Department of Energy & Climate Change

What people want from their heating controls: a qualitative study

October 2013 – Final Report

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Credits

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What people want from their heating controls: a qualitative study

Final Report

Prepared by new experience ltd

October 2013

Contents

Executive summary

Background

The Department of Energy and Climate Change (DECC) has set up a programme of work to understand the potential for smarter heating controls to save energy. As part of this DECC wished to understand what people need from their heating controls so as to improve their understanding of how emerging technologies could best meet these needs. This research gathered requirements for smarter heating controls by studying how people use their existing heating controls.

The study involved diary self-reporting of heating behaviours by a sample of 43 householders followed by in-home, in-depth interviews with the same participants. After a period of interim analysis a 'long-list' of requirements was inferred, and some emergent user types were identified. The requirements were then explored and prioritised in four 'participatory-design' workshops along with evaluation of three different concepts for smarter heating controls with four interviewed participants and 19 new participants.

Findings: factors influencing behaviours

The following factors were found to influence heating behaviours.

Functionality, usability and accessibility

Functionality, usability and accessibility together determine whether something can be done, and the amount of difficulty and effort involved. These factors in relation to heating controls therefore play a significant part in encouraging or constraining behaviours.

Beliefs, understanding and awareness

Participants' behaviours could be constrained or encouraged by the beliefs, understanding and awareness they had in relation to their use of heating. In particular, beliefs and understanding around efficient use of heating, and awareness of the cost implications of different behaviours.

Comfort versus spending

The research revealed a tension between the desire for the comfort that comes from feeling warm when you want to be, and the spending of money to achieve it.

When heating is desired

Participants' need for heating was driven by when they were in the home and what they were doing in the home. Both occupancy and activity could be more or less regular and predictable.

Heating and space

How participants thought about and used the different spaces in their home influenced heating behaviours.

Household considerations

Participants were more or less likely to consider themselves or others when controlling heating. Who was in the home and the extent to which people considered themselves or others could affect their heating behaviours.

Findings: emerging user types

Participants broadly fell into the following five user types. They provide a framework for considering how requirements for smarter heating controls vary across different households:

- **Rationers**. The main priority for 'Rationers' was minimising spending; heating was rationed to a minimum. They tended to control the heating manually for maximum control.

- **Ego-centric**. This type operated heating more according to how they felt. Their primary consideration was themselves, whether they lived alone or with others. They also often controlled their heating manually.

- **Hands off**. They did not want to think about or interact with their heating unless they had to. They wanted to be warm whenever they were at home, and to the extent that they were able to use them, were well served by controls that allowed them to set different temperatures at different times. Their routines and occupancy were more regular and predictable.

- **Planners**. 'Planners' thought ahead about when they needed their home to be warm and when they did not. They tried to avoid using the heating when they did not need it, and they made anticipatory changes to their timer and sometimes to their thermostatic radiator valves (TRVs). Their routines and occupancy were more variable.

- **Reactors**. 'Reactors' tended to live in larger, colder, family homes with some rooms warmer and some cooler. They reacted to internal and external variations in temperature using controls and auxiliary heaters, and mostly comprised family households including those where children had left home.

Findings: key requirements

A 'long-list' of requirements was inferred from discussion and observation of participants during in-home sessions. Workshop participants prioritised these requirements by indicating their relative importance. Key requirements came out as:

- Being able to monitor spending on heating, important across the board.

- Being able to control the temperature at different times in different rooms from one panel.

- Being able to turn the heating on before getting home.

- Being easily able to see the current state of the heating system e.g. current temperature, whether it is on, when it will be on, whether this varies in different parts of the home.

During the workshops participants also sketched out their ideal design of heating control. These often incorporated the key requirements above. From the requirements and participant designs, it was apparent that participants were generally looking to make informed choices about their use of heating and to have more rather than less control.

In relation to the emerging user types it was found that:

- ‘Rationers’ particularly cared about spending and their requirements reflected this.
- Being able to control heating from outside the home particularly resonated with the ‘Ego-centric’ user type, who are focused on their personal needs.
- Visibility of the current settings appealed to ‘Hands off’; they could see if everything was working optimally and leave it well alone.
- Ease of on-the-fly adjustment (e.g. not needing instructions) was important to ‘Planners’ as they interact with the controls more frequently.
- ‘Reactors’ saw zonal control (ability to control times and temperatures in different rooms from one panel) as helpful to achieving comfort in larger homes, while minimising waste.

