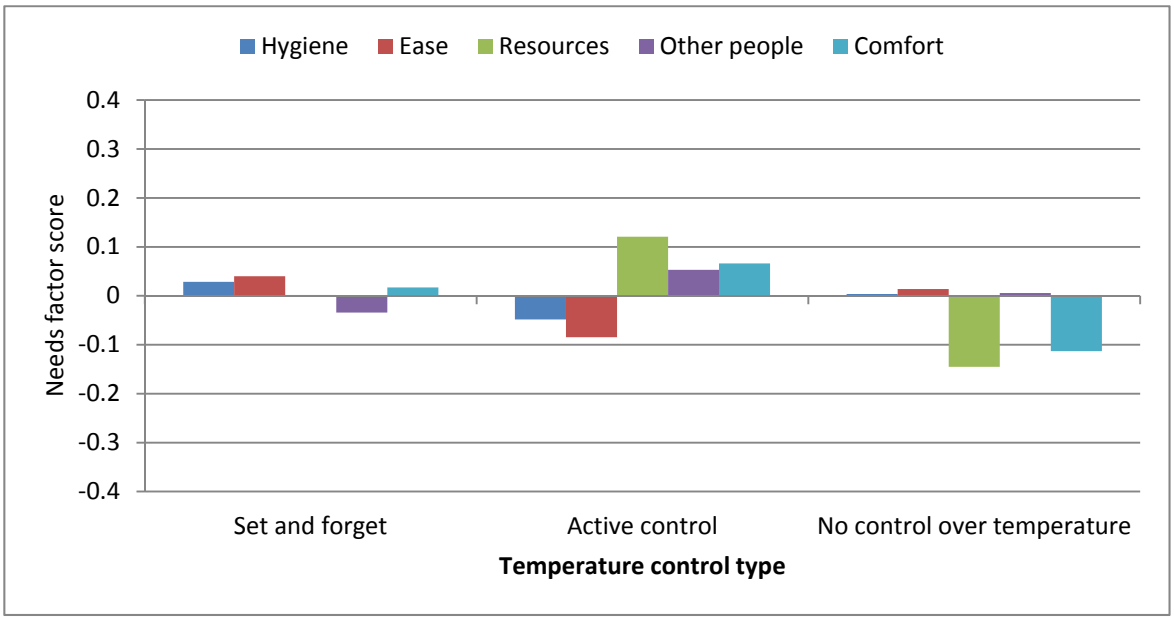


Base: all main systems (2287).

Figure 5.6 shows the distribution of the needs dimensions across the three different temperature control types, showing a greater variation by type than amongst those in the timing control types. Those classified as "Set and forget" place more emphasis on *Hygiene*, *Ease* and *Comfort*, and less emphasis on *Other people*, but with little overall variation. Those classified as active controllers by contrast, put more emphasis on *Resource*, *Other people* and *Comfort* than on *Hygiene* and *Ease*. Finally, those with no control over

temperature place little emphasis on *Resource* and *Comfort*; this emphasis may have resulted in this group not seeking out means to control the temperature, or the emphasis could be as a result of the system they have or resignation to the situation they find themselves in.

Figure 5.6 Needs factors by temperature control type



Base: all main systems (2287).

5.4.4 When households increase or decrease hours heating water

This section looks at when households might increase or decrease the number of hours when hot water is turned on. Respondents were first asked *"In which of these circumstances, if any, do you increase the number of hours when your hot water is turned on?"* and presented with several scenarios in which they might increase the hours they have hot water on for. Respondents were not asked this question if they had hot water on demand (combi boiler or instant hot water tap) or if they had their hot water on all the time. As Table 5.18 shows, 60% of respondents chose 'None of these' when presented with these scenarios. This reinforces the suggestion made throughout Section 5.4 that households are not as engaged with their hot water system as they are with their heating system. However, Table 5.18 also shows that some households do increase the hours they have their hot water on in specific scenarios. In particular, 22% of respondents increase the hours if someone comes to stay overnight, 18% if someone stays for several days and 13% if they have visitors during the day. This suggests that households are most likely to change how much hot water they use when they have visitors to their household.

Table 5.18 When households increase hours of heating water

When household increases hours of heating water	%
None of these	60
If someone comes to stay overnight	22
If someone stays for several days	18
If you have visitors during the day	13
When the season changes to colder weather (in autumn/winter)	10
If someone in the household is ill	6
If you do other physical activity in the home	6
If you have an elderly or sick visitor	4
When the season changes to warmer weather (in spring/summer)	4
During school holidays	4
If you take part in sport or exercise	3
If you have a day off work	3
Other	2
If you work from home	1
Base	746

All households, including those with on-demand or constant hot water, were then asked *"In which of these circumstances, if any, do you decrease the number of hours when your hot water is turned on?*[60]*"* Table 5.19 shows that, as when asked about when they might increase the hours their hot water is on, the majority (70%) said none of these scenarios. However, 24% said that they would decrease the hours hot water is on when they go away for a long period of time and 13% that they would decrease the hours hot water is on when they go away for a night. This suggests that households are most likely to decrease their use if they go away from the house for a period of time but this is not universal practice and it is even less common to decrease hours when away for only a night.

Table 5.19 When households decrease water use

When household decreases water use	%
None of these	70
If you go away for a longer period of time	24
If you go away for a night	13
When the season changes to warmer weather (in spring/summer)	9
When the season changes to colder weather (in autumn/winter)	3
During school holidays	1
Other	1
Base	2287

Based on responses to these two questions, and the suggestion made in Section 5.4 that households mostly do not engage with their hot water controls, Table 5.20 looks at the household type of those groups who said they never increase or decrease when they have hot water on; in both cases those with children are significantly less likely to increase or decrease than those without children.

[60] Households with combi boilers were asked this question because they might switch off their combi boilers.

Table 5.20 Households that do not increase or decrease by household type

	Household with children under school age	Household with children started or completed school	Households with no children and all adults over 60	Households with no children and at least one adult under 60	Total
Never increase	56	52	64	60	60
Base	*52*	*156*	*298*	*240*	*746*
Never decrease	67	65	72	71	70
Base	*174*	*538*	*828*	*747*	*2287*

5.5 Using hot water

The previous two sections have looked at the prevalence and distribution of hot water systems and how households control their hot water systems. This section now looks at how households use hot water and begins by looking at the variety of ways in which households use hot water and reports on a factor analysis of different uses of hot water. It then looks at how households use hot water in showers and baths, with a particular focus on when they use them, and how households use hot water away from home. Finally it looks at when households might increase or decrease their use of hot water and focuses on groups who say they would not increase or decrease their use of hot water.

The first question respondents were asked in the hot water section of the questionnaire was *"I now want to ask you about how you and your household use hot water in the home. By hot water we mean any water that has been heated. This might include warm water or water used in a washing machine cool cycle. Looking at this card, please tell me all of the ways in which you (or anyone else in your household) use hot water in your home."*. This question presented them with a series of ways in which they might use hot water and allowed them to select as many responses as were applicable. Table 5.21 shows the responses to the question. On average, respondents chose seven different ways of using hot water. The most prevalent stated uses are that 88% use hot water to have showers, 88% to wash hands, face or feet, 86% to wash clothes using a washing machine and 86% to wash dishes by hand. The response to this question shows that there are a wide variety of ways in which people use hot water in the home and that, even for the least frequently chosen option of washing pets with hot water, 12% chose this.

Table 5.21 Uses of hot water

Use of water	% of respondents
Have showers	88
Wash hands, face or feet	88
Wash clothes etc. using a washing machine	87
Wash the dishes (by hand)	86
Clean the home, using hot water	78
Make hot drinks or cook food	75
Have baths or bathe children	68
Hand wash or soak clothes, etc.	42
Wash the dishes (using a dishwasher)	38
Wash a car/other vehicle using hot water	22
Brush teeth with hot water	20
Wash pets with hot water	12
Base	2287

Base: all those who say they use hot water (2287).

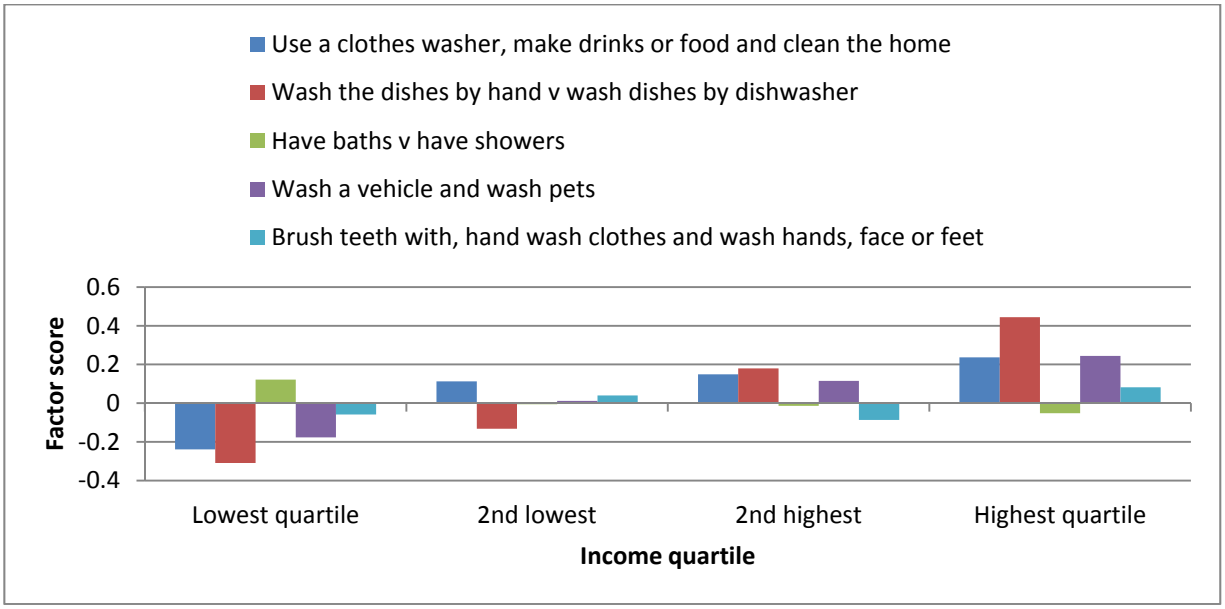
With a wide variety of reasons for using hot water, we did a factor analysis to try to understand any underlying dimensions[61]. The results suggest five underlying dimensions of use of hot water. Table 5.22 shows the results, which include practices that are related to each other (such as washing a vehicle and washing pets) and those in opposition to each other (such as washing the dishes by hand versus washing dishes using a dishwasher). These results were used to assess whether they varied across different groups.

Table 5.22 Water use factors

Factor 1	Use a washing machine, make drinks or prepare food, and clean the home
Factor 2	Wash the dishes by hand **versus** wash dishes using a dishwasher
Factor 3	Have baths **versus** have showers
Factor 4	Wash a vehicle and wash pets with hot water
Factor 5	Brush teeth with hot water, hand wash clothes and wash hands, face or feet

Figure 5.7 shows the results of comparing the factors against income quartiles. For 'Wash the dishes by hand versus wash dishes using a dishwasher' a negative score means on average a household is more likely to wash the dishes by hand, while for 'Have baths versus have showers', a negative score means on average a household is more likely to use a shower. While those in the two middle quartiles do vary in their results, there is a particular difference in the emphasis placed on different factors between those in the lowest and highest income quartiles. Households in the lowest quartile received negative scores for factors 1, 2 and 4, while those in the highest quartile received positive scores for factors 1, 2, 4 and 5. This suggests that those in the lowest quartile are less likely to use a washing machine, make drinks or food or clean the home using hot water compared to the highest quartile. They are also more likely to wash dishes by hand and wash dishes by hand while those in the highest quartile are more likely to use a dishwasher and use showers. It also suggests that those in the lowest quartile are less likely to wash a vehicle or pet with hot water compared to the highest quartile, and less likely to brush their teeth with hot water, hand wash clothes or wash hands and face with hot water compared to those in the highest quartile. The results of this analysis suggests that income is related to the ways in which people use hot water, although it does not suggest that income directly causes particular uses of hot water as this is also likely to be related to the systems they have, learnt behaviours around using hot water and the needs they have for using hot water.

Figure 5.7 Use factors by income quartile

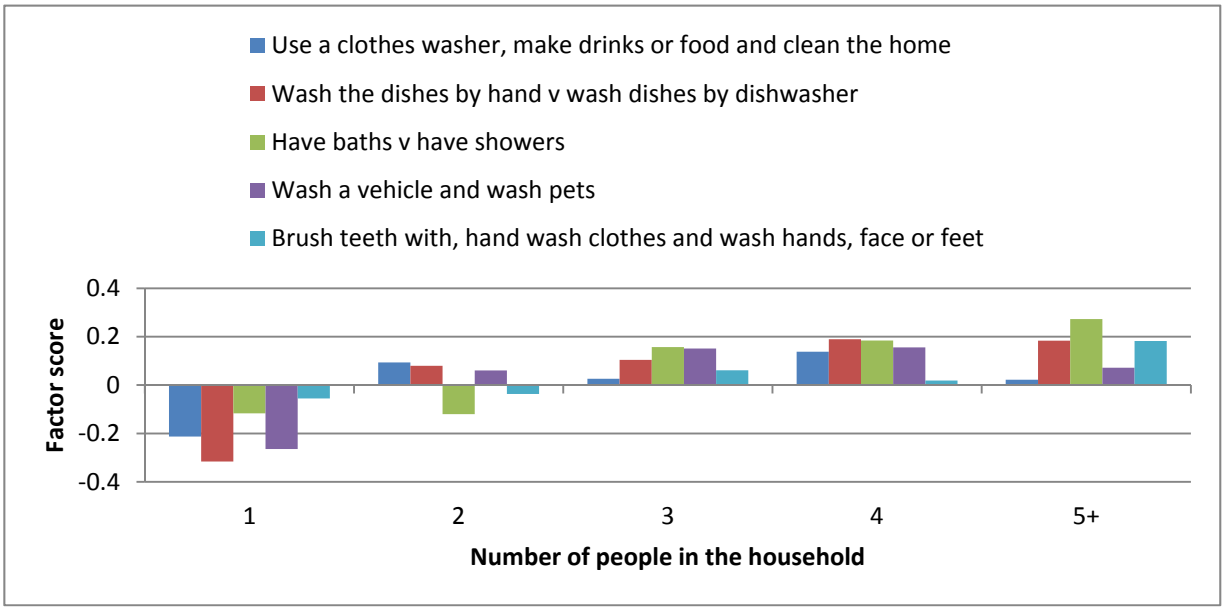


Base: all those with a main system (2287).

[61] For more information on the results of the factor analysis, please see Technical Appendix (p. 169).

Figure 5.8 shows the results of comparing the factors against the number of people in a household. It shows a particular difference between households of one person against households of more than one person. Households of one person receive negative scores for each of the factors, while households of three or more people present receive positive scores for each of the factors. Households of two people sit between these extremes, scoring positively on factors 1, 2 and 4, but negatively on factors 3 and 5.

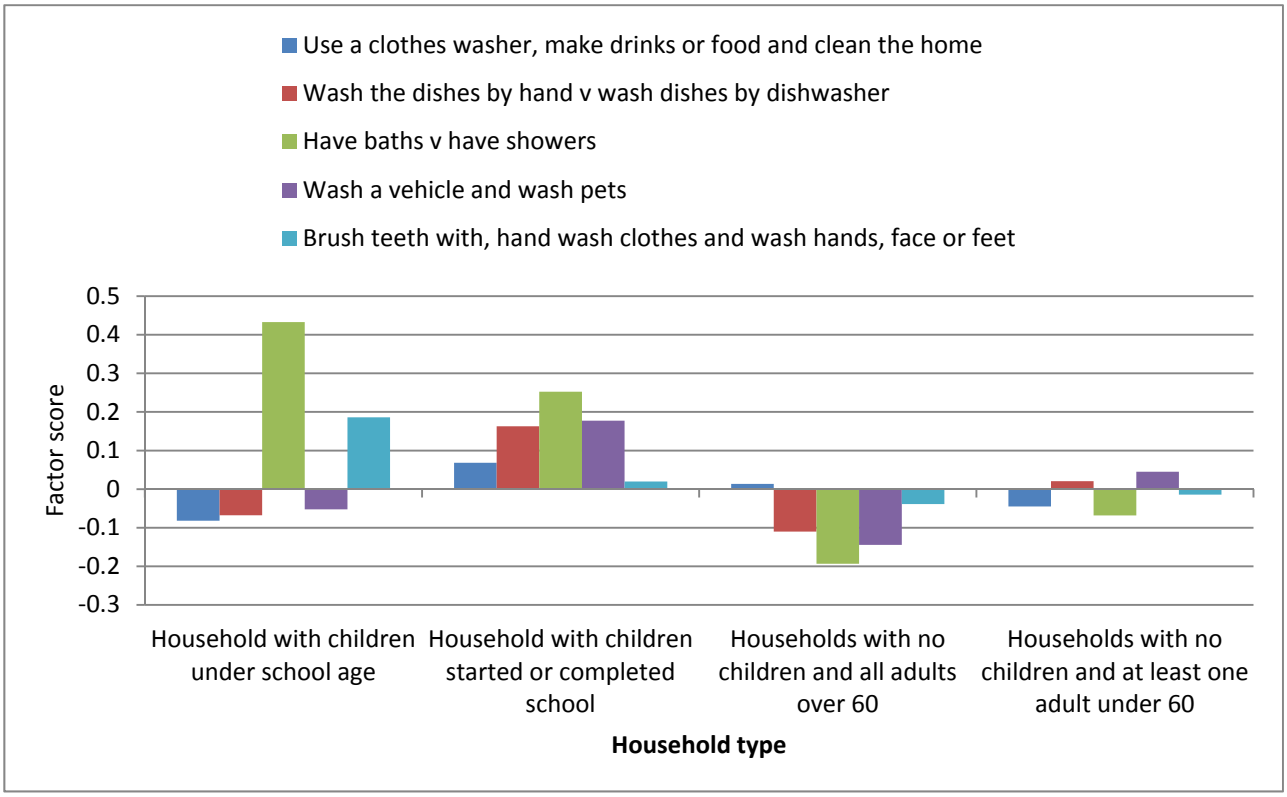
Figure 5.8 Use factors by number of people in household



Base: all those with a main system (2287).

Finally, Figure 5.9 shows the results of comparing the factors against different types of households. It shows variation between households with and without children and, for those with children, differences between households with younger children and households with children who have started or completed school. In particular, households with children under school age score more highly on factors 3 and 5.

Figure 5.9 Use factors by household type



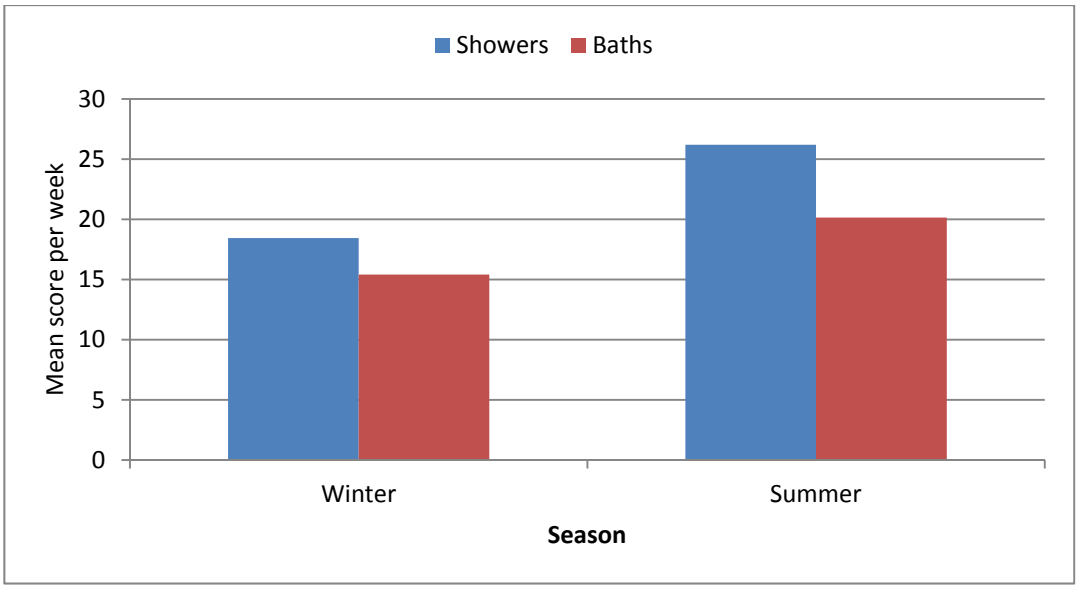
Base: all those with a main system (2287).

5.5.1 Using hot water for baths and showers

The previous section looked at a broad range of ways in which households use hot water. As one of the main ways in which people use hot water in their homes, this section focuses on how people use baths and showers.

Figure 5.10 shows that households tend to use showers more often than baths in both winter and summer, and more baths and showers in summer than in winter. In a winter week, the mean number of showers per household is 18 and the mean number of baths is 15. In a summer week, the mean number of showers per household is 26 and the mean number of baths is 20. The mean numbers per person per week are 5 showers and 2 baths in winter and, in summer, 6 showers and 2 baths. Per household figures are more important for solution design whereas per person is clearly more relevant to individual behaviour.

Figure 5.10 Mean number of showers and baths per week in winter and summer



Base: those who use a shower in winter (1520) summer (1411) and use a bath in winter (1237) and in summer (1111).

Respondents were also asked about when (during the day) they tended to have showers and baths. Table 5.23 shows that this differed between baths and showers: households were more likely to use showers in the morning and baths in the evening. Furthermore, households were more likely to use showers than baths in both the morning and the evening.

Table 5.23 When households have showers or baths

	% showering or bathing	
When households have showers or baths	Showers	Baths
In the morning	43	15
In the evening	19	53
In both the morning and the evening	19	7
It varies between days	6	6
It varies between people	7	6
It varies according to activities that day	5	6
Other – please say what	1	6
Bases	2021	1544

The differences between the use of showers and baths could be explained by the make-up of the household. Figures 5.11 and 5.12 show the results of looking at time of use by type of household. Households without children are more likely to have showers in the morning than households with children, while households with children are more likely to have baths in the evening than households without children. This could be because of potentially different routines in households both between households with and without children and households with working adults or retired adults.

Figure 5.11 When households have showers by household type

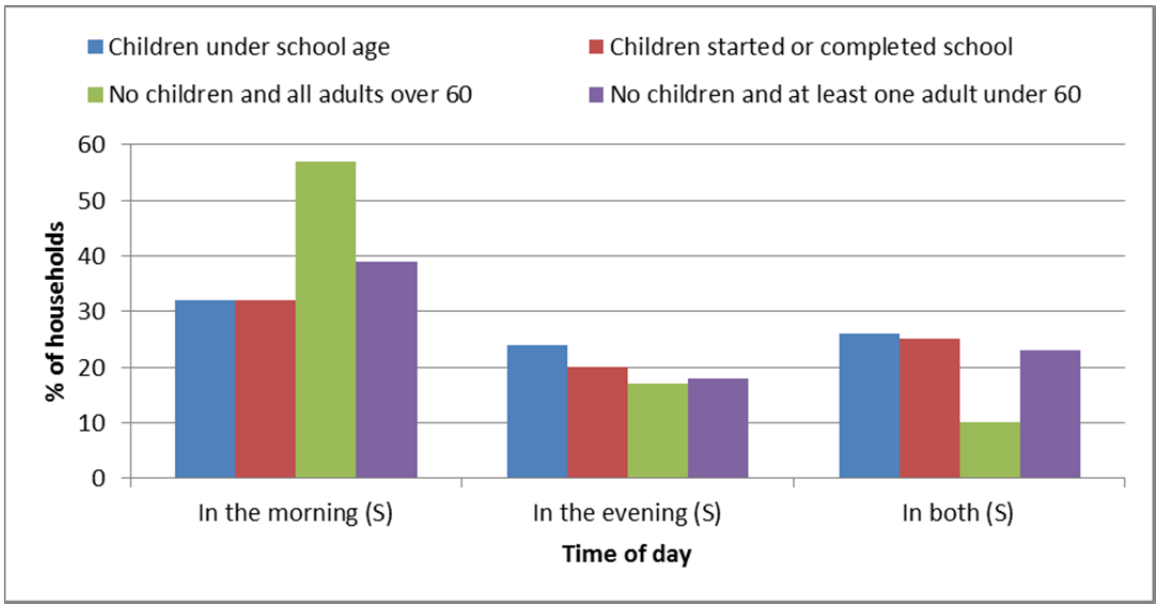


Figure 5.12 When households baths by household type

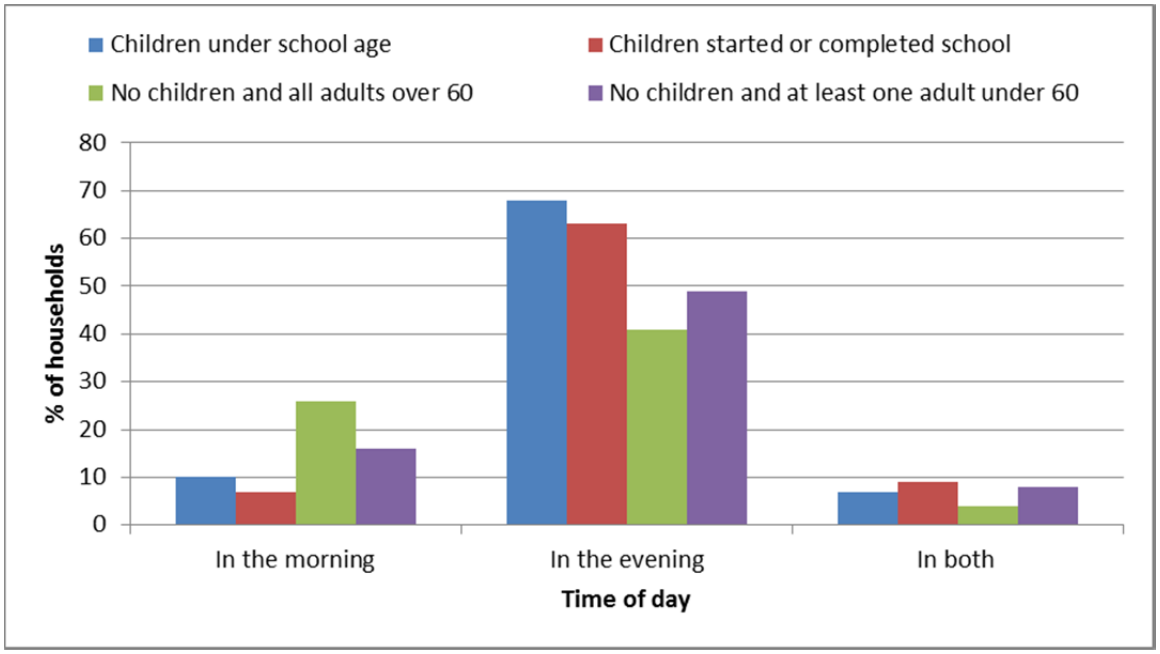


Table 5.24 shows that the percentage of households that have showers in the morning decreases with increasing household size, whereas the percentage that have showers in the evening varies little and the percentage having showers both morning and evening increases. This most likely arises because there is a more limited amount of time in the morning for everyone to take a shower. Table 5.25 shows a similar pattern for baths.

Table 5.24 When households have showers by household size

Showers	1	2	3	4	5+	Total
In the morning	57	47	35	29	29	43
In the evening	19	17	18	20	21	19
In both the morning and the evening	9	18	27	29	21	19
It varies between days	9	6	7	5	6	6
It varies between people	0	6	8	11	20	7
Bases	499	725	314	304	178	2021

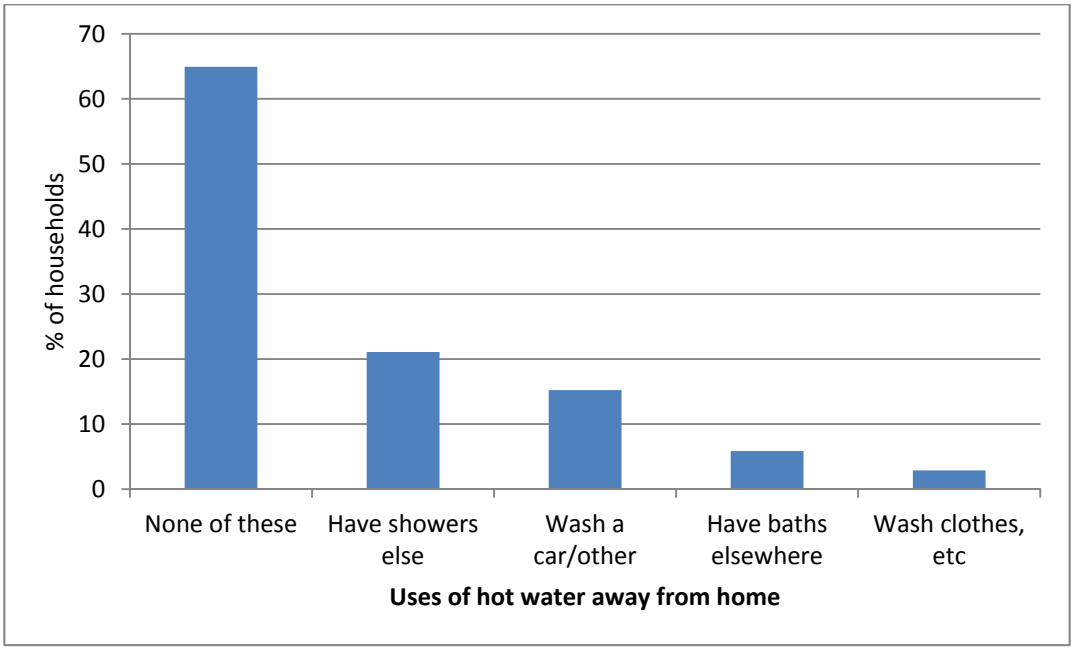
Table 5.25 When households have baths by household size

Baths	1	2	3	4	5+	Total
In the morning	24	20	11	8	7	15
In the evening	42	49	62	63	56	53
In both the morning and the evening	5	6	10	7	8	7
It varies between days	12	6	3	4	5	6
It varies between people	1	4	7	10	13	6
Bases	306	494	281	282	180	1544

5.5.2 Using hot water away from the home

This section looks at how households might use hot water away from home. Respondents were asked "*Thinking about your own personal use of hot water in places away from your home, do you do any of the following (other than when you are away from home for a night or longer)?*" and asked to choose from a series of ways they might use hot water away from home (see Figure 5.13). The majority (65%) of households say they never use hot water away from home. However, 21% said that they used showers elsewhere and 6% said that they used baths elsewhere. In addition, 15% said that they washed a car elsewhere and 3% said that they wash clothes elsewhere.

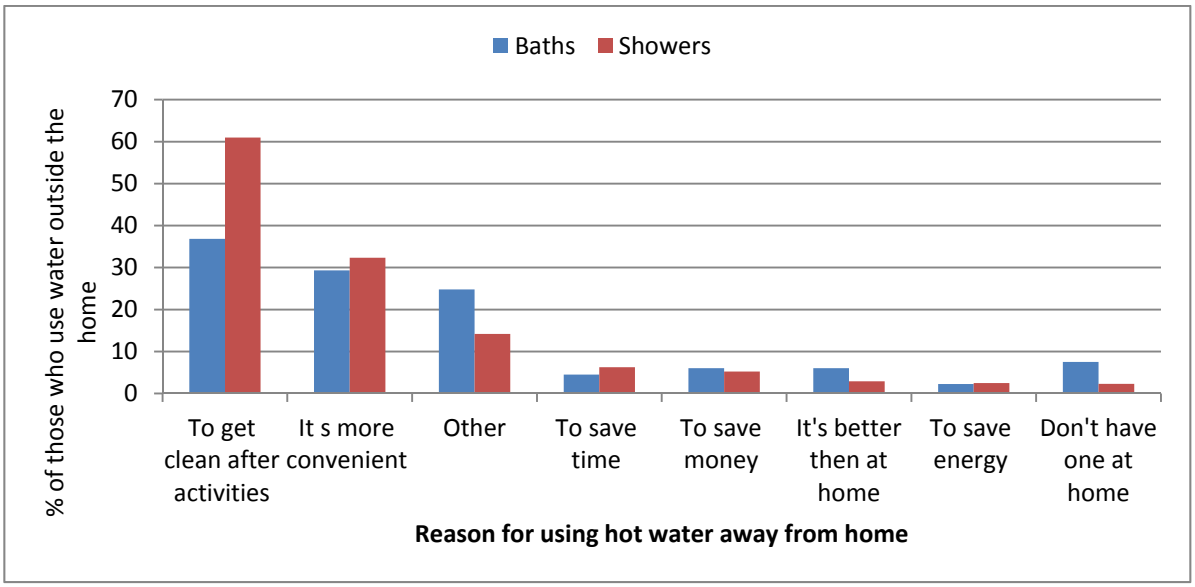
Figure 5.13 Using hot water away from home



Base: those who use water in different ways away from home (2287).

Respondents who said that they used showers or baths away from home were asked a follow-up question about why they did this (see Figure 5.14). In this group, 61% of those who used showers and 37% of those who used baths said that they did it to get clean after activities, while a further 32% of those who used showers and 29% of those who used baths said they did it because it was more convenient. Finally, 5% of those who used showers and 6% of those who used baths said that they did it was because they wanted to save money (while they are an interesting group, unfortunately the base size is too small for useful further analysis). Even fewer said they took baths or showers outside the home to save energy.

Figure 5.14 Reasons for using hot water away from home by baths and showers

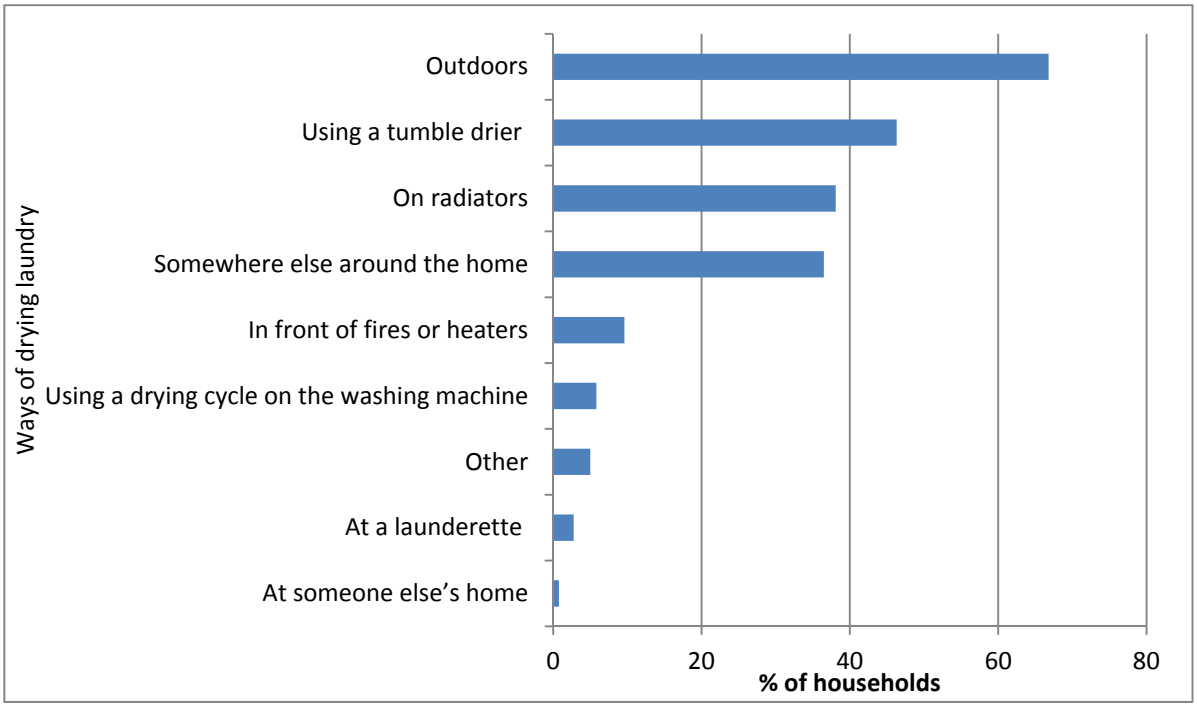


Base: all those who use a bath away from home (133) and those who use a shower away from home (479).

5.5.3 How households dry their laundry

Respondents were asked how they dry their laundry and allowed to choose more than one option (see Figure 5.15). The mean selection for this question was 2.1, suggesting that on average households tend to have at least two ways of drying their laundry: 67% said that they do this outdoors, 46% said that they use a tumble drier, 38% that they use radiators and 37% said that they dry their clothes somewhere else around their household. This has implications for heating the home (with a requirement for both warmth and good ventilation) and the particular means of heating the home (with a requirement for localised heat sources such as radiators). Flexibility around heating the home might be increased by providing secure covered outdoor drying areas.

Figure 5.15 How households dry laundry



Base: all (2287).

6 Findings: acceptability of heat energy solutions

6.1 Key insights:

Heat energy solutions

1. The desire for greater levels of control over heat energy systems is by no means universal. 44% of respondents either do not want greater control over any aspects of their heating systems or favour a greater degree of automation. The equivalent proportions for cooling and heating water are 44% and 62% respectively.
2. There is no single aspect of control over heating the home that most respondents would like to change, under a quarter of respondents selecting the most popular options (the temperature in each room and being able to heat rooms more quickly), followed by being able to control the heating system remotely from outside of the home or from any from any room in the home, the times when heating comes on and off, the rooms that are heated at any given time. Less than one in ten want to have more control to deal with unexpected need to heat the home or to know when someone else changes a heating control.
3. Despite the general absence of technologies for cooling the home, there is less demand for more control, compared to heating the home. The most popular options (although selected by fewer than one-fifth of respondents) were being able to cool the home more quickly, avoiding over-heating during heat waves and being able to cool particular parts of the home.
4. There was an even lower level of demand for increased control over heating water. The most popular area for greater control was around how quickly the water heats up, favoured by almost one in five. The desired changes related to hot water can be related to problems that people currently have: about one-sixth of households say that they have to run their tap for a long time to heat the water, or have more hot water than they need or not enough. Fewer than 10% say that their hot water is either at a low pressure, not hot enough or too hot.
5. The data allow the overall desire for change, and the desire for specific changes, to be related to a wide range of household and dwelling characteristics, in a way that could be applied to specific local populations or to Britain as a whole. The specific characteristics and aspects of control have a complex set of interrelationships that will have greatest meaning in specific applications of the data, rather than in the abstract in this report. However, the overall *absence* of desire for change in heating control is greatest among those who are always warm enough on a typical winter day.
6. The demand for greater control is mediated by the types of systems households already have in place to do this and how they interact with them, as well as the make-up of households. In particular the appetite for greater control of heat energy systems is greatest among households with young children and least pronounced among older households – although variation also exists among different types of households in the particular aspects over which more control is desired. The characteristics of the property, however, appear to make little difference. One implication of this is that the desire for greater control is not easily predictable from area-level property statistics: individual households need to be characterised.
7. Overall, 60% of respondents expressed interest specifically in maintenance contracts for heating systems to be serviced, maintained and repaired for a fixed annual fee. This percentage was higher among households with pre-school children and social tenants but was generally unrelated to characteristics of the household or the respondent's role in managing energy accounts or the use of energy in the home. Overall, choices appear to be influenced heavily by

8. Those who desire improved control are less likely to emphasise *Ease* (and sometimes *Comfort*) than the population as a whole, whereas those who did not want any more control – or who would conversely prefer more automation – are clearly differentiated by their emphasis on *Ease*. In fact, this finding perhaps reflects a perception that greater control will make things more complicated.
9. The need consistently expressed more strongly by those favouring more control over particular aspects of their heating systems is *Resource*. This may be because part of the desire for control is to avoid waste and to reduce energy costs. The dimension of *Resource* is most important to the subsample who would like extra control to know when someone else has changed the heating controls.

Renovation of the home

1. Households have undertaken a varied range of home renovations in the past five years. More than nine-tenths of households had made a change involving adding or re-fitting rooms. By far the most popular activity in this category is painting or re-decorating.
2. By comparison, three-quarters of respondents report work on the heating or hot water system (most commonly servicing a boiler or air heater unit or replacing a boiler) and six-tenths had made changes to the heating or hot water controls. A similar proportion had undertaken insulation or draught-proofing, most commonly putting in loft insulation. Less than one-tenth had made any changes to generate electricity, most commonly using solar photovoltaic panels.
3. Respondents' choices about where they would like to make changes over the next five years broadly reflected the prevalence of work undertaken over the previous five years, but at around half the prevalence in each case. Generating electricity was the only exception to this: there was a higher demand for undertaking changes than was evidenced by the proportion who had done this already.
4. The reasons that respondents give for the changes made vary with the type of change. Adding or refitting rooms is motivated primarily by a wish to improve the look of the home. In contrast, the most frequently reported motivation for other areas of renovation (related to energy systems and insulation) is to improve energy efficiency and save money. Comfort and heath are also frequently cited in relation to all types of change except "Generating electricity" whereas this last category is the only for which there is substantial mention of making the home environmentally friendly. System breakdown is relevant to changes to heating and hot water systems and controls.
5. The other motivations recorded had less influence on decisions. It is particularly notable that the wish to make life at home easier and more practical was cited by around a third of respondents in relation to adding or retrofitting rooms but not cited by more than one-fifth in relation to any of the areas directly relating to heat energy systems. This can be seen to confirm the finding reported above, in relation to heat energy needs of households with a desire for improved control, that the desire to change is primarily driven by considerations relating to *Resource*, rather than considerations relating to *Ease*.

6.2 Introduction

This chapter uses data provided by respondents to the WP5.7 quantitative survey to assess the acceptability of potential future heat energy solutions. Rather than considering specific solutions, it focuses on where British households would like to see improvements or changes in relation to their current systems for heating the home, heating water and cooling. It considers whether there are particular types of households with a greater appetite for certain types of change, which may be prompted by the characteristics of the people living in the household, the property itself or the current heating system and the nature of the household's interaction with it.

It then examines whether those with particular patterns of heat energy needs are more likely to favour particular types of heat energy solutions – which will be key to understanding how certain future solutions might best be marketed. We examine whether particular patterns of heat energy needs can be matched up with specific types or elements of solutions – or the general desire for greater control of heat energy systems. Finally, we consider future heat energy solutions within the context of home renovation – exploring the changes households have made to their homes in the recent past (and those they are planning to make it the future), the motivations driving these changes and plans, and how these might relate to or interact with a desire for improved heat energy solutions.