Reactions to smarter heating controls

Reactions to different smarter heating controls, expressed as concepts were also explored. Of the three concepts:

- **Zonal control** was explained to participants as allowing users to set times and temperatures for each room in the home and control whole areas of the home, such as upstairs and downstairs. This had the broadest relevance to participants, particularly for those in larger family homes. This resonated with the ‘Reactor’ user type.
- **Remote control** was explained as a simple heating control panel that allowed programming of different times and temperatures to best suit routines. It could be controlled from a smartphone app, by text on a mobile telephone, or by PC or tablet, from home or anywhere else. Remote control was seen as relevant but mainly for turning heating on before getting home. ‘Ego-centrics’ especially liked remote control.
- **Automation** was explained as managing the heating of its own accord after an initial learning period when users could make adjustments. The control could sense when people were at home and adjust the heating automatically. Participants were mostly sceptical about whether automation could work for them and were generally reluctant to cede control. The exception was the ‘Hands off’ user type who ranked automation highly in the workshops.

As well as scepticism around automation, there appeared to be two potential barriers to participants acquiring smarter heating controls. The first of these was that participants could believe there were bigger energy priorities in the home to address, such as single-glazed windows and poor insulation. The second was that most wanted to know the cost-benefit before they made a purchase. Often they had unrealistic expectations about payback time, expecting to see savings after a year, especially older participants.

Additional findings

All participants were interested in minimising waste, i.e. spending from which they did not receive benefit, but they were not always sure how to achieve this.

Analysis of ‘wasteful’ behaviours suggested automation could help minimise waste, but it was relatively unpopular. Participants seemed to want more rather than less active involvement in their heating, with a greater degree of control. They also wanted to be able to see how their behaviours related to their spending on heating.

Analysis suggested that remote and zonal control could be combined, with automation as an optional layer so that users could try it out and build trust in it over time. While some might ignore automation altogether, it would give people the opportunity to experiment and see automation in action, without having had it imposed on them.

1. Introduction

Domestic energy use accounts for 29% of UK energy consumption with space heating responsible for 66% of domestic energy consumption and water heating for an additional 17%.[1] Carbon budgets commit the UK to reduce overall CO2 emissions by at least 80% by 2050. Improving heating controls is seen as one potential way to reduce domestic emissions.

English Housing Survey data indicates that while 95% of homes have a boiler, over 70% lack the minimum levels of controls specified in the 2010 building regulations, a significant proportion have no room thermostat, and 800,000 have no controls at all.[2]

Industry estimates suggest that installing a timer, room thermostat and thermostatic radiator valves (TRVs) in every home could reduce energy used for heating and hot water by 30%.[3] There are claims that emerging heating control technologies could deliver even larger savings. However, experience in the US and several studies indicate it is not this straightforward.[4] One recent study has concluded that it is not the presence or absence of particular heating controls that is important, but rather how people choose to interact with the technology that matters.[5]

The Department of Energy and Climate Change (DECC) has set up a programme of work to understand the potential for smarter heating controls to save energy. As part of this DECC wished to understand what people need from their heating controls so as to improve their understanding of how emerging technologies could best meet these needs. This research gathered requirements for smarter heating controls by studying how people use their existing heating controls. Specifically it answered the following five questions:

1. What do heating practices reveal about heating control requirements?
2. How do these requirements vary for different households?
3. What will people want to be able to do with different emerging heating control technologies?
4. What is the relative priority of these different requirements?

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[2] CLG (2010) English Housing Survey: HOMES, Annual report on England's housing stock. Available at - https://www.gov.uk/government/publications/english-housing-survey-homes-report-2010 (22.09.2013).

[3] Heating and Hot Water Taskforce (2010) Heating and hot water pathways to 2020: Full report and evidence base. Energy Efficiency Partnership for Homes. Available at - www.beama.org.uk/en/news/index.cfm/hhwt_pathways_2020_report (22.09.2013)

[4] Shipworth, M., S. K. Firth, et al. (2010). Central heating thermostat settings and timing: building demographics, *Building Research & Information* 38(1): 50-69.; Moezzi, E. et al., (2009) Behavioural assumptions in energy efficiency potential studies. Prepared for the California Institute of Energy and Environment: 58-60

[5] Kelly, S., Shipworth, M., Shipworth, D., Gentry, M., Wright, A., Pollitt, M., Crawford-Brown, D. and Lomas, K. (2013) Predicting the diversity of internal temperatures from the English residential sector using panel methods, *Applied Energy*, 102, 601-621,.

5. What are the implications for DECC in terms of promoting adoption of heating controls that meet users' requirements while also creating greater energy-efficiency?