6.3 Response to options for control of heating, cooling and hot water

6.3.1 Future solutions for heating the home, cooling and heating water

The survey questionnaire explored behaviour in relation to three domains of heat energy use (heating the home, heating water and cooling). As part of this, respondents were asked about aspects of their current systems that they might like to change, specifically in relation to the household's ability to control heating, cooling or hot water. The responses should not be seen as estimates of likely uptake of particular smart energy solutions – they represent the immediate appeal of different elements that could be built into solutions. The respondent will have been thinking more than usual about how they manage heating, cooling and hot water but were not engaged in discussion over what the various suggested changes might mean.

In the heating the home section, respondents were asked "*Leaving aside how you currently make decisions about heating, are there aspects of your heating system or equipment that you would like to change? If you could design your own home or heating system, are there any of these aspects that you would like more control over?"* They were offered a list of pre-defined response options, with the choice of selecting as many as they wished, or offering additional suggestions or, alternatively, selecting either of two exclusive answer options – namely that they would like more, rather than less, automation of their heating system or that they would not like additional control over any of the aspects asked about.

The proportions of respondents selecting each response option are presented in Table 6.1. Just over one-third of respondents (35%) did not want to have more control over any aspects of their heating system, with around one in ten (9%) indicating that it would, in fact, be better to have more automation. This leaves just over half (56%) of respondents who did want their heating systems to be changed in one or more of the ways asked about.

It is interesting to note that there is no single aspect of systems for heating the home that most respondents would like to change. The most popular changes were being able to have more control over the temperature in each room and being able to heat rooms more quickly – both of which were favoured by around one in four respondents. Slightly fewer than one-fifth of respondents favoured being able to control the heating system remotely from outside of the home or being able to control the heating system from any room in the home. Other opportunities for change were favoured by around one-tenth of respondents in each case – specifically being able to deal with unexpected situations where heating the home was necessary and knowing when someone else changes a heating control.

Table 6.1 Desired improvements in control over heating the home

Desired change	Short description	% selecting each option
Temperature in each room	Temp each room	23
Being able to heat rooms more quickly	Heat rooms more quickly	23
Being able to control the heating system remotely from outside the home	Control remotely	19
Being able to control the heating system from any room in the home	Control from any room	16
Times when heating comes on and off	Times on off	13
The rooms that are heated at any given time	Rooms heated any given time	12
Being able to deal with situations when I/we unexpectedly need to heat the home	Unexpected need to heat	9
Knowing when someone else changes a heating control	Know others change control	4
Other	Other	8
None of these (EXCLUSIVE)	None of these	35
It would be better to have more automation so that we wouldn't have to think about controlling the heating (EXCLUSIVE)	More automation better	9
Base	2287 (all)	

Respondents were asked a comparable question at the end of the cooling section of the questionnaire, although, in recognition at the outset of the fact that a very small proportion of the sample had systems or technologies in place for cooling, they were asked not just about cooling systems but about aspects of their ways of cooling the home that they would like to change.

Despite the general absence of technologies or systems for cooling, there was less demand across the board for more control in this area, compared to that reported above in relation to systems for heating the home, which the vast majority of households do currently have in place. Almost half of respondents (47%) indicated they did not want greater control over any of the aspects of cooling asked about, compared to the 35% who stated this in relation to systems for heating the home. There was a comparable level of demand for more automation (and less control) – with 9% of respondents expressing a wish for this in relation to both heating and cooling.

The aspects of cooling that respondents most frequently wanted more control over were being able to cool the home more quickly, avoiding overheating during heat-waves and being able to cool particular parts of the home – all of which were desired by slightly fewer than one-fifth of respondents. Slightly more than one-tenth of respondents would like more control to make the home cooler than is currently possible and to be able to control the cooling from any room in the home. Being able to deal with unexpected situations when there was a need for cooling and being able to control the heating remotely were less popular options, favoured by slightly fewer than one-tenth of respondents in each case.

Table 6.2 Desired improvements in control over the cooling the home

Desired change	Short description	%
Being able to cool the home more quickly	Cool more quickly	19
Avoiding overheating during heat waves	Avoid overheating	18
Being able to cool particular parts of the home	Cool particular rooms	17
Being able to make the home cooler than currently possible	Cooler than currently	14
Being able to control the cooling from any room in the home	Control from any room	11
Being able to deal with situations when I/we unexpectedly need to cool the home	Unexpected need to cool	8
Being able to control the cooling remotely, from outside the home	Control remotely	8
Other	Other	3
None of these (EXCLUSIVE)	None of these	47
No, it would better to have more automation so that we wouldn't have to think about controlling how we cool the home (EXCLUSIVE)	More automation	9
Base	2287	

Base: all.

Finally, Table 6.3 demonstrates the presence of an even lower level of demand for increased control over heating water. More than half of respondents (55%) did not want greater control over any aspect of heating water in the home, while slightly fewer than one-tenth (7%) favoured a greater degree of automation. The most popular area for greater control was around how quickly the water heats up, favoured by almost one in five. This relates to the problem experienced by a significant minority and highlighted in Chapter 5 – that households reported that it took their hot water a long time to heat up. Around one in ten wanted more control over the temperature the water is heated to, the amount of hot water that is available, when the hot water comes on and off and being able to deal with unexpected situations where hot water is required. Fewer than one in 20 respondents would like to be able to control the temperature of the water remotely or from any room in the home or to know when someone else had changed a hot water control.

Table 6.3 Desired improvements in heating water

Desired change	Short description	%
How quickly the water heats up	Speed of heating	18
The temperature the water is heated to	Temperature of water	12
The amount of hot water that is available	Amount of hot water	10
When the hot water comes on and off	Times on off	9
Being able to deal with situations when I/we unexpectedly need hot water	Unexpected need to heat water	9
Being able to control the heating of water from outside the home	Control remotely	4
Being able to control the heating of water from any room in the home	Control from any room	3
Knowing when someone else changes a hot water control from how you set it	Know other change control	2
Other	Other	4
None of these (EXCLUSIVE)	None of these	55
No, it would better to have more automation so that we wouldn't have to think about heating the water (EXCLUSIVE)	More automation	7
Base	2287	

Base: all.

From the data presented above, we can draw the following conclusions about cross-cutting preferences for greater control in relation to the three domains of heat energy use.

- A sizable proportion of the public do not favour having greater control over any aspects of their current systems or methods: 44% either do not want greater control over any aspects of their heating systems or favour a greater degree of automation; the equivalent proportions for cooling and heating water are 44% and 62% respectively. So there is clearly a greater appetite for increased control in relation to heating and cooling the home, compared to heating hot water.
- In relation to each domain, the most commonly favoured changes involve the amount or extent of heating, hot water or cooling required or the speed at which the process of heating the home, heating water or cooling should occur. There is comparatively less support for the concept of remote control (either from within or outside of the home) or feedback on others' involvement with the heat energy systems.
- Although we saw in Chapters 3, 4 and 5 that a sizable proportion of respondents interact with their systems differently in particular situations, there is fairly limited demand for a greater degree of control in unexpected situations: only around one-tenth of respondents favour more control.

Nevertheless, there is a desire for change in some households and it is, therefore, of interest to understand which households these are. In the following section we consider the characteristics of those households where more control over heat energy systems, and over particular aspects, is favoured. In particular, we explore whether certain types of household are more likely to favour an increase in control, whether this demand is more common in particular types of properties and what the relationship may be between a desire for greater control and the households' current heat energy systems and the nature of their interactions with them.

6.3.2 Who would like more control over their systems for heating the home, cooling and heating water?

Heating the home

We consider first, and in greatest detail, the characteristics of households where greater control over heating is favoured, before considering whether the same patterns are evident in relation to the subsamples who favour greater control over systems and approaches for cooling the home and heating water.

The desire to change aspects of controlling the heating (as described in Table 6.1) varies among four household types identified as key to understanding heat energy needs in WP5.4 and around which the sampling strategy for the WP5.7 quantitative survey was based. In Table 6.4 and subsequent tables, within each row:

- red print indicates a lower than average proportion wanting more control;
- pink shading indicates the lowest proportion out of the groups shown in the table (plus any groups that are within 0.1 of the same ratio to the average);
- black print indicates a higher than average proportion wanting more control;
- green shading indicates the highest proportion out of the groups shown in the table (plus any groups that are within 0.1 of the same ratio to the average).

Household type

There is a markedly lower desire for increased control among households with no children and all adults aged over 60. Six in ten respondents in this type of household do not want more control over any aspects of their heating system; this is the case for around one-third of respondents in each of the three other household groupings. While the oldest household grouping indicate less support for each specific aspect of control, their differential levels of support are particularly marked in relation to the options that are most popular among the population as a whole. For instance, just 13% of older households favour more control over the temperature of each room, less than half of the proportion of each other household type that do so.

Table 6.4 Desired improvements in heating the home, by typology of households

Desired improvement	% of column total				Total
	Children under school age	Children started / completed school	No child, adults 60+	No child, 1+ adult under 60	
Temp each room	32	30	13	28	23
Heat rooms more quickly	27	27	16	26	23
Control remotely	25	26	10	23	19
Control from any room	20	21	9	20	16
Times on off	11	17	9	14	13
Rooms heated any given time	12	14	8	15	12
Unexpected need to heat	12	10	5	12	9
Know others change control	3	8	2	5	4
Other	6	8	10	8	8
None of these	25	26	49	29	35
More automation better	8	8	10	9	9
None / automation	33	34	59	38	44
Base	174	538	828	747	2287

In terms of the patterns of preferences among the individual household types, we see two key outcomes.

- Those with children are most likely to want some kind of additional control but the particular desired improvements depend on the age of the children. If there is a preschool child, the focus is on temperature, control from anywhere in the home and responding to unexpected need to heat; better timing is less important. With older children, timing becomes a more important improvement, along with knowing when others in the household have altered the control settings.
- The “No child, 1+ adult under 60” group also has an overall greater than average desire for some kind of additional control, spread across “Temp each room”, “Rooms heated any given time”, “Heat rooms more quickly”, “Unexpected need to heat”, “Control from any room” and “Control remotely”.

A range of other patterns are discernable from analysis of levels of support for more control over specific aspects of heating the home, by demographic characteristics.

Size of household

- Overall, single-person households are least likely to want some additional form of control, followed by 2-person households. A desire for some additional control increases sharply as household size increases to two and then to three but then levels off or declines a little as household size increases further.
- The type of additional control changes between households of 3, 4 and 5+ persons, with desire for control over:
  - “Times on off” and “Know others change control” increasing with household size;
  - “Temp each room”, “Rooms heated any given time”, “Unexpected need to heat” and “Control from any room” peaking at 4 persons (but remaining high with 5+ persons in the cases of “Temp each room” and “Control from any room”;
  - “Control remotely” peaking at 3 persons.
- A desire for greater automation is greatest in households of 5+ and least in single-person households.

Table 6.5 Desired improvements in control over heating by size of household

Desired improvement	% of column total					Total
	One	Two	Three	Four	Over four	
Temp each room	17	21	28	31	30	23
Heat rooms more quickly	19	23	25	24	25	23
Control remotely	11	18	27	23	22	19
Control from any room	11	16	19	22	20	16
Times on off	13	10	13	14	19	13
Rooms heated any given time	9	12	14	15	14	12
Unexpected need to heat	8	9	10	10	9	9
Know others change control	2	3	6	6	8	4
Other	10	8	7	8	8	8
None of these	45	36	26	27	29	35
More automation better	8	9	9	9	10	9
None / automation	53	46	36	36	39	44
Base	629	801	350	325	201	2306

Income quartile

- The desire for some form of additional control, and most individual forms, increases with income.
- Exceptions are “Times on off”, which peaks in the lowest quartile and “Heat rooms more quickly” which peaks in the middle quartiles.
- A desire for greater automation is also greatest in the highest top quartile.

Table 6.6 Desired improvements in control over heating by income quartile

Desired improvement	% of column total			Total
	Lowest quartile	Mid quartiles	Highest quartile	
Temp each room	22	24	32	25
Heat rooms more quickly	22	25	22	23
Control remotely	11	21	34	20
Control from any room	17	17	21	18
Times on off	14	11	13	12
Rooms heated any given time	11	12	17	12
Unexpected need to heat	9	10	12	10
Know others change control	2	4	7	4
Other	8	9	9	9
None of these	39	34	22	33
More automation better	8	7	10	8
None / automation	47	42	32	41
Base	567	818	360	1745

While the characteristics of the respondents' households then clearly relate significantly to their desire for greater control of their heating systems, the same cannot be said of the characteristics of their properties. For instance, no clear trend was found in relation to property age with little variation being evident among homes of different ages.

We also examined support for increased control by respondents' current heating systems and behaviours. Here we encountered a number of relationships which conceptually make sense between current heating systems and control behaviours, and desires for greater levels of control in the future.

Heating systems used

Overall, those with district heating are most likely to not want additional control, perhaps because they find it most difficult to envisage how it would be possible, but they are more likely that average to want greater control over timing.

- They are followed by those with central heating, with or without additional fixed heaters, and those with central heating plus other combinations of heating.
- Those whose main heating is individual appliances fixed in each room are more likely to want some additional form of control, especially over which rooms are heated and responding to unexpected need to heat, but not remote control.
- Those whose main heating is portable heating are the most likely to want some form of additional control, especially in relation to basic temperature and timing functions, but not over which rooms are heated or remote control.

Table 6.7 Desired improvements in control over heating by heating systems used

	% of column total						
Desired improvement	Any with district main heating	Central only	Central main + fixed other	Central main + other (not fixed)	Any with fixed main heating	Any with portable main heating	Total
Temp each room	18	21	22	27	26	43	23
Heat rooms more quickly	3	20	19	25	35	45	23
Control remotely	8	16	23	25	14	10	19
Control from any room	13	14	15	20	17	24	16
Times on off	23	12	8	10	27	31	13
Rooms heated any given time	8	10	10	16	19	5	12
Unexpected need to heat	10	6	5	12	20	17	9
Know others change control	3	4	4	6	3	5	4
Other	3	5	9	12	8	12	8
None of these	43	37	39	31	28	19	35
More automation better	15	10	7	9	11	14	9
None / automation	58	47	46	40	39	33	44
Base	40	838	674	455	286	42	2335

Heating control strategy

- Those whose control of temperature and timing is entirely manual are most likely to want some form of improved control, especially over timing and how quickly rooms are heated.

- Those who use a mix of control settings and manual control over temperature but rely on control settings for timing are the next most likely to want some form of improved control, especially over controlling remotely and knowing that other people have changed control settings.
- Those who use a mixture of control settings and manual control for both temperature and timing are particularly favourable towards improvements in control of the temperature of each room and the rooms heated at any given time.
- Those who use control settings for temperature and have their heating on all the time are the least likely to want some additional form of control, ahead of those who use settings for both temperature and timing.

Table 6.8 Desired improvements in control over heating by heating control strategy*

Desired improvement	% of column total								Total
	Temp M / Time M	Temp A / Time A	Temp A / Time SF	Temp SF / Time SF	Temp SF / Time A	Temp No / Time Any	Temp A / Time All	Temp SF / Time All	
Temp each room	15	15	12	13	14	13	14	11	524
Heat rooms more quickly	16	14	12	12	12	12	13	14	500
Control remotely	8	12	17	13	12	6	9	11	429
Control from any room	10	10	9	10	11	9	9	7	365
Times on off	12	7	6	5	6	12	9	6	280
Rooms heated any given time	8	9	6	7	6	6	5	6	266
Unexpected need to heat	6	7	5	4	4	5	8	4	201
Know others change control	2	2	3	2	3	2	2	3	94
Other	5	5	6	5	5	5	5	4	187
None of these	15	15	20	23	23	23	19	26	781
More automation better	3	4	4	6	4	7	6	8	198
None / automation	18	19	24	29	27	23	25	34	979
Bases	493	620	233	826	663	343	277	370	3825

* See explanation of heating control types in Table 3.22 (Section 3.4.6).

Therefore, we can conclude that the desire for greater control over aspects of respondents' heating systems is mediated by the type of household they live in, their current heating system and how they interact with it; however, relationships of this type are not evident in relation to the characteristics of the property.

Cooling the home and heating water

When we undertook comparable analysis for the subgroups who wanted more control in general, and in relation to specific aspects of cooling the home and heating water, in the light of the patterns identified in relation to heating the home above, we found the following.

- **Household type** again made a difference, with households with children being the most likely to want additional forms of control and the oldest households being the least likely to do so. In relation to heating water, almost two-thirds (63%) of households with no children and all adults over 60 did not want increased control in relation to any of the aspects asked about; the equivalent proportions for households with children were 45% (for those with children below school age) and 50% (for those where all children had started or finished school). This relationship was even more marked in relation to increased control of cooling: 60% of households with no children and all adults over 60 did not want increased control in

relation to any of the aspects asked about, compared to 33% of those with children under school age and 38% of those with children who had started school.

- Support for increased control rises with **household size**: 61% of single-person households do not want better control of any of the aspects asked about in relation to heating water, a proportion that declines to 47% of those in households of 5 persons or more. The equivalent figures for those who do not want additional control of cooling are 57% of single-person households and 33% of households of 5 or more.
- Household income appears to make a difference, with those in the **highest income quartile** being more likely to favour additional forms of control: 56% of those in the lowest income quartile did not want any additional control in relation to heating water, compared to 48% of those in the highest income quartile. The equivalent proportions for those who did not want any more control of cooling were 53% and 37% respectively.

In relation to the desire for more control over cooling, there was no clear trend by tenure, age of property or type of property. The same was also true of the desire for more control for heating water. However, for heating water, those with a private landlord were significantly less likely to not want additional control than owner occupiers; 47% and 57% of these two groups respectively did not want any additional control in relation to any of the aspects of heating water asked about.

When it comes to systems and technologies currently used by households, we again find evidence of a clear relationship between systems currently used and the desire for greater levels of control over systems in the future.

- Having a combi boiler as the main system for heating water was associated with a lesser appetite for increased system control: 61% of those with a combi boiler did not want more control over any of the aspects asked about, compared to 47% of those with a standard boiler with hot water cylinder and 46% of those who used immersion heaters as their main system for heating water.
- Amongst those with a standard boiler, 19% have a desire for more control over how quickly the water heats up, 12% over the temperature the water heats up to and 14% over the amount of hot water that is available. In comparison, amongst households that have a combi boiler as the main system, 16% have a desire for more control over how quickly the water heats up, 11% over the temperature the water heats up to and 6% over the amount of hot water that is available.
- Interestingly, those households who already use systems for keeping cool (such as air conditioning, mechanical ventilation or heat pumps) were more likely to favour a greater degree of control over certain aspects in the future. This could mean that these households have cooling systems because they have a high demand for control, or they have come to appreciate cooling systems and therefore want more from them.

Clearly then, the demand for greater control of systems for heating the home, cooling and heating water is mediated by the types of systems households already have in place to do this and how they interact with them, as well as the make-up of households, which might affect the demands they place upon their systems or what they need them to do. Interestingly though, the characteristics of the property appear to make little difference – suggesting that desires for additional control are driven very much by people, rather than property.

Given this last observation, we next consider, using the five dimensions of heat energy needs developed in Chapter 2, whether those who favour particular elements of heating solutions (in terms of additional control) are more likely to present certain profiles of heat energy needs. In other words, are households' underlying heat energy needs driving their desires for greater control of their heating systems?

6.4 Do people's heat energy needs link to preferred options for control?

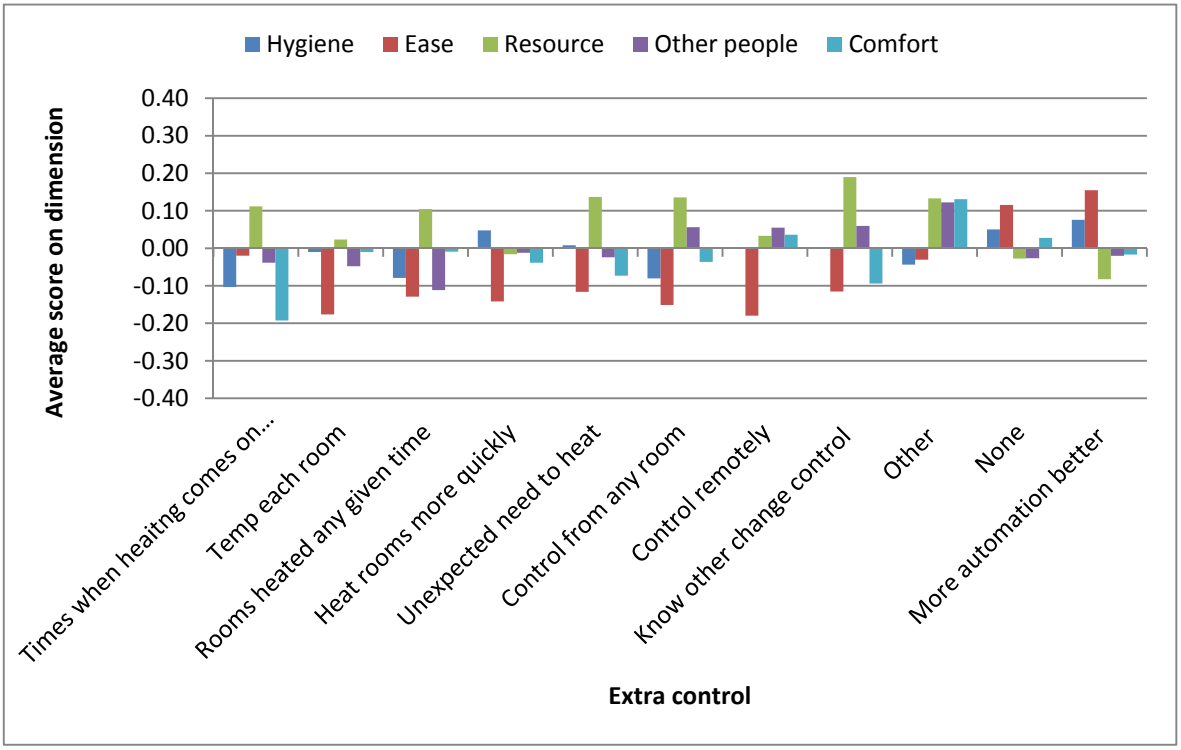
In this section, we focus on households' preferences for increased control of their systems for heating the home. This focus is because the five dimensions of need were developed in relation to needs reported for that domain and because, as reported above, heating the home is the domain where there is evidence of the greatest demand for additional control.

Figure 6.1 presents the average profiles of dimensions of heat energy needs for the subsamples who indicated that they would like increased control in relation to each of the aspects asked about, alongside the

needs profiles of those who indicated they did not want any additional control or would, conversely, prefer more automation. These key trends emerge.

- The underlying dimension of *Ease* differentiates most clearly between those who favour greater levels of control in relation to particular aspects of their heating systems, and those who did not want any more control – or who would conversely prefer more automation. However, contrary to expectation, those who desire improved control are less likely to emphasise *Ease* than the population as a whole. This is the case even for those aspects of control that we might envisage as having a greater association with *Ease* – such as controlling the heating system from other rooms or from outside of the home. This suggests that *Ease* is not a key dimension to consider when marketing these solutions – as it is of less importance to those who would be likely to favour them.
- The need consistently expressed more strongly by those favouring more control over particular aspects of their heating systems is *Resource*. This may be because part of the desire for control is to avoid waste and to reduce energy costs. The dimension of *Resource* is most important to the subsample who would like extra control to know when someone else has changed the heating controls.

Figure 6.1 Heat energy needs profiles of those favouring greater control over particular elements of their heating systems, no further control or greater automation



Base: respondents who completed heating needs sort card exercise (2287).

The above analysis suggests that those who currently favour greater control over particular aspects of their heating tend to prioritise *Resource* at the expense of *Ease* (and sometimes *Comfort*). This prioritisation could usefully be borne in mind when developing and marketing solutions encapsulating these aspects of control; ultimately, it seems that those who prioritise the need for *Ease* have little appetite for additional forms of control and, in fact, tend to favour a greater degree of automation.

6.5 Heat energy solutions and renovation of the home

In understanding British households' attitudes to future heat energy solutions, we recognised that households will make many types of changes to their homes within their lifetimes and that changes to the heating, heating water or cooling systems will need to be considered in the broader context of the behaviours undertaken in this area and the motivations driving them. It may be that the most successful approach to

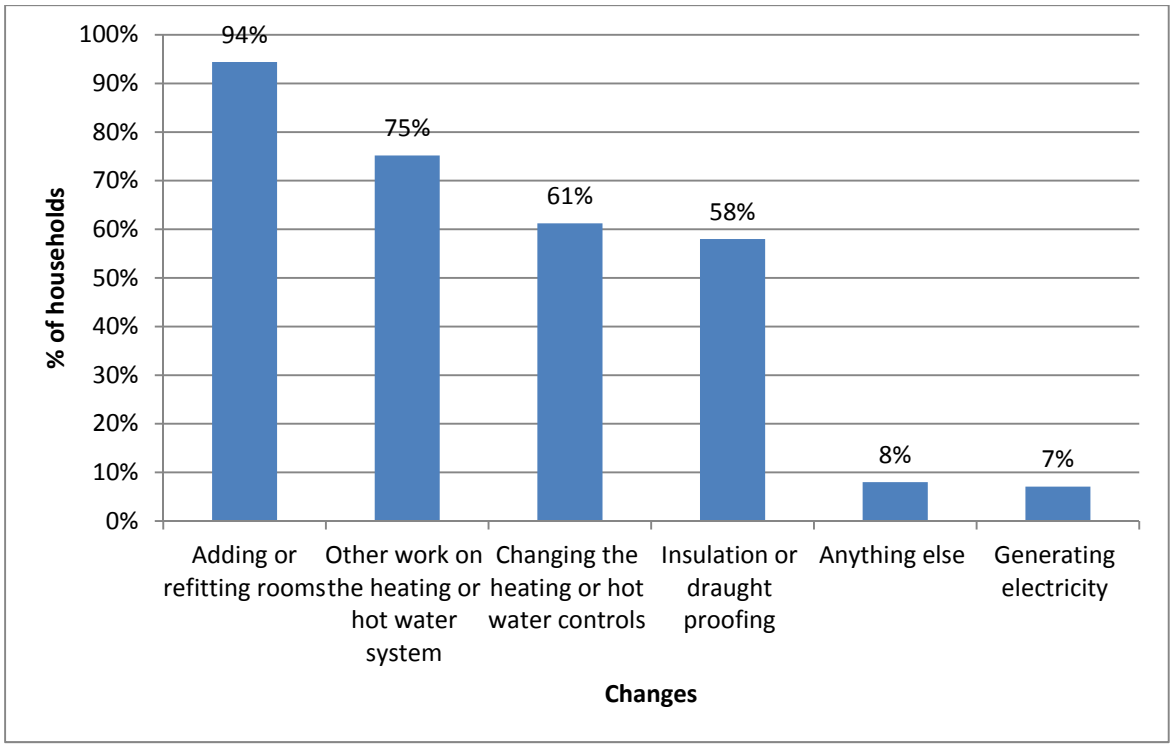
marketing future heat energy solutions would be to integrate them into existing household activities in this area, in a way that enables households to meet their key needs, including those for extra control.

For this reason, we included a series of questions on the self-completion questionnaire asking about the changes the household (or their landlord or freeholder) had made to the home in the past five years, and the main reasons why these changes were made. We also asked respondents what their renovation priorities for the future would be. While these questions included options for changes to systems for heating the home and heating water, they also featured a much broader range of options that were not specific to heat energy. We did this in order to understand the range of changes undertaken (and desired) and the role of changes relevant to heat energy systems within this context.

The data obtained indicated that many types of changes had been made to homes in the last five years.

- More than nine-tenths had made a change that can be categorised as involving adding or re-fitting rooms – with by far the most popular activity in this category being painting or re-decorating – undertaken by 75% of households. Activities included in this category were: painting or redecorating; refitting the kitchen; refitting the bathroom or adding a bathroom or toilet; refitting another room; replacing carpets or other floor covering; removing carpets and replacing with other floor covering; having a loft conversion; adding a conservatory; building some other extension; doing something else to add a room.
- Three-quarters of respondents reported that their household, landlord or freeholder had undertaken work on the heating or hot water system – a category of activities that most commonly entailed servicing a boiler or air heater unit (37%) or replacing a boiler (28%). Other activities included in this category were: putting in central heating; replacing a warm air heating unit; putting in a biomass/wood pellet boiler or stove; putting in a heat pump; changing the main fuel used for heating; putting in one or more extra radiators or storage heaters; replacing a hot water cylinder; adding or improving insulation on the hot water cylinder; putting in solar water heating.
- Six-tenths of households had made changes to the heating or hot water controls; specifically, 22% reported installing TRVs on one or more radiators, while slightly smaller proportions had replaced or installed a central heating thermostat (19%) or a timer / programmer for the central heating or hot water (18%). Other activities included in this category were: replacing or installing a thermostat to the hot water cylinder; some other changes to the controls.
- A similar proportion had undertaken insulation or draught-proofing – this most commonly involved putting in loft insulation or extra loft insulation (31%). Other activities included in this category were: putting in other roof insulation; putting in cavity wall insulation; putting in solid wall insulation – on the inside of the walls, or on the outside of the walls; insulating the floor; draught proofing windows, doors, walls, floors or ceilings; replacing single glazed windows with double-glazing; putting in better double or multiple glazing; fitting secondary glazing (see Table 6.9).
- However, we found that less than one-tenth of households had made any changes under the category of generating electricity; 4% of these respondents were not clear what change had been made (suggesting that this may have been done by someone else) and 3% had had solar photovoltaic panels installed. The other activity included in this category was: doing something else to generate their own electricity.
- Finally, 8% of respondents indicated that they had made other changes within the home; upon review, it became apparent that these data did not conceal any one further substantial type of activity, with the additional activities noted being highly variable and specific – and often being described in a vague way, making it impossible to allocate them accurately to the categories outlined above.

Figure 6.2 Categories of changes to homes made by households, landlords or freeholders within the last five years



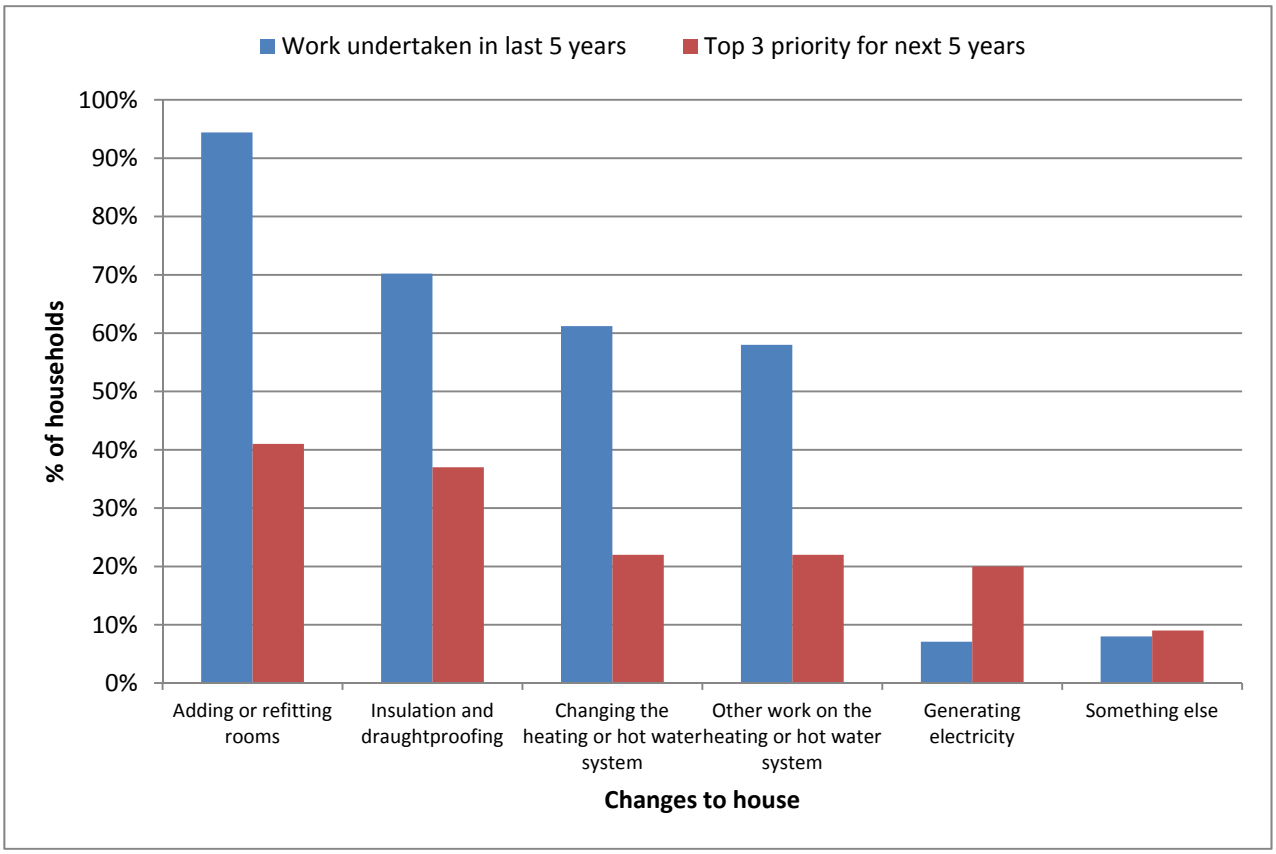
Base: respondent who completed self-completion questionnaire (1798).

Table 6.9 Different types of insulation and draught-proofing done in the home in the last five years

Improvement	%
Put in loft insulation/extra loft insulation	31
Put in other roof insulation	5
Put in cavity wall insulation	14
Put in solid wall insulation - on the inside of the walls	2
Put in solid wall insulation - on the outside of the walls	1
Insulated the floor (within the floor, not just carpets or other floor coverings)	4
Draught proofed windows, doors, walls, floors or ceilings	10
Replaced single glazed windows with double glazing	15
Put in better double/multiple glazing	9
Fitted secondary glazing	1
Don't know	6
None of these	42
Base	1732

Interestingly, when we asked respondents about their top three choices where they would like to make changes to the home over the next five years, their order of priorities broadly reflected the levels of prevalence of different categories of activity undertaken over the last five years depicted above, as shown in Figure 6.3. In most cases, around half of the proportion of households who had undertaken a particular activity in the last five years identified that area as one of their top three areas for renovation in the next five years. The area of generating electricity was the only exception – where there was a higher demand for undertaking changes than was evidenced by the proportion who had actually done this in the recent past.

Figure 6.3 Categories of changes to homes made by households, landlords or freeholders within the last five years, compared to top 3 choices for changes to home during next five years



Base: respondent who completed self-completion questionnaire (1798).

Taken together, these data suggest a considerable appetite among British households for making renovations to the home – though these data do not explicitly confirm whether these changes were desired by British households – or if they resulted from the wishes of others or problems with existing systems. To explore the question of the factors prompting this considerable degree of activity further, we asked each respondent who identified a change they had made in the last five years in any one of the five substantive areas above, to identify up to three reasons for making that change.

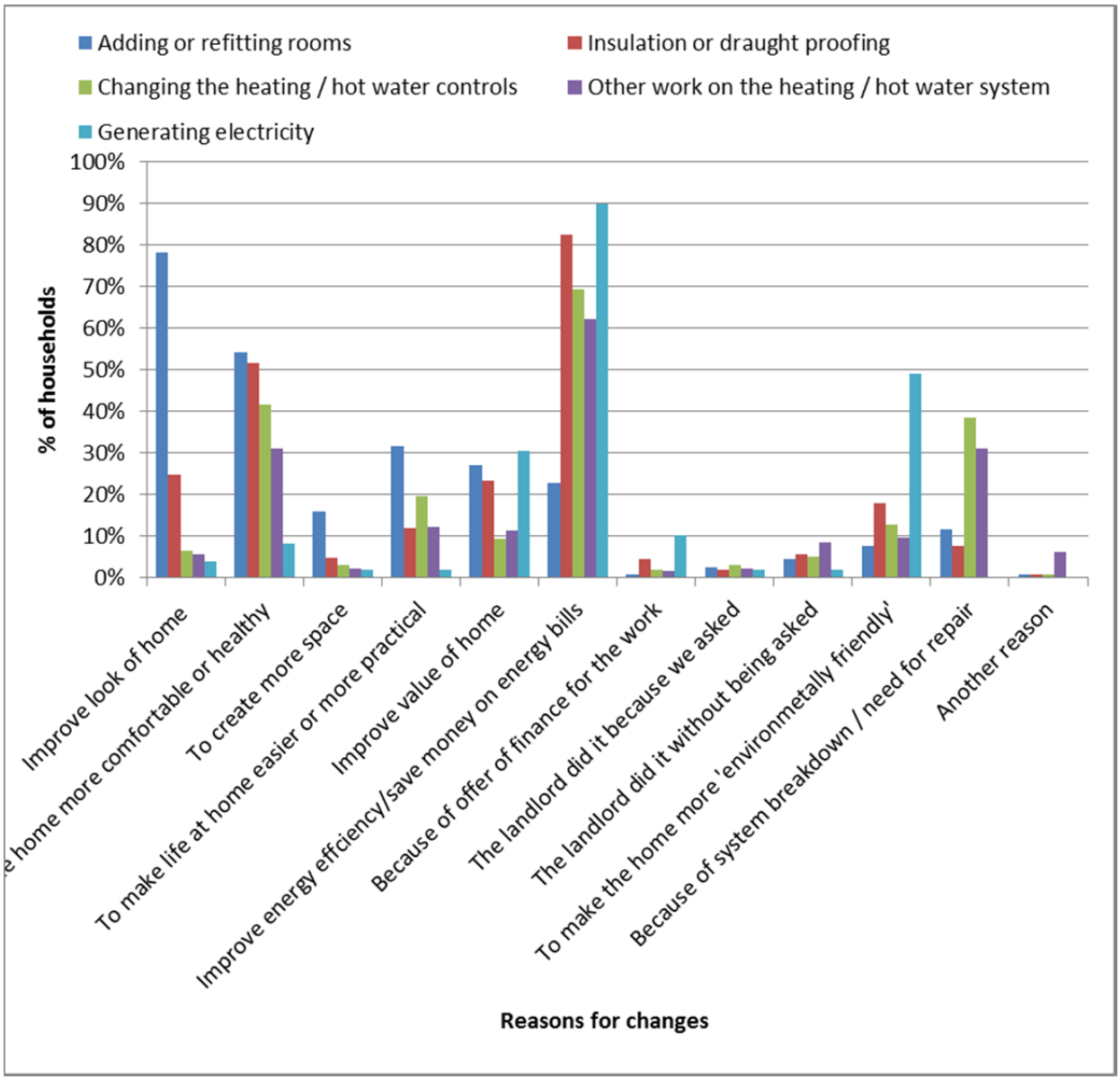
The reasons provided are presented in Figure 6.3, which demonstrates that different sets of motivations prompt activity in the five substantive areas of renovation asked about. Adding or refitting rooms is primarily motivated by a wish to improve the look of the home, identified by almost eight-tenths of respondents who had made changes within this category, with slightly more than half also wanting to make the home more comfortable and healthy.

In contrast, the other areas of renovation asked about are overwhelmingly motivated by a wish to improve energy efficiency and to save money on energy bills; this motivation was cited by 82% of those who had undertaken insulation or draught proofing, 69% of those who had changed the heating or hot water controls, 62% of those who had undertaken other work on the heating or hot water system and 90% of the few who had made renovations in the area of generating electricity. This suggests that heat energy solutions that tap into this motivation might appeal particularly to British households.

Comfort and heath are also cited by between 31% and 54% of respondents in relation to all categories of renovation except “Generating electricity” whereas this last category is the only for which there is substantial relevance of making the home environmentally friendly. System breakdown is relevant to system controls and other aspects of heating and hot water systems.

The other motivations recorded had less influence on British households in their decisions to make renovations to the home. It is particularly notable that the wish to make life at home easier and more practical was cited by around a third of respondents in relation to adding or retrofitting rooms but not cited by more than one-fifth of respondents in relation to any of the areas of activity directly relating to heat energy systems and usage. This can be seen to confirm the finding reported above, in relation to the analysis of the heat energy needs of households with a desire for system change – namely that the wish to change is primarily driven by considerations relating to *Resource*, rather than considerations relating to *Ease*.

Figure 6.4 Top three reasons for undertaking each category of change to the home within the last five years



Base: respondents who completed self-completion questionnaire (1798).

7 Conclusion

Analysis of the Consumer Response and Behaviour survey data has produced a wealth of information that will facilitate a range of aspects of the development and implementation of smart energy solutions. The following sections describe the main findings.

7.1 Heat energy needs

British households have many needs relating to the three heat energy domains investigated in this study (heating the home and keeping warm, cooling the home, and heating water and using hot water). More than two-thirds of households identify five particular heat energy needs as being big factors for them in relation to heating the home: being comfortable, energy costs, avoiding wasting energy, being able to rest and relax, and wanting to feel clean. The least prevalent needs are related more to social factors and household routines. However, even the least prevalent need (doing what they thought most people do) is included by 8% of respondents, showing that none of the needs is irrelevant. The prevalence of individual needs relating to heating water is extremely similar although mostly slightly lower, except that there is – unsurprisingly – greater emphasis on needs related to cleaning.

There is considerable consistency between the number and range of needs they try to meet but needs occur in many and complex patterns in different households. It is of great value, therefore, that it has been possible to define five underlying dimensions of need, common to both heating the home and heating water. For heating the home, these five dimensions relate to individual needs as follows.

Other people

- How you and your home appear to other people
- The needs of visitors
- Wanting to avoid arguments/ disagreements within the home
- Caring for other members of the household
- Wanting to be productive

Comfort

- Being comfortable
- Being able to rest and relax
- Feeling in control

Hygiene

- Keeping healthy
- Wanting to feel clean
- Wanting to keep the home clean
- Keeping the home looking, feeling or smelling nice
- Wanting to feel safe and secure

Resource

- Energy costs
- The value or cost of your home
- Concern for the environment
- Avoiding wasting energy

Ease

- Doing what you think most people do
- Keeping to your everyday routines
- Doing what you have traditionally done
- Doing what is easiest

Both the individual needs and the underlying dimensions can be aligned with findings from qualitative research, supporting the validity of both streams and allowing different perspectives to be taken. These perspectives have been set out in the report on qualitative research and will be followed up in the project synthesis report. The most significant deviations from the qualitative findings are that health and comfort fall into separate dimensions, concern for the environment becomes an aspect of resource rather than "relational dynamics" and the need to be in control is closely associated with comfort rather than "agency". It is also interesting that the need to be productive, rather than being part of "health and well-being", contributes to *Other people* for heating the home (perhaps because productivity depends on supporting each other in the home) and *Comfort* for heating water (because hot water is used to relax and be comfortable).