Section 2 of this report explains the methods used during the fieldwork and the rationale. Section 3 describes the findings from in-home interviews and requirements that emerged. Section 4 introduces five emerging user types. Section 5 highlights how requirements were prioritised and how they varied by user type. Section 6 analyses users' reactions to smarter controls. Finally, Section 7 presents the research team's conclusions. Detailed material covering research materials and so forth is available in a separate volume of appendices.

2. Research design

2.1 Sample

43 participants were recruited in and around London and Manchester for diary self-reporting and in-home interviews to provide a robust sample that struck a balance between achieving breadth and depth of data collection and analysis. The 43 included an additional participant recruited for a pilot session. Overall, data was collected from 60 people across the 43 households, when other household members are included. 19 separate participants took part in four follow-up participatory design workshops supplemented by four individuals who had already participated in the in-home interviews.

Participants were paid an incentive for their involvement and recruited through a third-party recruitment agency as the person most involved in controlling the household's heating, across the following three groups:

1. Retired singles and couples.
2. Working-age singles and couples.
3. Family households.

Recruiting across these three groups aimed to provide a spread of ages, household sizes, life-stages, lifestyles, and daytime occupancy.

Other areas that were actively screened for included: housing type and ownership; payment method; elderly and chronically sick; children of different ages.

A detailed breakdown of the recruited sample appears below:

Characteristic	In-home recruitment (N=43)	Workshop recruitment (N=23) *N.b. 4 participants from the in-home recruit came back for the workshops*
Age	18-59 - 28 60 and over - 15	18-59 - 14 60 and over - 9
Type	Working age not retired - 13 Family - 17 Retired - 13	Working age not retired - 7 Family - 8 Retired - 8
House type	Flat/ Maisonette - 15 Semi-detached - 14 Terrace - 11 Detached - 3	Flat/ Maisonette - 7 Semi-detached - 12 Terrace - 3 Detached - 1
Payment method	Direct Debit - 31 Prepay - 8 Quarterly - 4	Direct Debit - 15 Prepay - 3 Quarterly - 5

Characteristic	In-home recruitment (N=43)	Workshop recruitment (N=23) *N.b. 4 participants from the in-home recruit came back for the workshops*
Health conditions	Relevant health conditions (e.g. asthma etc) - 14	Relevant health conditions (e.g. asthma etc) - 4
Daytime occupancy	Fixed - 8 Irregular predictable - 20 Irregular unpredictable - 15	Fixed - 9 Irregular predictable - 6 Irregular unpredictable - 8
Children	With babies (up to 18 months) - 2 With infants (18 months to 12 years) - 9 With teens - 6 *Some overlap with children in different brackets*	With babies (up to 18 months) - 2 With infants (18 months to 12 years) - 4 With teens - 3 *Some overlap with children in different brackets*

2.2 Methodology

In order to capture reliable, rich data, the method was designed in three phases with fieldwork conducted from late February through to mid-March 2013.

2.2.1 Pilot study

Before the fieldwork started a pilot was conducted to test and refine the diary and in-home discussion guide.

2.2.2 Phase 1: diaries and temperature logging

Participants were briefed on the phone before keeping a diary for between seven and 12 consecutive days. Most participants completed diaries online, allowing researchers to monitor entries in real time. Nine participants who had problems reporting online had paper diaries sent out to them. Temperatures, sourced from wunderground.com, were low during the self-reporting period. In both London and Manchester the daily temperature only exceeded 5C on three days and was below 0C on two days.

Additionally, 21 of the 43 households took part in temperature recording. This involved three Joulo monitors (www.myjoulo.com) in each of the 21 households. One was placed on or near the thermostat, another was placed in a room that was infrequently used (e.g. a spare room), and one was placed in a room frequently used (e.g. the lounge). The locations were discussed and agreed on in a briefing call. Participants were sent specific instructions about how to place them so as to avoid direct sunlight, hot places and cold draughts.

Participants uploaded the data to a dedicated website at the end of seven days. The data created graphs of temperatures over the week which were printed and discussed in the in-home, in-depth interviews along with completed diaries. The primary aim of using the Joulos was to corroborate findings, and highlight unusual heating practices for later discussion. The data was also analysed to look for common behaviours within emerging user types.

2.2.3 Phase 2: in-home, in-depth interviews

Interviews lasted up to 2.5 hours and took place in participants' own homes. The interviews were grounded in real behaviours, discussing with participants what they actually did and why. Interviews mainly involved the recruited 'primary' participant, however, where appropriate and practical, other members of households were involved in both diaries and interviews, as secondary participants.

In multi-occupant households the primary participant was asked to act as a central point for reporting behaviours of all household members. Where possible, home visits were scheduled at times when other household members would be available to talk to with the researcher.