Using the five dimensions, British households can successfully be divided into seven needs-based segments. Although there is some evidence of segments differing in demographic characteristics, segments cannot easily be characterised by variables relating to people, property, system or process. So, while the

segments can be used to support the design of smart energy solutions, they are less useful for implementation because it will be difficult to assign individual households to a segment using readily available data. Nevertheless, the underlying dimensions provide a potentially powerful means to characterise any population group that can be defined using the survey data, as a guide for development and deployment of smart energy solutions. Examples are provided throughout the report but this approach is sufficiently flexible that it can support deployment at local level.

7.2 Heating the home and keeping warm

7.2.1 What heating systems are present and used in British homes?

Heating systems

As expected, the most common heating system is overwhelmingly central heating with radiators and the most common fuel is mains gas (87% of homes in each case). While over half the sample have some kind of heater fixed in one or more rooms, this is the main form of heating in only 12% of cases. Similarly, a quarter of homes have some kind of portable heater but it is the main heating in only 2% of cases. Electricity or some form of delivered fuel (e.g. oil or solid fuel) are used in 35% and 9% of homes respectively. More informative is the common combinations of heating systems that are used. Over half the homes with central heating also use some other form of heating and, in 3% of all cases, the central heating is not used as the main form of heating.

The type of heating system is related to a range of dwelling and household characteristics that can be used to ascertain what types are popular in the different contexts that smart systems would need to engage with. These characteristics include the age, size and type of dwelling, the sector of tenure, the household income and which of four household types occupy the home (those with children under school age, those with children who have started or completed school, those with no children and all adults in the household aged over 60, and those with no children and at least one adult aged under 60). These effects should not be seen as independent, there being many possible overlaps in what is being measured. The size of home is likely to be a key factor, this being related to the type of household, tenure, income and dwelling type.

Heating controls

On the boiler or other central heating source, about two-thirds include some form of switch for controlling the item itself and/or the temperature of the water. Most households (86%) have a timer/programmer to control the heating, with digital models, combined heating and hot water devices, and devices visible in the room (not in a cupboard) each accounting for about two-thirds of households. Over half have an ‘extra time’ option. There is a room thermostat in the majority (71%) of cases and 6% have more than one. Interviewers were able to observe thermostatic radiator valves (TRVs) in 59% of homes that had central heating with radiators and many of the 41% remaining may have also had TRVs that the interviewers were unable to observe.

Where observations of the presence or absence of timer/programmers, room thermostats and TRVs were all made, almost two-thirds had timer/programmers and both room thermostat(s) and thermostatic radiator valves. Over a quarter had a timer/programmer with either a room thermostat or TRVs. Only a small minority either did not have a timer/programmer or only had a timer/programmer.

Use of rooms in the home

The size of the home and the number of rooms in the home will affect the use of heating and the amount of energy used for heating. It can be estimated from the data that 35% of households may be heating rooms that are rarely used. However, asked directly about selected types of room (day rooms, bedrooms, gym/exercise/games rooms, conservatories and heated outbuildings) respondents regard very few as ‘not used’, and in most homes there are no or very few rooms that are ‘rarely used’.

This suggests that solutions aimed at reducing heating in rarely used or unused rooms may not have a large impact on energy demand. The exception is in the largest homes: as the number of rooms increases, there is increasing divergence between the number of rooms and the number that are in general use. It is also the largest homes where zonal controls would most easily be introduced because they are the most likely to

have existing central heating. Homes with central heating may also be more likely to heat all rooms. The largest homes are almost exclusively owner-occupied. In smaller homes, zonal control is more likely to be attractive as a means of dealing with the different times when each room is used and possibly the different individuals using the rooms and the different activities carried out, rather than managing unused rooms.

7.3 What do people do to keep warm?

Common strategies

Households use a wide range of methods to keep warm at home on a typical winter's day – a mean of 5.2 – and each method could itself encompass considerable diversity. There is also considerable diversity in the additional methods to keep warm that respondents report using if the usual methods are not sufficient (a mean of 2.7 per household).

Unsurprisingly, the main heating is used in most cases, with around one in five using some other form of heating instead of, or in addition to, the main heating. Around two-thirds close external windows and doors but under half manage heat loss by closing curtains, blinds or internal doors. Only 19% use the alternative of not heating all rooms but 14% do combine this with closing internal doors. Insulating the person is a common strategy with wearing warm clothes the most frequently reported approach (62%), followed by using warm bedding in bed (45%) and – perhaps most interesting – using bedding when not in bed (31%). Directly warming the person is reported less often than other strategies but more often than might have been expected, and with a range of specific approaches: using warm food or drink (45%); using a hot water bottle (23%) or something else warm to hold (3%); or having a bath or shower to warm up (15%).

Additional methods are used to keep warm when the usual methods are insufficient: only 21% say they do not need to do anything extra because the usual methods of keeping warm are always enough. A further 2% say they are always doing all they can, without this necessarily always being enough. The most common approach is to have the main heating on for more time and/or turn up the thermostat but all the usual strategies are repeated among the additional strategies, and with greater diversity. While 2% heat more rooms, 5% heat fewer rooms. This appears to signal a difference between advance (heat rooms when they need heating) and retreat (heat as many rooms as can be afforded but perhaps maintain comfort in the rooms that are still heated). In 3% of cases, the respondent reports going somewhere warmer, away from the home, rather than trying to keep warm at home.

To facilitate further analysis, the methods of keeping warm were further categorised, as: using the *main heating; u*sing *other heating*; c*ontrolling* where heat goes (keep windows & external doors closed, shut doors between rooms, not heat all rooms, heat all rooms, close curtains or blinds); r*etaining one's* own warmth (wear warm clothes, use warm bedding in bed or when not in bed) and heating the *person* (warm food or drink to keep warm, bath or shower to warm up, use hot water bottle, use something else warm to hold, use electric blanket or bed warmer).

Many combinations of these methods are used. In around four-fifths of cases, one form of heating is being used, but in most cases with some supplementary method. A further one in seven use two forms of heating, again with some supplementary method or just one form of heating and no supplementary method. The most frequently reported approach (over half the sample) is one form of heating, controlling where the heat goes plus insulating and/or heating the person. More surprising is that 5% are not using any heating.

In contrast to the usual methods, approaches other than room heating dominate the additional methods used to keep warm when the usual methods are insufficient: those using non-heating methods or doing nothing extra account for just over half the respondents. Of course, the available additional methods will depend on what is usually already being done. However, the type of additional method varies little with the usual means: whatever the household is usually doing to keep warm in winter, when they need to do something additional, it is as likely to be more of the same as it is to be something different.

Do these actions always keep people warm enough?

While 72% of respondents report that what they do on a typical winter's day always keeps the warm enough, 23% report that it only 'sometimes' does, a further 4% said 'rarely' or 'never'. Those who do not say 'Always enough' may be expected to show more interest in improving their heating. A range of factors were found to

be related to this response, which can in turn be used in identifying avenues for deployment of smart systems: the methods currently being used to keep warm, including the particular heating types being used, the age and size of the dwelling, tenure, household income and household type.

Of those households who always feel warm enough in winter, a large majority sometimes overheat in winter whereas, for those who do not always feel warm enough in winter, similar numbers do and do not overheat in winter. This suggests some kind of conflict between ability to keep warm and ability to avoid overheating in winter. The cause might be related to the fabric of the building or to the heating systems and controls.

Variation with time of year and time of day

From November to February, almost all respondents are using the heating. More surprisingly, 8% are still using the heating for at least part of July and August (these are more likely to be older households and those where someone has a disability affecting "how warm or cool they keep the home or the amount of hot water they require". The increase in percentage using heating between August and November is slightly steeper than the decline from February to July. This perhaps arises from people being more aware of getting cold at some point during autumn than they are of the opportunity to be warm without the heating on as spring progresses. This may indicate an opportunity to reduce heating energy demand by using feedback that signals to the household that the home would be warm enough without having the heating on.

Out of the whole sample, 20% of respondents reported that, during the months when they use their heating, the heating is on at all times, including overnight and when there is nobody at home. The majority of this group of respondents (60%) report that they do this because they would be too cold otherwise, while 35% give convenience as their motivation, and 27% base this behaviour on the belief that having the heating on all the time will cost less or will use less energy. The peak heating periods are early morning and early evening but a quarter of homes are also heated at night.

Weekdays and weekends follow a generally similar pattern and this is likely to arise from some combination of the need for heating being similar and households not varying the timer settings. Where there is a difference, heating is more likely to be in use during the day at weekends. The overall pattern is very similar across the four household types, but with greater levels of daytime heating among households made up entirely of those aged over 60 and households with pre-school children. There are relatively few instances when there is regularly nobody in the home but the heating is on (a maximum of 2% of households report such occasions). The proportion of times when there is sometimes someone in (or when it is too variable to say) but the heating is turned on is also relatively small, rising to a maximum of 11% in late afternoon. This identifies variability of occupancy as a potential key factor in the heating being on when nobody is at home.

Those with district heating have less pronounced differences across times of day, including much higher levels of overnight heating. Dissatisfaction with the lack of control over district heating (as revealed in the literature review and qualitative research for this project) may stem from district heating systems not providing the normally employed pattern of heating.

Control of heating

Overall, 62% of respondents control temperature room-by-room (including by including by opening or closing windows or doors) and 26% also use central control, whereas 27% use only central control. This leaves 10% who report that they do not control the temperature. Of these, 73% saw no need to change the temperature, 22% did not believe they had the means to control it and 6% believed it would increase energy use. Respondents also describe controlling the timing of the heating manually (28%), using timing/programming controls (31%), both (18%) or neither (1%).

To facilitate further analysis, control strategies were categorised according to whether temperature and timing are each controlled manually, by thermostat or timer ("set and forget"), a combination of the two ("active control") or not controlled. The categorisation simplifies an otherwise highly complex range of strategies and allows the strategies to be related to the type of heating system in particular. The effect of heating type sets a background against which any effects of household demographics need to be seen, effectively constraining the possibilities. Hence, there is relatively little variation among the four household types. This finding also indicated that control strategies should not be seen as an inherent characteristic of persons or households, but variable according to the heating system provided or chosen.

Circumstances when households change what they do

The circumstances under which households change something about how they heat the home are varied. The reason most frequently given was it being cold outside, followed by variations in the householders themselves or visitors being at home. It makes little difference whether the visitors are during the day or overnight: adjusting for those who do not have visitors in the way described, over half of respondents would do nothing different; around one in five would heat for more hours and/or turn up the temperature. In contrast, if there is a visitor who has a particular need to keep warm (e.g. babies, the elderly or those who feel the cold), around three-quarters would do something different. Only 64% reported changing something when they are away from home, which suggests significant potential for reducing energy demand.

7.3.1 The use of heating and dimensions of heating needs

The profiles of the five needs dimensions are similar for homes with central heating with and without other methods of heating and similar to the typical national profile. Respondents with district heating place the least emphasis on *Resource*, and low emphasis on *Other people* and *Comfort*, perhaps reflecting that heat tends to be available all the time through a system that they have little control over. Those with portable heating also place little emphasis on *Comfort*, despite people with portable heating being the least likely to report that they usually feel warm enough. Those using fixed heating place little emphasis on *Other people*, whereas the opposite is true of those using portable heating.

Examining the dimensions of heating need for the combinations of methods people usually adopt to keep warm, the dimension with the highest level of emphasis in any group is *Resource*, which is particularly important to those using the widest range of methods to keep warm, who also place a slightly lesser emphasis on *Comfort*. The groups with the least diversity of methods tend to emphasise *Ease* and they also emphasise *Comfort* the least of all of the groups, particularly those who do not use any form of heating.

The profiles of needs dimensions also vary with the strategies used to control the heating. Those who control both the temperature and the timing of their heating manually do not emphasise *Comfort* highly at all, while those who control both the temperature and the timing using a combination of manual and 'set and forget' controls emphasise *Comfort* the most out of all of the dimensions but place less emphasis on *Ease*. Those who do not control temperature at all and those who have their heating on all the time place the least emphasis on *Resource* but tend to emphasise *Ease*. The two most common types of control strategy adopted (set and forget temperature, with timing either set and forget active) present the smallest range of values of dimensions, but tend to emphasise *Resource* slightly over other dimensions.

7.4 Keeping cool

7.4.1 Avoiding overheating in winter

Households' strategies to stay cool can be conceptualised at a range of levels. At the highest level, there are two groups: households that keep cool enough by what they usually do (37%) and those that sometimes do one or more things extra in order not to overheat in winter (63%). While the first group do not need to do anything specifically to avoid overheating, this does not mean that they are doing nothing. It is just that whatever they do normally (to heat the home or for other reasons) is sufficient to not overheat. Conversely, households that need to do something specific to avoid overheating should not be interpreted as though they actually get too warm – they should mostly succeed in avoiding overheating in winter through the strategies they adopt. However, the fact that 63% of households need to do something specific to avoid overheating even in winter indicates potential for improved control of heating systems with the dual aim of improving comfort and reducing energy demand, through eliminating overheating.

The actions that households take can be targeted either at the indoor environment or at the self. Those targeted at the environment involve strategies to control/limit heat gain (turning the heating down/off or creating shade) or remove heat (e.g. increasing natural ventilation by opening windows or doors, or using mechanical ventilation or cooling systems). Those targeted at the self involve measures of insulation (e.g. changing clothing or using lighter bedding), cooling the body (e.g. from inside through a drink or outside through a fan or shower) or a change of location, either within the home or by leaving the home. The main combinations of methods that households use to avoid overheating in winter involve turning the heating

down or off in four-fifths of cases, most often in a combination involving natural ventilation. This leaves one in five who do something else in preference to turning the heating down or off (again, most often in a combination involving natural ventilation). Less than 1% of households use air conditioning (including use of heat pumps for cooling).

Strategies to avoid overheating in winter vary by both household and property characteristics. A dominant effect appears to be that of age: while 40% of households with all members over 60 stated that it would not get too warm in winter, this was the case for only 28% of households with children under school age, 35% for households with children in or having completed school and 37% for households with no children and at least one adult under 60. Consequently, younger households are more likely to engage in strategies to keep cool, such as turning the heating down or off, or opening windows during the day to keep cool. Effects of age may arise because of age (directly (e.g. some kind of physiological change), a cohort effect (i.e. the current generation of older people has had particular life experiences that would not necessarily be repeated in another generation) or simply because older people have been longer in their current home and therefore understand better how to keep cool there.

A need to do something to avoid overheating in winter is also more prevalent in households that are larger (until the number gets to five or more), owner-occupiers or have higher incomes, and in homes that are newer or have double, triple or secondary glazing, or that have central heating or (especially) district heating.

7.4.2 Keeping cool in summer

What households usually do to keep cool in summer

As with overheating in winter, households' strategies to stay cool in summer can be conceptualised at a range of levels of description, from detailed individual strategies to more abstract groupings. In contrast with winter, only 9% of households stated that it would not get too warm on a typical summer day. The combinations of things that households do to keep cool in summer often appear not to include reducing heat input, but in most cases this is because the heating is not used in summer. Taking this into account, it is clear that strategies are dominated by natural ventilation – used alone in 61% of households and with other methods in 32%. Over half of the sample use light clothing or bedding, or cool the body directly, e.g. with cold drinks or a fan. About one-third circulate air within the building or change location and a quarter use shading. By far the least prevalent strategies are mechanical ventilation (4%) and mechanical cooling (2%).

In general then, the home itself is used to keep cool, rather than mechanical systems. The focus is on ventilation and air movement. Fewer use shading, and the shading is in the most effective location (on the outside of the windows in only 4% of the sample. External shading can be very effective and there is clearly potential for greater application in Britain, perhaps supported by smart control systems.

The factors that affect whether something needs to be done to keep cool in summer are similar to those that affect the need to do something to avoid overheating in winter. Having no need to do anything in summer is more prevalent in older households and older homes, the smallest and largest households, homes in the social rental sector, and households with lower incomes. However, of those who do need to do something to keep cool, the majority (70%) say that it always keeps them cool enough on a typical summer day and 28% say that it sometimes does so. Only 2% say it rarely or never keeps them cool enough. Overall then, 73% always keep cool enough. By this measure, there are no clear trends by household size, income or age of property but keeping cool in summer is a greater issue for households aged under 60, with no children; households occupying flats rather than houses or bungalows; and renters.

Those who say it would not get too warm in summer are less likely to express most heat energy needs – unsurprising as this indicates that their needs are met, with the exception of *Ease*. However there is little difference between those who always keep cool enough and those who only sometimes do so.

Using windows

As opening windows and doors is a key strategy for cooling homes, respondents were specifically asked for reasons why they sometimes open windows. Almost all households open windows for some reason and they do so mainly for fresh air (85%) and to keep cool (79%), while 44% of households open windows to let out smoke or smells and 38% to sleep better or to avoid condensation. Unsurprisingly, those households that sometimes get too warm in summer are more likely to open windows than those who do not (85% vs 50%).

Generally, households where all members are over 60, and those in the lowest income quartile, are less likely than other types of household to open windows for most of the reasons offered. Owner-occupiers are more likely to open windows to stay cool or to sleep better than those who rent. There are no clear trends by age or type of property except that those in a flat/maisonette are less likely to open windows in order to sleep better (28%) as compared to those in a Bungalow (33%) or house (42%).

Respondents were also asked whether there were times when they would like to open windows to keep cool but did not do so for a range of reasons. Only 32% of respondents said that this never happens. Concerns about security are the most common barrier and have influenced about one-third of respondents, followed by noise (24%) and other reasons to do with conditions outdoors, e.g. smoke, odours, wind, rain (18%). The older households and those with higher incomes are slightly *more* likely to indicate they never face any barriers to opening windows, so this may explain why they have fewer issues with cooling in general. Safety is of greater concern to households with young children. Noise is of greater concern to those living in a flat whereas security is of greater concern to those in a bungalow. If such barriers could be addressed through smart design, this could be a cost-effective means to address cooling issues.

Which additional strategies do households use to keep cool in summer?

More than half of households use a wide range of additional strategies when their usual methods of keeping cool are not enough (for example on particularly hot days). On average they do 2.4 extra things but there is no overriding strategy: the most prevalent is opening windows during the day (21%). A familiar demographic pattern is seen here, with the percentage who do not use any additional strategies being a little higher among older households and social renters although is no clear overall trend and relatively little variation with dwelling type, age of property or household income.

Circumstances in which households do more to keep cool in summer

Generally, besides the obvious situation when the weather is particularly hot, the main driver for households to change what they do to keep cool is when someone at home is unwell (which prompts change in one-sixth of households), especially if there are children in the household. All other options, such as when there are visitors, are chosen by less than 10% of households. In addition, 23% change their behaviour in none of the listed circumstances.

Older household are least likely to change what they do and, unsurprisingly, households with children who have started or completed school are most affected by school holiday with 22% of them doing something different during school holidays. There is no large variation by income, but those in highest income quartile are much more likely to change their behaviour when someone is working from home (18% as compared to 6% in lowest quartile), which likely reflects that people in this quartile are generally more likely to work from home. There is no overall trend or large variation by dwelling type, age of property or tenure.

7.5 Heating water and using hot water

7.5.1 Hot water systems

Across the whole sample, 54% of households had a combi boiler, 34% a standard boiler with a storage tank/cylinder and 15% an immersion heater. Less prevalent systems included 2% of households with district heating, 1% with instant hot water taps and 1% with solar thermal water heating. Most households have a single system available to heat water. Since 86% identified either combi boilers or standard boilers as their main system for heating water, the remaining analysis focuses on these two systems. In comparing the two types of boiler, it should be kept in mind that the combi boilers may be more recent installations. One consequence of this could be a greater likelihood that they were installed by the current household, who therefore could have more awareness of how to operate them.

In properties built up to 1980, combi boilers are the most prevalent system, whereas standard boilers are more prevalent in later homes. This suggests that older properties have replaced previous systems with newer systems, while properties built most recently still have the systems that were initially in the property when they were built. Standard boilers are also more prevalent in homes built after 1981, in larger homes, and in houses and bungalows. Flats and the smallest homes are the least likely to have a boiler at all.

Households with children are more likely than those without children to have a combi boiler, while older households are more likely to have a standard boiler. Possibly related to this, households of more three people are more likely to have a combi boiler whereas standard boilers are least prevalent in single-person households. Standard boilers are most prevalent among owner-occupier and least among the social renters, with private renters being intermediate. The prevalence of combi boilers follows the opposite pattern but with much less variation. The prevalence of combi boilers varies little between income quartiles, except that it is lowest in the highest quartile, whereas the prevalence of standard boilers increases with income.

The overall pattern of variation with dwelling and household characteristics can be accounted for by a combination of factors. Combi boilers need less space and provide better for households that are unpredictable as to when someone will be at home or need hot water. Standard boilers can more easily service multiple hot water outlets and maintain a satisfactory flow rate. While standard boilers may be more suitable for larger homes but combi boilers for larger households: a clear conflict in choice of system.