The interviews followed a written protocol to ensure there was consistency across all interviews and researchers. Interviews were divided into a number of parts:

- **Occupancy patterns:** participants indicated on a 7-day calendar typical occupancy patterns for members of the household, or they talked about them in more general terms if they felt uncomfortable giving this information to a stranger.

- **Home tour:** participants took researchers on a tour of their home describing how each room was used, when it needed to be heated, whether it ever got too warm or too cool, and any use of TRVs and/or auxiliary heaters.

- **Heating controls:** participants walked interviewers through their use of their heating controls.

- **Frustrations and 'wasteful' behaviours**: Following the tour and discussion of controls participants described any frustrations they had with their heating and their views on energy efficiency including what, if anything, they perceived as 'waste'.

- **Ideal controls:** When time allowed researchers asked participants to describe their ideal controls. Smarter heating technologies were also discussed, with the researcher prompting and probing on remote control and automation and zonal.

2.2.4 Phase 3, participatory-design workshops

Participatory-design workshops actively involve users into the design process through the use of exercises that allow people to express their views and ideas visually as well as verbally. Each workshop featured a number of activities and exercises:

- Users rated themselves against the emerging user types. Each was given a sheet of paper with a skeleton framework of the five user types (emerging from initial analysis of the in-home sessions). They were asked to rate from 1-5 how much each user type resonated with them.

- A general discussion about heating controls. This built rapport and got participants thinking about heating controls. Any new requirements were recorded and added to the list for the final voting exercise.

- A discussion around new smarter technologies of automation, zonal and remote control. Participants ranked each one as their first, second or third choice. The rankings were then discussed as a group. The concepts were explained as follows:

    - **Automation**. After an initial learning period when users could make adjustments, it would manage the heating of its own accord. It could sense when people were at home and adjust the heating automatically.

  - **Remote control**. This would comprise a simple heating control panel that allowed programming of different times and temperatures to best suit routines. It could be controlled from a smartphone app, by text on a mobile telephone, or by PC or tablet, from home or anywhere else.

  - **Zonal control**. This would allow users to set times and temperatures for each room in the home. It could also be used to control whole areas of the home, such as upstairs and downstairs.

- A design exercise whereby participants designed their 'ideal' heating controls. Participants could use features from any of the concepts to create their ideal heating controls. They worked in pairs to force them to think through and justify their choices. They presented their designs to the rest of the group.

- Prioritising requirements. Each participant considered a 'long-list' of requirements inferred from the in-home research and used ten sticky, colour-coded dots to 'vote' for those requirements they considered important to them. By this point participants had spent two hours thinking and talking about heating controls, and so were in a good position to 'vote' in an informed and thoughtful manner.

- A discussion around acquisition of new heating controls to explore whether participants would consider buying the controls if they were available.

2.3 Interpretation and use of qualitative data

Qualitative research can be an extremely valuable tool in circumstances where, for example, there is a paucity of quantitative data, or where more needs to be understood about a situation before quantitative data is gathered.

Despite the relatively large number of research participants for a qualitative study, there are no numeric results presented in the findings. The findings are not statistically 'representative' and may not be generalisable to the population as a whole.

3. Main findings: factors influencing behaviours and user requirements

This section of the report describes the factors which influenced behaviours and requirements from interviews with in-home session participants. The findings were themed into six categories: **Functionality, usability and accessibility; Beliefs, understanding and awareness; Comfort versus spending; When heating is needed; Heating and space**; and **Household considerations**. The section also lists the user requirements that were inferred from these findings.

A diversity of heating behaviours was observed including both manual and timer control. The most common behaviour was to set heating to come on a few hours in the morning and the evening. Some put it on in the day if they were in and felt cold. Some turned it down or off when they expected the home to be empty for an extended period of time. A range of factors influenced participants' current heating practices from which requirements for control of heating could be inferred.

3.1 Functionality, usability and accessibility

Functionality refers to the actual functions offered by the controls, such as setting the heating to come on and go off at different times, and whether they are recognised as such by users.

Usability of a device describes the ease with which a person is able to perform a task to achieve their goal. Applied to heating controls this term principally refers to the ease with which a person can turn heating on or off, adjust the temperature up or down, or make changes to time settings.

Accessibility of a device describes the extent to which a person can literally access the device physically and/ or visually in order to use it. Accessibility is a function both of the design and location of the device, and the capabilities of the person.