7.5.2 Control of hot water

Households whose main system is a combi boiler or instant hot water tap are assumed to have hot water on demand. Of the remaining households, 30% say that hot water is available all the time, 50% that it is available at times when they set the controls for it, 16% that they use controls to set when the hot water is available and 13% said that they use boost buttons to increase the time their hot water is on. Of the respondents who say that they have hot water at times when they have set the controls for it, the majority never change the controls. How respondents use their controls can be categorised into three different types of control: “On demand” (54% of households), “Available all the time” (14%) and “Controlled” (32%).

Asked how they control the temperature of the water (from the hot taps), 33% of respondents said that the hot water was set up once and they have left it like that, 22% said that they change the temperature directly on their boiler (but few ever change this), 21% that they are not able to control the temperature of their hot water and 16% that they are able to control their hot water, but do not do this. The majority of respondents either do not use their temperature controls or, having set them up once, do not use them afterwards. Based on these responses, we can categorise households into three temperature control types: “Set and forget” (48%), “Active control” (26%) and “No control” (22%).

The findings indicate that, for the majority of respondents, their hot water system operates in the background of their everyday lives, either because they have hot water on demand or available all of the time, or, when looked at by how they control temperature, because they have set and forgotten about it, or because they have no control over how their temperature is set. There is, however a substantial minority, actively engage with their system although the frequency with which they engage with their system can vary.

Households with a combi boiler were categorised as “On demand” and so the variation in the two other control types was mainly due to homes with standard boilers: 72% of households with standard boilers were categorised as “Controlled”. Regarding temperature control, around half of households with either type of boiler are “Set and forget”, whereas those with a combi boiler are more likely to be “Active control” and less likely to be “No control”. Focusing on “Controlled” timing and “Active control” f temperature, these types were both more prevalent among owner-occupiers, households with higher income, and households without children – especially those without school-age children. These findings most likely relate to a combination of having access controlling differently with the controls they have.

Comparing the timing control types by the distribution of needs dimensions, those categorised as “On demand” place more emphasis on *Hygiene* but with little overall variation between dimensions. Those classified as “Controlled” place less emphasis on *Hygiene*, and more emphasis on *Resource* and *Comfort*, but again with little overall variation. The strongest effect is that the “Available all the time” households emphasise *Ease* and are less concerned about *Resource*.

The “Set and forget” temperature households place more emphasis on *Hygiene*, *Ease* and *Comfort*, and less emphasis on *Other people*, but with little overall variation. Those classified as “Active control” put more emphasis on *Resource*, *Other people* and *Comfort* than on *Hygiene* and *Ease*. The “No control” households place little emphasis on *Resource* and *Comfort*; this emphasis may have resulted in this group not seeking out means to control the temperature, or the emphasis could be as a result of the system they have or resignation to the situation they find themselves in.

7.5.3 Using hot water

All uses

The ways in which households use hot water are many but relatively predictable; the most common are for washing themselves, clothes or dishes, cleaning the home, and cooking (or making hot drinks). While most homes use a washing machine for laundry, hand-washing is more prevalent for dishes. Less common uses are washing vehicles, washing pets, and brushing teeth with hot water. Factor analysis of these various uses revealed these five factors, which can be used to characterise households to describe their water use.

Factor 1: Use a washing machine, make drinks or prepare food, and clean the home.

Factor 2: Wash the dishes by hand versus wash dishes using a dishwasher.

Factor 3: Have baths versus have showers.

Factor 4: Wash a vehicle and wash pets with hot water.

Factor 5: Brush teeth with hot water, hand wash clothes and wash hands, face or feet.

Using hot water for baths and showers

Households use showers more often than baths in both winter and summer, and more baths and showers in summer than in winter. In a winter week, the mean number of showers per household is 18 and the mean number of baths is 15 (5 and 2 per person, respectively). In a summer week, the mean number of showers per household is 26 and the mean number of baths is 20 (6 and 2 per person, respectively). Households are more likely to use showers in the morning (or both the morning and the evening) and baths in the evening.

Households without children are more likely to have showers in the morning than households with children, while households with children are more likely to have baths in the evening. The percentage of households that have showers in the morning decreases with increasing household size, whereas the percentage that have showers in the evening varies little and the percentage having showers both morning and evening increases with household size. There is a similar pattern for baths. This most likely arises because there is a more limited amount of time in the morning for everyone to wash.

Using hot water away from the home

The majority (65%) of households say they never use hot water away from home (other than when away for a night or more). However, 21% say that they use showers elsewhere and 6% that they use baths. The reasons most often given are to get clean after activities (61% for showers, 37% for baths) and because it is more convenient (32% for showers, 29% for baths). Only 5% of those who use showers away from home and 6% of those who use baths said that they do it to save money, and even fewer to save energy.

Only 3% report washing clothes away from home but methods of drying clothes are more interesting from a heat energy perspective. Households tend to have at least two ways of drying their clothes and 67% say that they dry their clothes outdoors, 46% in a tumble drier, 38% using radiators and 37% that they dry their clothes somewhere else around their home. This has implications for heating the home (with a requirement for both warmth and good ventilation) and the particular means of heating the home (with a requirement for localised heat sources such as radiators). Flexibility around heating the home might be increased by providing secure, covered outdoor drying areas.

When households increase or decrease hours of heating water

Presented with scenarios in which they might increase the hours they have hot water on, 60% of respondents without “On demand” hot water say “None of these”. This reinforces the suggestion that hot water systems tend to operate in the background of people’s lives. However, some households do increase the hours they have their hot water on in specific scenarios, principally if there are visitors overnight or for longer and, to a lesser extent, if they have visitors during the day.

All households were asked whether there were circumstances in which they would decrease the hours hot water is heated. The majority (70%) say “None of these” but 24% say that they would do so when they go away for a long period of time and 13% when they go away for a night. Households with children are less likely either to increase or to decrease hours of water availability.

7.6 Heat energy solutions

7.6.1 Demand for greater control

Future solutions for heating the home, cooling and heating water

Respondents were asked about specific aspects of their current situation that they might like to change, specifically in relation to the household's ability to control heating, cooling or hot water. These stated desires give an indication of the acceptability of aspects of potential future heat energy solutions.

Just over one-third of respondents (35%) did not want to have more control over any aspect of heating their home, with around one in ten (9%) indicating that it would, in fact, be better to have more automation. This leaves just over half who did want a change in one or more of the ways asked about. There is no single over-arching aspect that respondents would like to change, 23% of respondents selecting the most popular options (the temperature in each room and being able to heat rooms more quickly). The next most popular was being able to control the heating system remotely from outside of the home (19%), or from any from any room in the home (16%), followed by times when heating comes on and off (13%), the rooms that are heated at any given time (12%), being able to deal with situations when I/we unexpectedly need to heat the home (9%) and knowing when someone else changes a heating control (4%).

Despite the general absence of technologies for cooling the home, there is less demand for more control, compared to heating the home. Almost half of respondents (47%) indicated they did not want greater control over any aspect of cooling, compared to the 35% in relation to heating the home. There was a comparable level of demand for more automation (9% of respondents in relation to both heating and cooling). The most popular options (although selected by fewer than one-fifth of respondents) were being able to cool the home more quickly, avoiding over-heating during heat waves and being able to cool particular parts of the home. Only slightly more than one in ten would like more control to make the home cooler than is currently possible or to be able to control the cooling from any room in the home. Least popular were being able to deal with unexpected situations when there was a need for cooling; and being able to control the cooling remotely.

There was an even lower level of demand for increased control over heating water. More than half of respondents (55%) did not want greater control over any aspect of heating water in the home, while 7% favoured a greater degree of automation. The most popular area for greater control was around how quickly the water heats up, favoured by almost one in five. Around one in ten wanted more control over the temperature the water is heated to, the amount of hot water that is available, when the hot water comes on and off and being able to deal with unexpected situations where hot water is required. Fewer than one in 20 respondents would like to be able to control the temperature of the water remotely or from any room in the home or to know when someone else had changed the temperature of the hot water.

These desired changes related to hot water can be related back to problems that people currently have. Presented with a series of statements of different challenges they might face when using hot water, 17% of households say that they have to run their tap for a long time to heat the water, 16% that they have more hot water than they need, 15% that they do not have enough hot water, 9% that their hot water is at a low pressure, 9% that their water is not hot enough and 5% that the water is too hot.

Who would like more control over heating the home, cooling and heating water?

Overall, a sizable proportion of the British public do not favour having greater control although there is a greater appetite in relation to heating and cooling the home, compared to heating water. In relation to each domain, the most commonly favoured changes involve the amount or extent of heating, hot water or cooling required or the speed at which the process of heating the home, heating water or cooling should occur. There is less support for the concept of remote control (either from within or outside of the home) or feedback on others' involvement with the heat energy systems. Nevertheless, there does exist a desire for change in some households. It is, therefore, of interest to understand which households are most interested in change, accepting that other households might also respond positively to specific propositions.

The data allow the overall desire for change, and the desire for specific changes, to be related to a wide range of household and dwelling characteristics, in a way that could be applied to specific local populations or to Britain as a whole. The specific characteristics and aspects of control have a complex set of

interrelationships that will have greatest meaning in specific applications of the data, rather than in the abstract in this report. However, the overall *absence* of desire for change in heating control is:

- greatest among those who are always warm enough on a typical winter day (and this group is particularly more likely to want better control over the temperature in each room and being able to heat rooms more quickly).;
- greatest among households with no children and all adults aged over 60;
- greatest in single-person households, reduced in two-person households and levelling out at three persons;
- greatest in households in the lowest income quartile, decreasing a little in the middle quartiles and decreasing markedly in the top quartile;
- greatest in homes with district heating, only slightly less in homes that rely on central heating only, or central heating plus fixed heaters, and least in homes that rely on portable heaters;
- greatest among households that have the heating on all the time with a "set and forget" approach to temperature control, and least among homes that use manual control of timing and temperature (with or without some use of controls);
- relatively little affected by property characteristics.

In relation to specific aspects of cooling the home and heating water, we found that:

- household type again makes a difference, households with children being the most likely to want additional forms of control and the oldest households being the least likely to do so;
- support for increased control rises with household size;
- those in the highest income quartile being more likely to favour additional forms of control;
- there was no clear trend by age of property or type of property.

The few households already using air conditioning, mechanical ventilation or heat pumps are more likely to favour a greater degree of control in the future. This could mean that these households have cooling systems because they have a high demand for control, or they have come to appreciate cooling systems and therefore want more from them. There was no clear trend by tenure. For heating water, those with a private landlord were more likely to want additional control than owner occupiers. Using a combi boiler was associated with a lesser appetite for increased control over heating water, compared with using a standard boiler or immersion heater.

Clearly then, the demand for greater control of systems for heating the home, cooling and heating water is mediated by the types of systems households already have in place to do this and how they interact with them, as well as the make-up of households. The characteristics of the property, however, appear to make little difference. One implication of this is that the desire for greater control is not easily predictable from area-level property statistics: individual households need to be characterised.

Maintenance preferences

Respondents were asked to state, if the long-term costs (over many years) were similar, whether they would prefer their heating system to be serviced, maintained and repaired for a fixed annual fee, or to be responsible themselves for arranging the servicing, maintenance and repair of the heating system as and when it is needed. The majority (60%) expressed a preference for paying a fixed annual fee and this percentage was higher among households with pre-school children and social tenants. Generally, however, preferences did not seem to be related to characteristics of the household or the respondent's role in managing energy accounts or the use of energy in the home.

Homes with central heating (in any combination with other types of heating) result in responses of 61-63% in favour of a fixed annual fee, this rises to 74% for those with district heating but drops among those relying on individual heaters (to 39% for portable heaters and 44% for fixed heaters. Overall, choices appear to be influenced heavily by the current heating arrangements.

7.6.2 Do heat energy needs link to demand for new solutions?

Those who desire improved control are less likely to emphasise *Ease* (and sometimes *Comfort*) than the population as a whole, whereas those who did not want any more control – or who would conversely prefer more automation – are clearly differentiated by their emphasis on *Ease*. In fact, this finding perhaps reflects a perception that greater control will make things more complicated.

The need consistently expressed more strongly by those favouring more control over particular aspects of their heating systems is *Resource*. This may be because part of the desire for control is to avoid waste and to reduce energy costs. The dimension of *Resource* is most important to the subsample who would like extra control to know when someone else has changed the heating controls.

7.6.3 Heat energy solutions and renovation of the home

Respondents were asked what changes the household (or their landlord or freeholder) had made to the home in the past five years, the main reasons for these changes, and what the renovation priorities for the future would be. It may be that the most successful approach to future heat energy solutions would be to integrate them into existing household renovation. The questions therefore included a range of options that were not specific to heat energy. Many types of changes had been made to homes in the last five years, with the following general patterns.

- More than nine-tenths of households had made a change involving adding or re-fitting rooms. By far the most popular activity in this category is painting or re-decorating (75% of households).
- Three-quarters of respondents report work on the heating or hot water system – most commonly servicing a boiler or air heater unit (37%) or replacing a boiler (28%).
- Six-tenths of households had made changes to the heating or hot water controls: 22% reported installing new TRVs, while slightly fewer had replaced or installed a central heating thermostat (19%) or a timer / programmer for the central heating or hot water (18%). A similar proportion had undertaken insulation or draught-proofing, most commonly putting in loft insulation or extra loft insulation (31%).
- Less than one-tenth had made any changes to generate electricity, most commonly using solar photovoltaic panels.

Respondents' choices about where they would like to make changes over the next five years broadly reflected the prevalence of work undertaken over the previous five years, but at around half the prevalence in each case. Generating electricity was the only exception to this: there was a much higher demand for undertaking changes than was evidenced by the proportion who had actually done this in the recent past.

The reasons that respondents give for the changes made vary with the type of change. Adding or refitting rooms is motivated primarily by a wish to improve the look of the home. In contrast, the other areas of renovation are overwhelmingly motivated by a wish to improve energy efficiency and to save money. Comfort and heath are also frequently cited in relation to all types of change except "Generating electricity" whereas this last category is the only for which there is substantial mention of making the home environmentally friendly. System breakdown is relevant to changes to heating and hot water systems and controls.

The other motivations recorded had less influence on decisions to make renovations to the home. It is particularly notable that the wish to make life at home easier and more practical was cited by around a third of respondents in relation to adding or retrofitting rooms but not cited by more than one-fifth in relation to any of the areas directly relating to heat energy systems. This can be seen to confirm the finding reported above, in relation to heat energy needs of households with a desire for improved control, that the desire to change is primarily driven by considerations relating to *Resource*, rather than considerations relating to *Ease*.

8 Technical Appendix

8.1 Sampling

The WP5.7 quantitative survey employed a quota-based sampling approach. Quota-based sampling involves issuing interviewers with a set of quota characteristics (e.g. tenure) and a corresponding number of interviews to be achieved in each category of each characteristic (e.g. owner-occupiers and renters). Its aim is to achieve a representative sample by reflecting the demographic make-up of the areas interviewed in.

250 sample points were selected at random covering England, Scotland and Wales, with interviewers being asked to achieve 10 interviews in each. Sample points were based on groupings of Census Output Areas, derived from the 2011 Census, and contained an average of 300 addresses. When selecting Census Output Areas, we stratified the population of COAs by Government Office Region (GOR) and a measure of socio-economic characteristics at the household level – namely approximate social grade of Household Reference person (% Grade A or B). In using stratifiers, we arranged all sample units by the first stratifier then, within these categories, by the second stratifier. We then select the Nth sample unit (depending on the number of units overall and the number of areas we want to select e.g. 250 in this instance). We selected sampling units proportionate to the numbers of households within each Government Region (as this is primarily a survey of households).

Within each selected sampling unit, we issued the interviewer with a set quota to achieve 10 interviews. The quotas reflected sampling unit-level characteristics, determined using Census data (for instance, if, in a given sampling unit, 40% of addresses are owner-occupied, we issued a tenure-based quote of: 4 owner-occupied addresses; 6 rented addresses. In terms of specific quotas, used the following:

- Quota 1: Tenure (owner-occupied V rented);
- Quota 2: Presence of dependent children (any dependent children V no dependent children);
- Quota 3: Type of property (house V flat).

These quotas were selected as findings from other Work Packages have shown them to be closely linked to heat energy needs and behaviours.

The sample was based upon household, rather than individual characteristics – as the primary aim was to collect data from individual respondents, relating to their household's heat energy needs, behaviours and systems. There was no respondent selection and interviewers were asked to interview anyone aged over 18 living at the address. To ensure that both main decision makers (in relation to energy) and others were included in the sample, we stressed to interviewers that potential respondents should be reassured that we wanted to hear from individuals with a range of involvement in and knowledge of heat energy use within the household.

8.2 Questionnaire design

The questionnaire design process was iterative in nature and involved extensive collaboration between the research team, other parts of the consortium and the Energy Technologies Institute. This was particularly necessary as the survey was seeking to quantify certain needs, behaviours and attitudes to solutions uncovered or highlighted by other strands of the programme. In addition, the qualitative research undertaken under WP5.4 provided considerable learning in terms of the terminology used by the public to discuss heat energy needs and behaviours, which was taken on board in the design of quantitative survey questions.

The full questionnaire was tested in a pilot (September 2013) and certain elements (especially those aspects relating to the measurement of heat energy needs) were subject to cognitive testing in October 2013.

8.2.1 Dress rehearsal pilot

A questionnaire pilot of a full draft of the questionnaire was undertaken using a PAPI (paper-based) approach. Pilot fieldwork lasted three weeks and involved five interviewers, who were asked to achieve 10 interviews each, using the sampling approach, procedures and doorstep materials being developed for the

main-stage survey. The aims of the pilot were to: test the feasibility of the sampling approach and procedures being proposed for the main-stage survey; ascertain what guidance and documentation would be most helpful to interviewers to assist them in implementing the sampling approach, explaining the purpose of the study and securing agreement on the doorstep; collect accurate data on the length of the current version of the questionnaire, and its component parts; test individual questions – to determine whether they are understood and can be answered effectively by all sections of the public, and whether they yielded data that will enable us to explore the issues being addressed by this project

The key findings, recommendations and implemented changes from the paper pilot in relation to the sample, selling the survey and the questionnaire were as follows.

- Interviewers felt that a longer fieldwork period would be helpful for them – not just to maximise the chance of achieving all quotas but to enable them to work on their sample points in 'batches' (which would make the process more effective). This was reflected in the revised timetable, which included a five week fieldwork period starting in January.
- It was suggested that interviewers receive a 'play pack' for using with families with children. This could include colouring books, puzzles, games for younger children and could help busy families take part in the survey. NatCen uses a similar strategy on other surveys, such as the National Travel Survey and took on board the learning developed there by providing play packs.
- One interviewer found that by being clear with potential participants early on about the quota could help secure later appointments (e.g. potential respondents understood the rationale for their involvement). This was reflected this in the documents and guidance developed for interviewers in the main-stage.
- Given the difficulties experienced by interviewers in obtaining the final two interviews (in line with the three quotas) we developed guidance for interviewers on procedures to follow in these situations (and which quotas to prioritise). These was to be considered across the board and resulted for instance in special guidance on how to deal with this situation provided in briefings and project instructions.
- Interviewers' feedback helped develop an updated version of the leaflet and the postcard and led to the development of an advance letter which was be dropped by interviewers were they felt this was necessary.
- Given that similar issues in relation to heating the person and the home, heating water and cooling and ventilation, were explored it was suggested that the 3 card sort exercises should be run in a row; this was expected to be less time consuming for both interviewer and respondent than completing these exercises separately.
- The pilot made clear the need to consider how the final average interview length is a maximum of 60 minutes could be ensured. This involved identifying which items were the most essential and which data could be collected using a less time-consuming format.
- The pilot showed the need to and helped consider how information on heating systems and heating controls could be collected effectively and quickly from most respondents – using a combination of questionnaires questions and interviewers observations – ensuring that the survey was collecting accurate data on what is objectively the case as well as respondent perceptions / knowledge.

In summary, in addition to testing individual questions, the top lessons learned from the pilot were in these three areas.

- The sort card exercises, more specifically the decision to run these consecutively and include this exercise in the cognitive testing for further refinement (see next section on Cognitive testing for details).
- Respondent recruitment material, more specifically leading to the inclusion of an 'advance letter', a play pack and the updating of other respondent materials for the main stage.
- Management of fieldwork, including a longer fieldwork period and the development of procedures and incentives around obtaining the final interviews in accordance with interviewers' quotas.

Some questions, topics and terms were recommended for inclusion in a cognitive pilot – including the sort card exercises for measuring heat energy needs: relevant issues identified to be tested through a cognitive pilot were: developing sort cards with examples relating to particular needs; developing specific sets of sort cards for the 3 exercises, including examples of relevant needs; determining the most appropriate way for respondents to categorise their needs (albeit using a categorisation based on frequency or importance; developing a greater understanding of respondent thought processes when undertaking these exercises.

8.2.2 Cognitive testing

Cognitive testing focused on the three proposed sort card exercises as well as some specific issues of terminology pertinent to the design of survey questions. Overall, 16 respondents were interviewed, one-to-one, lasting approximately 1-1.5 hours. The respondents who were interviewed represented different household types, building types, tenure types and included both men and women and people of different income groups.

Based on the findings of the pilot and cognitive testing, the content, structure and order of the final questionnaire were agreed in collaboration between the consortium and ETI in December 2013. The final questionnaire involved a CAPI interview (with respondents' answers being entered by interviewers on a laptop), two or three sort card exercises undertaken by each respondent focussing on their household's heat energy needs, an observation of the household's heating systems and controls and a self-completion element, where the respondent was invited to complete an additional set of questions in a paper booklet.