Functionality, usability and accessibility together determine whether a control function can be achieved, and the amount of difficulty and effort involved. If controls don't enable a function then it won't be performed. If controls make a function hard and difficult to perform then it is less likely that it will be performed. These factors in relation to heating controls therefore play a significant part in encouraging or constraining behaviours.

3.1.1 Analogue and digital controls

A majority of participants used a timer to set heating to come on and go off at different times.

Clock-style analogue timers made the times set for heating to come on and go off clear and offered intuitive control as the toggles on the clock also indicated on and off times. This made it easier for participants to be aware of their timer settings. A higher proportion of those with analogue timers adjusted them on the fly than those with digital timers.

The clock-style timers mounted on boilers could be hard to set as they involved the manipulation of very small teeth that slid inwards for heating to be on, and outwards for heating to be off. One participant also reported that the 24-hour clock was confusing and had caused them to set the heating to come on at the wrong time. Timers mounted on boilers did not offer an advance function allowing users to bring forward the time when heating comes on while retaining the timer settings. When heating was required between timer hours participants using these types of boiler-mounted timers tended to switch the controls from timer mode to constant mode. But then they had to remember to switch it back to timed mode for the heating to go off at a later time. Several reported occasionally forgetting to do this.

The experience of using digital controls was almost the reverse of using analogue, clock-style timers. Input involved pressing buttons which was easier than manipulating small sliding toggles. Digital controls also made it relatively easy for participants to turn heating on or up temporarily, outside timer periods. However, the icons for this and other functions were not always intuitive.

On the other hand, digital controls did not offer good visibility of on and off times as they tended to be accessible through menus, and screens could be hard to read. The use of menus to find and change times was not intuitive. Participants found them hard to learn and so could need to consult a guide if they wanted to change a setting.

The consequence was that people with digital controls were less likely to remember the times that their heating came on and went off, and less likely to make changes to the times.

Familiarity with digital technology did not appear to help participants use digital controls. This may be because digital heating controls work differently to more familiar digital technologies such as websites and mobile apps.

3.1.2 Accessibility of controls

A couple of participants mentioned that they had personally chosen to install their heating controls in cupboards because they were unattractive to look at. This made controls harder to access, as well as more difficult to read because of poor light.

Radiator valves and TRVs were in some cases broken, stiff or physically inaccessible to participants, for example being behind beds. Participants did not always know which way to turn valves to turn the radiator on or off. TRVs were more obvious in this way and easier to manipulate than valves, but the numbers on them had limited meaning.

Overall participants did not find individual valves or TRVs a convenient or accessible way to vary their use of heating in different rooms at different times. A common refrain went along the lines of 'I can't be bothered running around the house constantly turning radiators on and off'.

Radiator controls are located on radiators in different rooms around the home so their setting was only visible when participants were in the same room. Some participants reported that they were concerned about remembering to reverse changes they had made to individual radiators.

Physical impairment exacerbated accessibility issues. General immobility meant that some participants found it hard to get to their controls. Poor vision affected some participants' ability to read control displays. One with arthritis in her hand did not interact with her timer because it was too hard for her to press the buttons. Several participants had bad backs and a couple reported that this put them off bending down to adjust their radiators.

3.2 Beliefs, understanding and awareness

The way people use their heating can be influenced by beliefs, understanding and awareness.

3.2.1 Efficient use of heating

Quite a number of participants reported that they had heard from friends or from their boiler engineer that it was more efficient to keep their heating on all the time rather than let their home cool down and then warm up again. Although they did not all follow this guidance there was uncertainty as to whether or not this was the right thing to do. One participant had heard that most of the cost of the gas bill was in the first 'x hundred' units so although she did turn her heating off she doubted whether she was saving much.

Several reported that they were not sure whether turning radiators off in certain rooms would save them money or not. Some did not see how adjusting a radiator would affect the heating done by the boiler. One participant suggested that the cold created in a room by turning off the radiator could leak back into the house and actually cause the boiler to work harder.

Several participants used an auxiliary electric heater to warm the room they were in at a time when the central heating was off but they were not sure whether this was more efficient than turning the central heating on and heating a larger part of their home. No one reported turning on the central heating but turning off radiators in all other rooms.

3.2.2 Fear of damaging the system

One participant who was attempting to minimise their spending by limiting their hours of heating reported they were reluctant to turn a radiator off because a boiler engineer had warned him that it would 'break the system'. Others had heard that they would 'unbalance' the system if they turned one or more radiators off. There was a general reluctance to 'mess around' with the boiler settings after these had been set up by the engineer.

3.2.3 Connection between usage and cost

Several participants indicated that they were unclear on the cost implications of their heating behaviours, i.e., whether they would save by turning a radiator off, and if so how much. This became especially apparent in the participatory design workshops.

A couple of participants pointed out that if they changed their heating behaviours, for example by turning off radiators in unused rooms, it would be very hard for them to make expenditure comparisons and know whether or not they had saved any money. Price changes and variation in temperatures across two winters would make it harder to see the impact of changing their heating behaviours on their bills.

3.3 Comfort versus spending

There was a tension between the comfort that comes from feeling warm when you want, and the spending required to achieve it.

At one end of the spectrum were those who were very spending driven. They had very low levels of disposable income and needed to limit their spending on heating by using it sparingly.

In the middle were those who made compromises and would sacrifice some comfort if they felt it would result in savings. Typically this meant that they would set their heating to come on in the morning and evening, rather than leaving it on all day long, and resist turning the heating on outside a time period by adding on an extra layer of clothing instead.

At the other end of the spectrum were people who were very comfort driven and who were not prepared to sacrifice comfort to save money. If they lived in colder homes they would have their heating on higher and longer to compensate. Despite their determination to be comfortable above all, these people did not like the idea of wasting money. While they weren't prepared to compromise on comfort, they didn't like the idea of spending money for which they would receive no benefit.

A number of factors determined where people sat on the spectrum from spending to comfort driven.

3.3.1 Disposable income and extent to which heating costs were perceived to impinge on other spending needs

Those that did not perceive heating costs would affect their ability to spend on other things were most likely comfort driven. Those with extremely limited disposable income had no choice but to be expenditure driven. Those who felt that heating costs might impinge on other spending needs could decide to make compromises between comfort and spending. They weren't able to precisely quantify how they would spend the money they saved, it was more of a generalised desire to be frugal. One participant reported that when they retired they made a number of lifestyle changes to cut down on spending. As well as controlling their use of heating they also stopped using a tumble dryer to dry clothes. It wasn't that they couldn't afford the heating, but rather that they wanted to be able to offer the maximum support possible to their two grown-up sons and their families.

3.3.2 Chronic and acute health conditions

A couple of participants had chronic health conditions that were alleviated by warmth. Neither of these participants had high disposable incomes but both prioritised their comfort over any spending considerations. An elderly participant cited a need to keep warm and prioritised comfort for this reason. Participants also reported keeping heating on for longer when someone in the household had an acute illness such as flu, indicating that temporary shifts towards comfort can occur.

3.4 When heating is desired

People's need for heating was driven by when they were in the home – occupancy – and what they were doing in the home – activity. Both occupancy and activity varied, sometimes predictably, sometimes less so.

3.4.1 Occupancy

People wanted their home to be warm when they were in, but also when they returned home. Several participants complained about the time it took for their home to heat up if they returned when the heating was off.

There were a range of patterns of occupancy. There was also considerable variation in how much participants were able to predict when they would be at home.

Participants who had retired, worked from home or looked after children were often in for large parts of the day. However, they were not always able to predict when they were going to be in or out.

Conversely, some participants were out more often at regular and predictable times. For instance those who worked regular hours, five days a week.

A household that had regular and predictable occupancy was represented by one where a couple lived in a flat and went out to work during office hours. They had a digital timer-thermostat that they had set up two years ago when they moved in. They had set the heating to go off when they left for work and come on before they returned.

A household that had an irregular and non-predictable occupancy pattern was represented by one where a mother lived with her three grown-up sons, and much younger daughter. The sons and daughter were out all day at work or school. The mother was a care worker working different shifts each day resulting in highly variable occupancy. She collected her daughter from school but never knew exactly when she'd return home. For instance, she commented that some days she might go to a supermarket on the way home from school. On others she'd talk to another mother in the playground and end up going back to the other mother's house for tea. This participant reported adjusting her timer on a daily basis according to her variable working pattern but still didn't always know when she'd be home.

It is worth noting that most homes in the study were occupied for large parts of the day and this may not be representative of households more generally. This may have been because a high proportion of interviews needed to take place during daytime.

Where it was discussed it was apparent that if participants went out for a short period of an hour or so they were less likely to turn their heating down or off than if they were away for longer periods. Not wanting to return to a cold home could be a reason not to turn heating off when going out. When away for a night or more several talked about turning the temperature down to about 15 degrees rather than any lower. This was either to protect against frozen pipes or because they had pets staying at home. Participants did not always appear to be aware of frost protection features that they had on their controls.

3.4.2 Activities in the home

Some participants described how their level of activity could influence how warm they felt and therefore how they used their heating. If they were doing physical activity like cooking and cleaning they might stay warm enough during the period when the heating was off, but if they were more sedentary they might need to turn the heating on.