Recommendations from the cognitive testing were as follows.

Measuring heat energy needs

We viewed this as the central purpose of the questionnaire and recommended allocating the majority of the cognitive pilot to exploring how this can be done most effectively. Building on the sort card exercises developed so far, the cognitive pilot was used to;

- Inform the development of bespoke sort cards for each of the 3 exercises, including specific examples relating to particular heat energy needs. This might facilitate reducing the number of items overall, if some are not viewed as relevant or are measuring the same thing, in the public's eyes.
- Determining the most appropriate way for respondents to categorise their needs (albeit using a categorisation based on frequency or importance).
- Develop a greater understanding of respondent thought processes when undertaking these exercises and identify what further changes we can make to ensure that they adequately capture household heat energy needs.

Following the field pilot and the cognitive testing, there were a number of changes that were implemented to the exercises. These included the following.

- Increasing the size of the sort cards.
- Changing the sorting categories from 'Always, Sometimes and Never' to 'Big factors, small factors and Not a factor'.
- Slight tweaks to the wording of the particular needs on each sort card (e.g. 'Being able to keep costs low' was changed to 'Energy costs').
- Adding examples to the cards to help clarify the particular needs.
- Adding an additional need to the sort card pack (Caring for other individuals in the home).

Testing public understanding of key terminology

There were a number of key terms used throughout the questionnaire where there is some evidence of different understandings, a lack of knowledge or confusion among the public. We explored through the cognitive pilot what is understood by these terms, how far understandings are consistent and how the terms could be phrased to make them as meaningful as possible to the public, as well as consistent with the concepts we were trying to measure. Particular terms which were recommended to be investigated included:

- turning on the heating;
- the number of times the heating is turned / comes on;
- control the temperature of hot water;
- cooling and ventilation.

8.2.3 The final questionnaire

The interview was expected to last about 60 minutes on average to complete. Its key elements were a CAPI interview, an interviewer observation of heating systems, a self-completion and an Address Record Form to be filled in after the interview.

CAPI interview

- *Household demographics – Part 1.* This section included a basic household grid (involving the collection of information on age and relationship to the respondent, for all household members).
- *Heating the home and keeping warm.* This was the first of the three main sections of the CAPI questionnaire, all of which were structured in a similar way.
- *Cooling.* We considered 'cooling' from the separate perspectives of avoiding over-heating in the winter and staying cool in the summer. While the former set of questions was relevant to many respondents, due to the timing of the survey, the latter set of questions was routed only to those who were in their current home during the previous summer.
- *Heating water and using hot water.* Again, this section largely followed the structure of the previous two sections, with a number of additional items. Additional items included questions on types of baths and showers within the home, and how often and when the respondent and other members of the household bathe and shower and displacement use of hot water in locations away from the home and the reasons for this.
- *Sort card exercises.* In this section, the respondent undertook 2 or 3 sort card exercises. In each exercise, the respondent was presented with a range of sort cards relating to heat energy needs and was asked, in relation to the specific aspect of heat energy being considered, to sort them into those that are "big factors", those that are "smaller factors" and those that are "not a factor". For further details on the sort card exercise, please see section 8.2.4 below.
- *Paying for heat energy use.* This section included a number of questions about paying for energy within the household and the respondent's role in this. The questions asked were determined by previous information provided about the type of heating in the home and whether the household was single or multi-person. In addition, there were some questions about devices within the home used to monitor energy use.
- *The home.* This section asked a range of questions about the home including expected length of residence, tenure, age of property and attitudes to the home. In addition, there were questions about problems experienced within the home (e.g. damp), types of windows and types of insulation. For the latter questions, we were interested in the respondent's perception of what they had or the problems they experienced.
- *Household demographics – Part 2.* This section included some further questions on demographics, which were potentially more sensitive – such as education levels, experience of disability and household income. This section did not follow on directly from that on The Home – in the interim, interviews undertook an observation of the respondent's heating systems and controls, as explained below.

Interviewer observation of heating systems

Towards the end of the interview, before interviewers undertook the final household demographics section there was a section on "Interviewer observations of heating systems and controls". The interviewer at this point requested permission from the respondent to have a look at the heating systems and controls within their home, in order to collect some further information. Information was recorded in a paper document and was later entered into the Admin Block. At the start of this section, the CAPI programme informed the interviewer (based on previous answers) which sections they needed to complete. The purpose of this section was to establish the details of the heating systems and controls which the respondent actually had, not what they thought they had (previous research has shown the two are often rather different).

Self-completion

The self-completion contained questions which we were unable to include in the CAPI given the length of the interview, and because the respondent may be able to answer more easily and quickly in a self-completion mode. It was answered by the respondent and in most cases the interviewer waited for the respondent to

complete the self-completion and took it with him to return to the office. If this was not possible interviewers left a prepaid envelope with the respondent to return the self-completion by post.

Address Record Form

In addition to standard details of the address, the ARF included four questions on property characteristics to be answered from outside of the home after the interview.

8.2.4 Sort card exercise

All respondents were asked to do the sort card exercise for heating and hot water. Respondents were only asked to do the sort card exercise for cooling if they had a mechanical source of cooling in their household (e.g. air conditioning) - we estimate that that this constituted around 10% of the overall sample, meaning that most respondents only undertook two sort card exercises.

Prior to handing respondents the sort cards and mat, interviewers were asked to shuffle the sort cards before to try to ensure that each respondent was presented with a random selection of the sort card set. Respondents were then presented with the set of sort cards (details in the table below) and a sort mat with three titles: 'Big Factor', 'Smaller Factor', 'Not a Factor'.

Interviewers asked respondents to sort the cards under the three titles on the mat, for example if respondents considered 'Keeping healthy' a big factor, they were asked to place this under the 'Big Factor' title, while if 'Doing what is easiest' was not a factor, they were asked to place this under the 'Not a factor' title. If a respondent had chosen three or less cards, interviewers were asked to probe respondents on whether there were any further cards they wanted to choose.

Once respondents had finished sorting the cards, interviewers coded the respondent's choices into the questionnaire. Respondents who had chosen more than three 'Big factors' were asked to review the options they had selected and chose which three needs were the 'biggest factors'.

Below is the actual text from the questionnaire on how interviewers introduced the card sort exercise and a table illustrating the content of the card sort.

> *You told me earlier some of the things you {and your household} do to heat the home and keep yourself{selves} warm – including {TEXTFILL SPECIFIC EXAMPLES SELECTED AT EARLIER QUESTION}.*
>
> *[HAND OVER SET OF SORT CARDS AND 'HEATING YOUR HOME AND KEEPING WARM' SHEET OR LABELS.]*
>
> *Different people and households take into account different kinds of need as they decide how to heat the home and keep warm. I would like you to tell me what is important to you {and your household}, using these cards. Each card has on it a factor that might influence how a person {household} decides to heat the home and keep warm. Some of the factors will probably not seem relevant to you {or your household} in your current home, in which case you can just tell me that.*
>
> *The cards show the basic factor or need that you could be thinking about – in the bold headings – and have some examples of how each factor could influence how you {and your household} decide how to heat the home and keep warm. These examples are included to explain some particular ways in which the factors might influence what you do. If you feel that the need could influence what you do, it doesn't matter if some or all of the examples are not relevant to you – just think about things that are relevant and focus on the basic need that you are trying to meet.*
>
> *So, thinking about you {and your household}, please sort the cards into big factors, smaller factors and those that are not a factor in how you decide to heat home and keep warm.*
>
> - *Big factors would be those that are very important in influencing what you do.*
> - *Smaller factors would be less important but still influence what you do to some extent.*

- *"Not a factor" means that something that does not influence what you do or something that is not relevant to you or your current situation.*

Place the cards under the headings on this larger card / by these labels.

	Examples		
Sort cards	**Heating home**	**Cooling**	**Heating water**
Being comfortable			Having enough hot water at the right temperature
Keeping healthy	Using heat to sooth aches and pains Keeping warm to avoid or treat health problems	Cooling to avoid heat stress Having fresh air in order to keep healthy	Using hot water to avoid or treat health problems Using hot water to soothe aches and pains
Wanting to feel clean	Having a warm room where people can wash and dry themselves Having a warm place or radiator to dry laundry	Wanting to avoid over-heating or sweating	Wanting to keep people and their clothes clean
Wanting to keep the home clean	Using the heating to avoid damp/mould Not using open fires that leave ash or soot	Getting rid of dust / dirt / smells by opening windows (or closing windows to stop them getting in) Keeping cool while cleaning the home	Using hot water to keep the home clean
Being able to rest and relax			Relaxing by having a hot bath or shower
Wanting to be productive	Being warm enough to do work at home	Avoiding the home becoming too warm to work	Having a hot shower to feel awake Having hot water for housework
Wanting to feel safe and secure	Not using heating that you worry might be unsafe Switching heating systems off when no-one is at home because of safety concerns	Closing windows at night or when no-one is at home Not opening windows because of concerns about privacy	Ensuring water is not scalding hot
Energy costs	Not spending more than is necessary Keeping the cost of heating under control	Not spending more than is necessary Keeping the cost of energy for cooling under control	Not spending more than is necessary Keeping the cost of heating water under control
The value or cost of your home	Preventing damage to your property that might cost you money Installing heating that could increase the value of the home	Preventing damage to your property that might cost you money Installing ways of cooling that could increase the value of the home	Preventing damage to your property that might cost you money Installing hot water appliances that could increase the value of the home

	Examples		
Sort cards	Heating home	Cooling	Heating water
Doing what is easiest	Letting the heating controls do the work	Always leaving certain windows open Having an extract fan in the bathroom that comes on automatically	Letting the hot water controls do the work Having hot water available all of the time
Feeling in control	Knowing the heating will come on when you want, at the temperature you want	Knowing that you can keep the home cool in hot weather	Knowing there will be hot water available when you want, at the temperature you want
How you and your home appear to other people	How the temperature of your home appears to other people Avoiding appearing either mean or extravagant in your use of heating	How the temperature of your home appears to other people Avoiding appearing either mean or extravagant in the way the home is cooled	What guests might think about the amount of hot water Avoiding appearing either mean or extravagant in use of hot water
The needs of visitors	Ensuring the home is warm enough for visitors	Ensuring that guests do not become overheated	Ensuring enough hot water is available for guests
Concern for the environment	Concern about air pollution, climate change, or the effect of heating on the country's energy resources	Concern about air pollution, climate change, or the effect of using energy for cooling on the country's energy resources	Concern about air pollution, climate change, or the effect of heating water on the country's energy resources
Avoiding wasting energy	Not leaving the heating on when it is not needed.	Avoiding using more energy to cool the home than is needed	Avoiding using more hot water than is needed
Keeping the home looking, feeling or smelling nice	Avoiding feeling dry or having mould or ugly equipment. Using fires or heaters to make the home appear cosy	Cooling the home by ventilation to get rid of smells	Using hot water to clean the home so that it looks and smells nice Having attractive hot water appliances
Wanting to avoid arguments / disagreements within the home	Avoiding arguments about how warm it is or when the heating is on	Avoiding arguments about how the home is cooled	Avoiding arguments about when (or how much) hot water is available
Doing what you think most people do	Heating your home in the way you think most people with similar homes would do	Cooling your home in the way you think most people with similar homes would do	Using hot water in the way you think most people with similar homes would do
Keeping to your everyday routines	Always having the heating come on at the same time	Always opening or closing windows at the same times	Always following the same timing of baths / showers
Doing what you have traditionally done	Doing what you did in previous homes	Doing what you did in previous homes	Doing what you did in previous homes

	Examples		
Sort cards	Heating home	Cooling	Heating water
Caring for other members of the household	Making sure the home is warm enough for people (adults or children) with particular needs	Making sure the home is cool enough for people (adults or children) with particular needs	Making sure there is enough hot water for people with particular needs, e.g. babies or young children

8.3 Briefings

Briefings of all interviewers took place in England, Scotland and Wales between January 6th and 17th. There were 14 briefings altogether, each attended by between 20 to 30 interviewers. Briefings were conducted by NatCen researchers together with collaborators from UCL and PRP, which presented on some of the technical details of the study and answered technical questions throughout the day. There were three overarching aims of briefings:

- For interviewers to understand the purpose of the study
- For interviewers to understand the study procedures and how to undertake the interview
- For interviewers to feel enthusiastic and confident about the study and selling it to potential respondents

Briefings were interactive and besides presentations (e.g. on the scope and purpose of the study, on procedures, admin and interview content) they included exercises on the purpose of the study, on specific doorstep techniques for this survey and on working with quota samples. Moreover, briefings included a practice interview of the whole questionnaire including the sort card exercise.

8.4 Fieldwork

The fieldwork period was planned to run from 13th January until 24th February 2014. Fieldwork was extended by a week to 3rd March due to a lower than expected number of achieved interviewers after the first five weeks of fieldwork.

Throughout fieldwork, we monitored our achieved interviews to measure the extent to which our sampling approach was achieving a data-set broadly representative of the population of British households on the characteristics outlined above – and on others of significant interest (such as OGG) which we were not be able to quota on. This involved generating a data-set of achieved interviews on a regular basis and providing updates against a pre-agreed set of criteria. More specifically, fieldwork monitoring included the following:

Interview status:

- Number of productive interviews achieved and Length of productive interview (median)
- Agreement to heating observation
- Self completion completed immediately after interview
- Self completion left with respondent (to be returned)
- Self completion refused
- Agreement to future re-contact

Quota characteristics

- Tenure
- Property
- Presence of children <18

Non-quota characteristics:

- Country of residence

- Gas grid status
- On gas grid
- Off gas grid
- Don't know
- Age of property (self-reported)
- Detailed interviewer classification of property
- Household size
- Household income
- Households composition (children present)
- Ages of adults in all households

The final achieved sample included 2313 interviews, with the following quota characteristics.

	Achived productive
Quota characteristics	**Achieved Final**
Tenure	**%**
Owns home	65
Rents home	35
Property	**%**
House	78
Flat	21
Presence of children <18	**%**
Children	32
No children	68

Final agreement to the observation of heating systems and controls was 89% and 75% of respondents agreed to be recontacted in the future. In total 1798 self-completion questionnaires were returned and included in the dataset, this relates to 78% of the total number of achieved interviews and means that, as expected, very few respondents who agreed to return the self-completion at a later date actually did so.

	Week 6
Interview status	**N**
Number of productive interviews achieved	2313
Length of productive interview (median)	58
Heating observation sheet	**%**
Agreement to heating observation	89
Self completion	**%**
Self completion completed immediately after interview	78
Self completion left with respondent (to be returned)	13
Self completion refused	10
Recontact	**N**
Agreement to future re-contact	75

8.5 Editing and coding

The coding and editing process was managed by the Data Unit. The Research team provided the Project Programmer and Data Unit with a specification of written instructions of the coding and/or editing operations required. The specification included details of all variables that required coding and editing, along with details of the potential code-frames. This document specified where the "other" response codes needed to be back coded into an existing code frame and other requirements or special instructions specific to the project. Generally, all 'Other' or 'anything else' answers were examined and where possible recoded. Where an 'Other' or 'anything else' question contained a 'Don't know', 'Refusal', or similar the original question was recoded 'Don't know' or 'Refusal'.

The edit program was tested by the Research Team and the Data Unit to ensure that it worked as specified before editing commenced. Subsequently a briefing for coders took place. According to NatCen's standard policy, every coder's first batch of work was 100% dependent verified by the Data Unit. Coders cannot undertake more work on the project until the first batch has been checked and confirmed to be of an acceptable standard. Throughout the editing and coding process any queries that could not be answered by the Data Unit were sent to the Researchers and, where necessary, decided upon in collaboration with experts from UCL or PRP.

8.6 Data weighting

Before the start of analysis, consideration was given as to the need to weight the data. Because the achieved sample closely matched the population of interest on a wide range of characteristics (including the three which formed the bases of the quotas), there was less necessity to do this than in a scenario where the key subgroups of interest were not accurately represented in the final data.

Nevertheless, a set of weight was developed – with the key discrepancies addressed relating to region (with households in London being under-represented) and tenure (with owner-occupiers being over-represented and those buying their homes on a mortgage being under-represented). Because none of our analysis focussed on these characteristics, all of the data presented in this report is unweighted.

8.7 Analysis and reporting

8.7.1 Approach to analysis

At the end of fieldwork, the questionnaire was reviewed to identify a bespoke set of derived variables, to be saved on the main data-set and used consistently by all analysts working on the report. An initial run of derived variable frequencies was undertaken, so as to identify a suitable level of aggregation for particular characteristics, on the basis of which to take forward the analysis.

Analysis was undertaken in SPSS. Don't know and refusal responses were included in bases, as they are regarded as valid response in relation to questions around heating needs, behaviours and systems. Statistical significance testing primarily involved Chi Square tests, with the creation of binary variables; however, where dependent variables were ordinal, a T test was undertaken to compare means for groups defined by an independent variable.

In a small number of instances, more complex multivariate analysis was undertaken – in the form of factor analysis and Latent Class Analysis (LCA). Factor analysis was undertaken in order to identify whether a larger number of variables could be reduced into a small number of underlying dimensions; analysis of this type was undertaken in relation to respondents' reported heat energy needs and for activities involving heating water. LCA was undertaken to attempt to segment households on the basis of their heat energy needs; its aim is to group people using unobservable data on associations between measures. Further details of the approach to and results of the factor analyses and LCA undertaken are presented at the end of this section.

Advantages of factor analysis include a reduction of the number of variables by combining two or more into a single factor that allows for a more general description of a set of variables. In addition, factor analysis can

identify latent dimensions or constructs that direct analysis may not, e.g. this may be difficult to do by simply using cross-tabulations of pairs of variables. However, there are also disadvantages to this approach, including that an interpretation of factor analysis is somewhat subjective. More than one interpretation could be made of the same data factored the same way, and factor analysis cannot identify causality. Also, naming factors may require knowledge of theory because seemingly dissimilar attributes can correlate strongly for unknown reasons. Overall, factor analysis can also be only as good as the data used.

LCA similarly has a number of advantages as well as disadvantages. As a key advantage, it provides a way to group people together who are similar on a number of variables, and different to people in other groups. Unlike other clustering techniques, it can use both continuous and categorical variables. LCA does not rely on the traditional modeling assumptions that are often violated in practice (linear relationship, normal distribution, homogeneity). Hence, it is less subject to biases associated with data not conforming to model assumptions. Finally, LCA is a probability-based classification, meaning that cases are classified into clusters based upon membership probabilities estimated directly from the model. On the other hand, disadvantages include that the more variables used to create classes, the less likely it is that people will fit neatly into well-defined classes, and hence the more complicated classes can be to define and interpret. Ideally, any individual would have a probability of belonging to a single class equal to 1 and a probability of belonging to all other groups of 0. In practice this does not happen, meaning there is variability within classes. And similarly to factor analysis, interpretation of classes can be quite subjective. More than one interpretation could be made of the same data segmented in the same way.

8.7.2 Data conventions

The following conventions were applied consistently throughout the analysis and reporting:

- While “don’t know” and “refusal” responses are always included in the base, they are only set out in tables in the report where they are of particular interest. These responses were included in bases because they are considered relevant responses when measuring behaviour, perceptions and needs e.g. there may be an interest in understanding the proportions of households who are unclear about what their needs or normal behaviour are.
- Bases (numeric) are included, along with descriptions of base membership for all tables. For multiple response questions, where respondents were permitted to provide more than one answer, bases are based on the number of respondents who answered the question – not the total number of responses received. In these scenarios, the percentages add up to in excess of 100%.
- Cells containing no cases are marked “-“. Cells containing less than 0.5% of cases are marked “*”.
- Question test, where directly quoted, appears in speech marks and is italicized. In other instances, precise question wording can be obtained from the accompanying questionnaire documentation.
- We only refer to differences between proportions where they have been shown to be statistically significant – or are of substantive interest and would be significant given a larger sample size (in which case this is stated explicitly). Significant testing was undertaken using a Chi Square test with the independent variable re-coded into 2 categories if necessary (for example, testing what the respondent does when it gets too cold by type of system for heating water, with one category for Combi boiler and the second category for all other types of system). This approach was undertaken in order to test existing hypotheses, rather than to subject the data to data mining (by examining all possible combinations of categories of dependent and independent variables, where significant differences are more likely to have occurred at random). In the rare instances where the outcome (dependent) variable was ordinal, a T test was undertaken instead of Chi Square in order to compare means of two pre-defined groups on the dependent variable of interest.

8.7.3 Factor analysis

Factor analysis was undertaken in two instances – in relation to the heat energy needs identified by respondents in relation to heating the home and heating water in Chapter 2 and in relation to the activities households undertake when heating water (in Chapter 4).

Factor analysis is designed to identify, where they exist, a smaller number of underlying unobservable dimensions, using a larger number of variables measured using an identical scale – based upon the associations that exist between them. Factor analysis was undertaken in SPSS. In each case, prior to the

analysis being undertaken, a correlation matrix of all the variables to be entered into the model was examined – to check for a sufficient degree of correlation that would make the existence of a smaller number of underlying dimensions incorporating all of the variables a valid possibility. Further, we checked for the existence of multi co-linearity (two or more variables being very highly or entirely correlated) which would suggest they were measuring the same single dimension and would invalidate the assumptions of the factor analysis. In each case, the identified variables were found to be suitably related to each other for factor analysis to take place.