Participants wanted their home to be warm when they got out of bed in the morning, especially if getting children up and off to school. Those using a timer would set it to come on before they got up. A few reported adjusting their timer according to when they planned to get up. One participant described in his diary how he had reset their timer for the heating to come on later on a Sunday when their young children were away staying with their grandparents, and he and his wife would be able to sleep in later than usual.

Some had kitchens that were slow to warm up or were in cold parts of the home. A few participants reported using an electric heater to speed the heating of their kitchen at breakfast, and two reported turning on the oven and leaving the door open.

Some participants and members of their household engaged in activities that could broadly be described as 'work'. Such activities included paid work, studying, general PC activity like emailing, children's homework and hobby-type activities. These activities took place in the kitchen, dining room or an 'office'. They were sedentary activities where the person involved often used their heating to stay warm. Paid work and studying was likely to take place during the day when heating might not be turned on. In some homes people used an electric heater to warm where they were, rather than turn on the central heating. Home offices were sometimes in cold extensions meaning that heating was more rather than less important at this time.

Participants wanted to be warm when relaxing in the evening watching TV or reading. This sedentary activity coincided with a drop in outside temperature resulting in some people wanting extra heating. One participant described how they would temporarily increase the temperature on their programmable timer-thermostat each evening. They learnt how to set their controls to a higher temperature in the evening than the morning during the interview and said they would change it to this setting in future.

Participants wanted to be warm when getting undressed and into bed but not once they were in bed and sleeping, when they preferred the room to be cool. Some used hot water bottles or electric blankets to warm the bed. One described how before getting into bed she warmed it using a hairdryer. Several reported they had woken up in the night hot and uncomfortable, having accidentally left the heating on.

3.5 Heating and space

3.5.1 Single space versus differentiated space

Participants tended to think of their home as either a single space or more of a conglomeration of different spaces.

Those that lived in smaller flats were most likely to perceive and use their home as a single space. When at home they wanted to be able to use all of their rooms and therefore wanted all of them to be warm.

Those that lived in larger houses were more likely to perceive and use their home as a conglomeration of different spaces. These people were more inclined to think about heating different spaces at different times and considered space in three different ways:

Live space: used as a part of daily household routines. Radiators in rooms that comprised live space were least likely to be adjusted according to how the room was used, because these rooms were used frequently and it was seen as too arduous to be 'running around the home switching radiators on and off'.

Standby space: had a role within non-daily routines for example as a spare room that grandchildren or other guests regularly slept in. Approximately half the rooms that comprised standby space had radiators turned off or down when these rooms were not in use. Remembering to turn radiators off or on in standby space could be an issue. One participant said they did not turn their heating off in their spare room because their grandchildren regularly stayed and they did not want to forget to turn it back on again.

Dead space: did not fit into routines and was only rarely occupied. Such space included rooms used for storage or dining rooms used only for rare and special occasions. Radiators in rooms that comprised dead space were nearly all turned off despite a couple of participants reporting a

reluctance to 'close off' rooms they rarely used. It was a part of their home and they didn't want to feel their access to it was essentially denied.

3.5.2 Achieving desired temperature across different spaces

Some participants complained about certain rooms being too hot or too cold. In cold rooms they used an auxiliary heater, or sat under a blanket.

Several reported that upstairs got too warm when they heated the downstairs to the right temperature but they had been unable to make suitable adjustments. In one case it was the opposite.

3.6 Household considerations

3.6.1 Self versus others

People were more or less likely to consider themselves or others when controlling heating. Those who lived alone controlled heating according to how they felt. People who lived with others mostly considered those others in their control of heating, although some did not. Instances of both sacrifice and conflict were apparent. Quite a few reported considering the heating needs of their guests either by turning up the thermostat, leaving heating on for longer or turning on an auxiliary heater to increase the warmth of where the guest was.

People who worked at home sometimes endured the cold, not turning on the heating until other family members returned. Alternatively they used some form of auxiliary heating to heat the room they were in.

On the other hand instances of people making surreptitious changes were also reported. While touring the home a participant commented that the TRVs were not as they had left them, and it transpired their partner had made changes without them knowing.

With digital programmable controls only one household member might know how to make changes to settings, if indeed anyone did. Others were forced to work around the controls.

3.6.2 Babies

Babies represented an extreme instance of people considering others in their heating behaviours. Parents were very anxious to have the heating level right for babies. They believed it was imperative that babies were kept at the right temperature and in some instances would tolerate higher temperatures elsewhere in the home to be sure the baby was warm enough. This could involve keeping heating on at night. A family who had young children reported that since they had had their baby they had 'got used' to a higher temperature and now kept their home warmer than before. One couple with very little money limited their heating to keeping the baby warm when it needed to rest.