Results and statistics in relation to the three factor analyses undertaken are presented below.

a) Factor analysis for heat energy needs for heating the home

The initial analysis suggested a five factor solution. These five factors explained 43% of variance in the underlying data – as shown by the Scree Plot and table depicting the Total Variance Explained below.

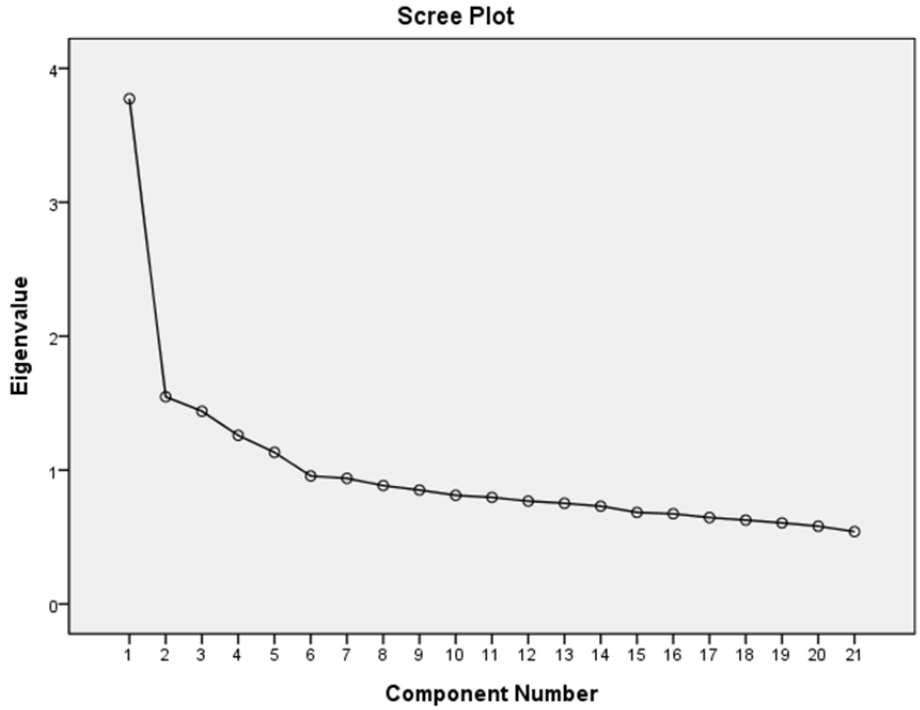
Relevant statistics suggest the factor analysis produced a good fit for the data. The relevant KMO statistic (measure of sampling adequacy) is .829 – with the literature defining between .7-.8 as "good" and any higher figure as very good.). Bartlett's test of sphericity – which tests whether there is some relationship between the variables we want to include in the analysis – produced a significance level of .000 – indicating that we can be confident that this is the case.

Figure 8.1 Heating the home factor analysis – total variance explained

Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.773	17.967	17.967	3.773	17.967	17.967	2.300	10.953	10.953
2	1.547	7.368	25.335	1.547	7.368	25.335	1.877	8.937	19.890
3	1.440	6.856	32.191	1.440	6.856	32.191	1.767	8.414	28.304
4	1.260	5.999	38.189	1.260	5.999	38.189	1.665	7.929	36.233
5	1.133	5.394	43.583	1.133	5.394	43.583	1.543	7.350	43.583
6	.956	4.554	48.137						
7	.938	4.469	52.605						
8	.884	4.212	56.817						
9	.851	4.054	60.871						
10	.812	3.864	64.735						
11	.796	3.791	68.527						
12	.768	3.659	72.185						
13	.752	3.583	75.768						
14	.731	3.479	79.247						
15	.684	3.258	82.505						
16	.674	3.209	85.714						
17	.646	3.075	88.789						
18	.627	2.985	91.774						
19	.606	2.885	94.659						
20	.581	2.767	97.426						
21	.541	2.574	100.000						

Figure 8 2 Heating the home factor analysis – scree plot



The component score coefficient matrix below indicates the relationship between each of the original 21 variables and the five components or underlying dimensions identified by the factor analysis. A positive relationship is identified by a positive figure, a negative relationship by a minus figure. Generally, numbers of +/-.4 are interpreted as demonstrating a significant relationship between the original variable and that particular dimension.

Figure 8.3 Heating the home factor analysis – component score coefficient matrix

Component Score Coefficient Matrix

	Component				
	1	2	3	4	5
Being comfortable	-.028	-.061	-.054	-.012	.509
Keeping healthy	.241	-.075	-.105	.040	.030
: Wanting to feel clean	.312	-.070	-.059	-.097	.094
Wanting to keep the home clean	.397	-.044	-.041	-.103	-.079
Being able to rest and relax	-.050	-.001	-.045	.006	.494
Wanting to be productive	-.039	-.024	-.002	.289	.099
Wanting to feel safe and secure	.284	.001	.103	-.057	-.153
Energy costs	-.014	-.010	.438	-.135	-.013
The value or cost of your home	.148	-.017	.201	.005	-.138
Doing what is easiest	-.092	.315	.086	-.126	.126
Feeling in control	-.059	.083	.179	-.054	.260
How you and your home appear to other people	.043	.139	-.074	.230	-.128
The needs of visitors	-.138	-.067	-.020	.468	.073
Concern for the environment	-.086	-.019	.302	.157	-.055
Avoiding wasting energy	-.069	-.061	.457	-.043	.050
Keeping the home looking, feeling or smelling nice	.300	.011	-.027	-.055	-.008
Wanting to avoid arguments / disagreements within the home	-.069	.116	-.017	.314	-.149
Doing what you think most people do	-.081	.362	-.031	.065	-.091
Keeping to your everyday routines	-.013	.386	-.027	-.143	.050
Doing what you have traditionally done	-.002	.372	-.068	-.037	-.048
Caring for other members of the household	.020	-.197	-.050	.428	-.011

Factor analysis for heat energy needs for heating water

The initial analysis suggested a five factor solution. These five factors explained 46% of variance in the underlying data – as shown by the Scree Plot and table depicting the Total Variance Explained below.

Relevant statistics suggest the factor analysis produced a good fit for the data. The relevant KMO statistic (measure of sampling adequacy) is .835 – with the literature defining between .7-.8 as "good" and any higher figure as very good.). Bartlett's test of sphericity – which tests whether there is some relationship between the variables we want to include in the analysis – produced a significance level of .000 – indicating that we can be confident that this is the case.

Figure 8.4 Heating water factor analysis – total variance explained

Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.112	19.583	19.583	4.112	19.583	19.583	2.160	10.286	10.286
2	1.710	8.143	27.727	1.710	8.143	27.727	1.955	9.309	19.595
3	1.521	7.244	34.971	1.521	7.244	34.971	1.896	9.027	28.622
4	1.226	5.838	40.809	1.226	5.838	40.809	1.882	8.961	37.583
5	1.136	5.409	46.218	1.136	5.409	46.218	1.813	8.635	46.218
6	.944	4.497	50.715						
7	.934	4.446	55.161						
8	.866	4.122	59.284						
9	.833	3.966	63.249						
10	.789	3.759	67.009						
11	.760	3.617	70.626						
12	.724	3.449	74.075						
13	.720	3.429	77.504						
14	.678	3.227	80.731						
15	.649	3.088	83.819						
16	.633	3.015	86.834						
17	.607	2.889	89.724						
18	.598	2.846	92.570						
19	.579	2.756	95.326						
20	.507	2.412	97.738						
21	.475	2.262	100.000						

Extraction Method: Principal Component Analysis.

Figure 8.5 Heating the home factor analysis – scree plot

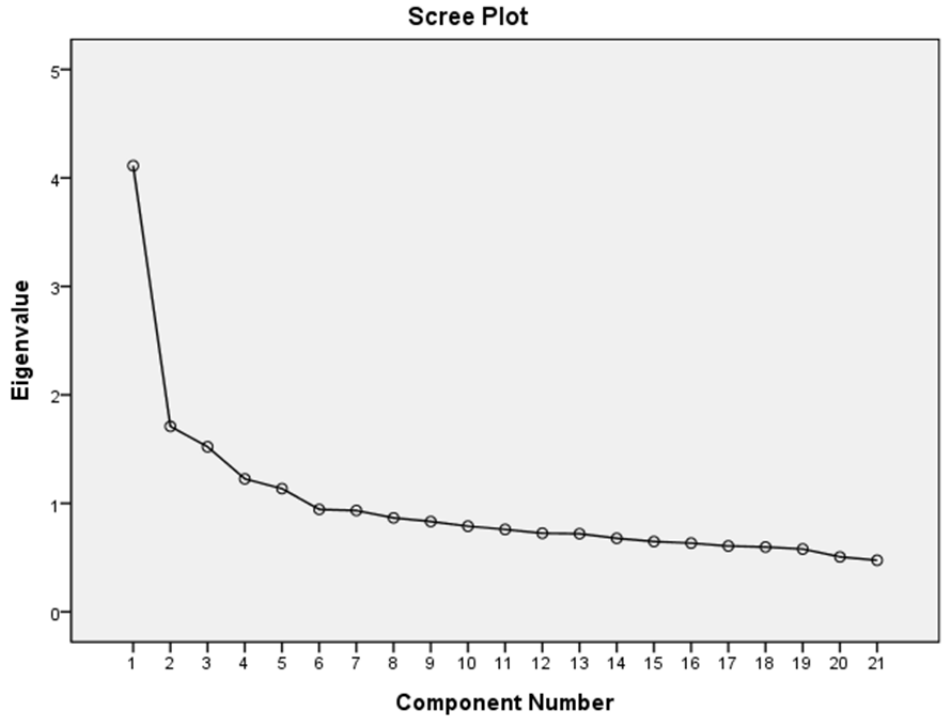


Figure 8.6 Heating water factor analysis – component score coefficient matrix

Component Score Coefficient Matrix

	Component				
	1	2	3	4	5
Being comfortable	.040	.345	-.050	-.135	-.040
Keeping healthy	.270	-.129	.009	-.046	.116
Wanting to feel clean	.385	-.010	.003	-.070	-.139
Wanting to keep the home clean	.427	-.093	-.004	-.014	-.090
Being able to rest and relax	.091	.233	-.096	-.072	.050
Wanting to be productive	-.020	.175	-.051	-.050	.191
Wanting to feel safe and secure	.007	.121	.065	-.047	.142
Energy costs	.024	-.023	.442	-.019	-.138
The value or cost of your home	-.032	-.019	.190	-.020	.190
Doing what is easiest	-.143	.430	-.038	.112	-.145
Feeling in control	-.149	.431	.031	-.013	-.046
How you and your home appear to other people	-.030	-.138	-.059	.172	.281
The needs of visitors	-.095	-.016	-.028	-.085	.426
Concern for the environment	-.052	-.094	.333	-.001	.103
Avoiding wasting energy	.018	-.006	.448	-.020	-.133
Keeping the home looking, feeling or smelling nice	.312	-.078	-.007	.105	-.043
Wanting to avoid arguments / disagreements within the home	-.093	-.103	.010	.211	.214
Doing what you think most people do	-.102	-.014	-.009	.364	.008
Keeping to your everyday routines	.050	.043	-.025	.374	-.191
Doing what you have traditionally done	.031	-.054	-.005	.439	-.133
Caring for other members of the household	.000	-.024	-.075	-.125	.396

c) Factor analysis for activities households undertake when heating water

Figure 8.7 Hot water activities factor analysis – total variance explained

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.937	14.898	14.898	1.937	14.898	14.898	1.625	12.501	12.501
2	1.383	10.640	25.538	1.383	10.640	25.538	1.328	10.215	22.716
3	1.221	9.395	34.933	1.221	9.395	34.933	1.228	9.449	32.165
4	1.038	7.982	42.915	1.038	7.982	42.915	1.219	9.377	41.541
5	1.016	7.816	50.731	1.016	7.816	50.731	1.195	9.190	50.731
6	.965	7.426	58.157						
7	.945	7.268	65.426						
8	.878	6.755	72.180						
9	.837	6.438	78.618						
10	.782	6.018	84.636						
11	.729	5.610	90.247						
12	.710	5.463	95.710						
13	.558	4.290	100.000						

Figure 8.8 Hot water activities factor analysis – scree plot

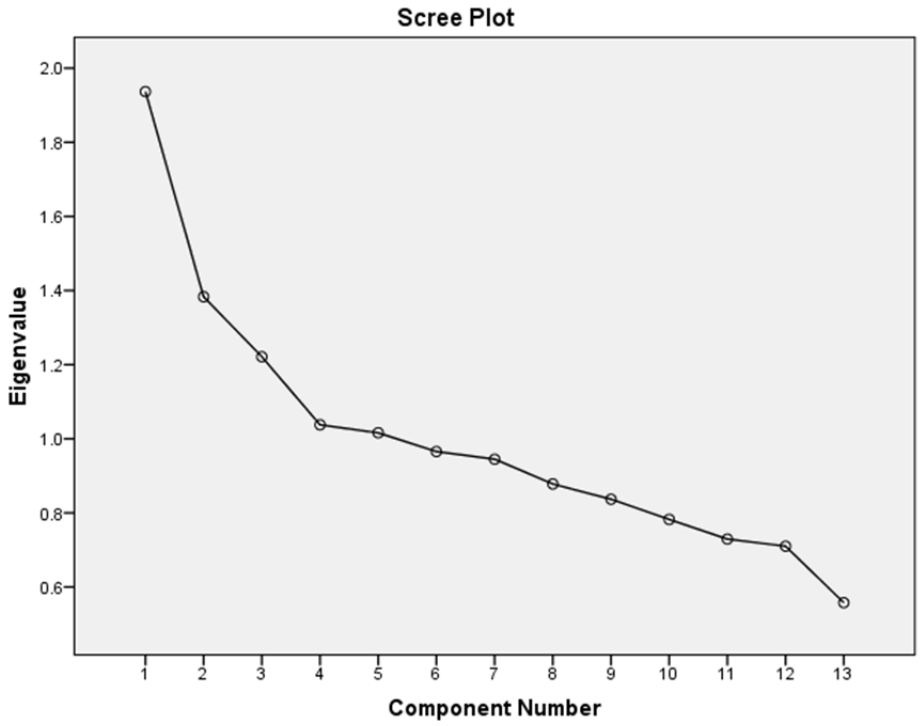


Figure 8.9 Hot water activities factor analysis – component score coefficient matrix

Component Score Coefficient Matrix

	Component				
	1	2	3	4	5
WtrUse1 Have baths or bathe children	.089	.097	.616	.087	-.017
WtrUse2 Have showers	.109	.058	-.598	.128	-.020
WtrUse3 Wash hands, face or feet	.134	.015	.136	-.005	.329
WtrUse4 Brush teeth with hot water	-.213	.064	-.061	-.150	.799
WtrUse5 Wash pets with hot water	-.085	-.024	.124	.462	-.045
WtrUse6 Wash clothes etc. using a washing machine	.448	.070	-.050	-.178	-.057
WtrUse7 Hand wash or soak clothes	.066	-.096	-.036	.167	.361
WtrUse8 Wash the dishes (by hand)	.152	-.618	-.067	.095	-.006
WtrUse9 Wash the dishes (using a dishwasher)	.131	.579	-.027	.072	.006
WtrUse10 Make hot drinks or cook food	.441	-.017	-.051	-.145	-.042
WtrUse11 Clean the home, using hot water	.316	-.083	.116	.113	-.054
WtrUse12 Wash a car/other vehicle using hot water	.064	.048	-.047	.442	.026
WtrUse13 Other – PLEASE SAY WHAT	-.184	-.062	-.128	.553	-.021

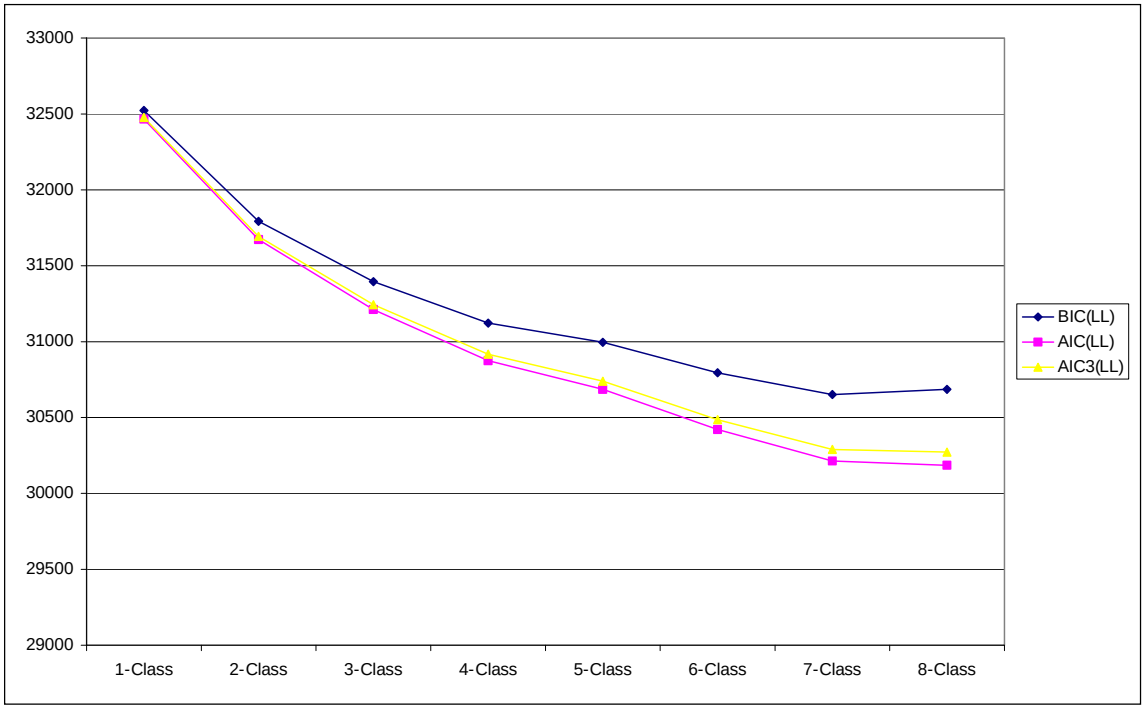
8.7.4 Latent Class Analysis

Latent Class Analysis (LCA) is a statistical technique for identifying 'latent classes', or groups, of individuals not directly observable in the data. It is especially useful for measuring multi-dimensional concepts, such as people's views of their heating needs. LCA was used in this project to categorise individuals into classes according to their responses to the heating needs card sort exercise ('factor scores' were used in the LCA to summarise individuals' responses to the 21 needs, for more details see Factor Analysis).

LCA works by exploring the structure within a set of observed variables in order to establish whether associations between these observed measures (i.e. the structure of the data) can be explained by a set of underlying classes. The process of identifying this typology involves estimating multiple latent class solutions, beginning at first with just one class, and then each time adding an additional class until the optimal solution is found. The estimation procedure runs through a complex set of algorithms designed to identify the best classes to fit the data. An individual is then assigned to the class for which they have the highest probability. The software Latent Gold version 4.0 was used to carry out this analysis (http://www.statisticalinnovations.com/products/latentgold_v4.html).

Establishing the optimal solution generally follows a number of steps: First, we used several statistical tests to assess the goodness of fit. The recommended guidelines for good fitting models indicate that small values of BIC, AIC and AIC3 correspond to a good fit. According to these rules the number of classes should be seven or eight (see Figure 7).

Figure 8.10 Latent class models and goodness of fit statistics



Note: BIC (Bayesian Information Criterion), AIC (Akaike Information Criterion), AIC3 (Akaike Information Criterion 3).

Second, the solution was examined to ensure that it was both interpretable and useful for the aims of the study. At this step the classes were also examined to ensure they were distinguishable from one another (i.e. they represent qualitatively different groups of people according to their needs). Third, the validity of the classes was tested by examining the relationship of the classes with other measures known to be associated with heating needs, such as age, family composition, income and type of housing.

This analysis suggested that a seven-class model was optimal. Ideally, each individual should have a probability of one of being in one class and zero of being in other classes, showing that the model assigns individuals into their designated class with accuracy. An examination of the average membership probabilities indicated that the probability of being assigned to a class for which they have the highest probability was 0.78. The percentage of respondents that had a class membership probability of less than 0.6 was between 13% and 23%. This suggests that there is still some variability within classes which can make interpretation difficult.

8.7.5 You, Me and Us groups

These groups, defined in the qualitative research, were defined using two questions in relation to each of the three domains of heat energy use. Single-person households were automatically placed in the “Me” group.

The first question asked how the household decides about heating, cooling or hot water. Answer options were classified into the You, Me, Us typology as follows.

- It’s largely down to one person (ME).
- It’s mainly to care for someone who needs to keep warm or cool, for example because of a health condition or age (YOU).
- It depends on the needs of the person deciding at the time how to heat the home (DEPENDENT ON NEXT QUESTION).
- Everyone has a say but one or more people’s needs have a greater influence than others (DEPENDENT ON NEXT QUESTION).

- It varies – depending on whose needs are greatest at the time (US); It depends more-or-less equally on the needs of everyone who is at home at the time (US).

The second question was asked of those who selected answer options ‘3 and ‘4’ at the previous question and asked the respondent how much influence they personally have over decisions about heating. Response options were classified as follows.

- I tend to have the most influence (ME).
- Someone else tends to have the most influence (ME).
- It varies – different people influence decisions about the heating at different times (US).
- Nobody – we all make decisions about it separately (ME); SPONTANEOUS - We decide together (US).