Some parents kept thermometers in their baby's room. They were also concerned not to overheat the room the baby was in. (Two retired participants had thermometers; one of them read the external temperature which they used to judge what to wear when they went out.)

3.6.3 Teenagers

Younger teenagers and pre-teens didn't seem to get too involved in controlling heating. Parents reported that older teenagers tended to look for the easiest option which might involve opening a window when they felt too warm, or switching the controls to constant if returning home at a time

when the heating was off and they felt cold. Two different participants both reported that their teenage sons would switch the heating to constant and then not tell them. In one instance this led to a household running out of credit overnight and waking up feeling very cold without heating. One participant commented that his teenage son didn't pay the bill so had a more casual attitude to waste.

3.7 User requirements ‘long-list’

A ‘long-list’ of User Requirements emerged from discussions and observations of participants in the in-home sessions. These user requirements were inferred by considering reported frustrations, noting potentially wasteful behaviours and asking participants to articulate their ideal means of controlling their heating. They broadly fell into the following four categories:

3.7.1 Controlling heating

1. Simple way to switch heating on and off.
2. Quick and easy to adjust the times when heating would come on and go off.
3. Use controls without needing to use instructions.
4. Easy access to controls.
5. Aesthetic heating controls.
6. Control heating in a specific room using a wall control (like in a hotel).
7. Be able to set a time and temperature and be able to leave the system to work out when to turn the heating on.
8. Ability to remotely turn on heating before returning home.
9. Ability to remotely turn off heating after leaving home.
10. Heating system to adjust itself to changes in daily routines and occupancy.
11. System works out the best compromise temperature to suit different people with different preferences in the home.
12. Ability to set different temperatures at different times for different rooms – all from one central panel.

3.7.2 Advisory

13. Be reminded to turn heating off when not needed.
14. Reminder if heating left on constant.
15. Be made aware of when control settings are not working as efficiently as possible for your routines and occupancy patterns.

16. Know how far ahead you need to turn heating on to achieve a particular level of warmth at a particular time (alternative to 7 in controlling heating).

17. Clear and permanent display of times and temperatures set (no need to press buttons to view this information).

18. Option to switch between Celsius and Fahrenheit on the thermostat.

19. Temperatures on TRVs, not just numbers.

20. Feel confident that temperature will always be right for babies and young children.

21. Be alerted when someone else makes changes to heating control settings.

22. Be alerted remotely when someone turns heating on (e.g. by text).

23. Be reminded to make adjustments to different zones (rooms) according to intended usage (e.g. turning heating on in a spare room before guests arrive).

3.7.3 Heating system capability

24. Rapid warming when turning heating on.

25. Heating system takes account of when you feel cool or warm, not just the actual temperature.

26. Heating system automatically adjusts to take into account outside temperature.

27. Automatic frost protection (or awareness of it).

3.7.4 Spending

28. See how much heating is costing.

29. Avoid going over a heating budget.

30. Know you can use your heating on cold days because your system works out you'll spend less on predicted upcoming warmer days.

31. Avoid running out of credit unexpectedly.

32. Understand the cost of heating by the hour.

33. Know whether it's more expensive to have gas central heating on or just heat the room you're in with an auxiliary heater (e.g. electric heater).

34. Understand savings that can be made by making adjustments to settings on the heating controls.

35. Be made aware of higher spending than normal.

These user requirements are further discussed in Section 5 – prioritisation of requirements.

4. Main findings: emerging user types

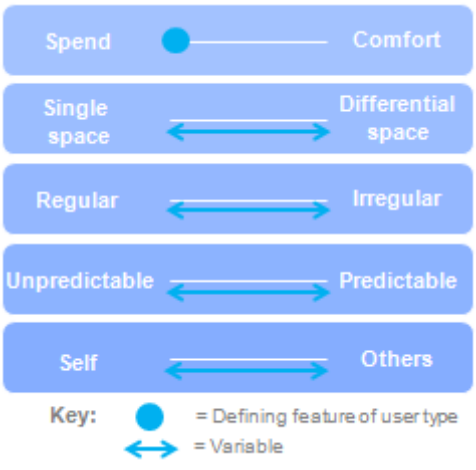
Five ‘scales’ emerged during analysis of in-home interviews: spending versus comfort; single space versus differential space; regular versus irregular routines; unpredictable versus predictable routines; self versus others.

These scales help to define characteristics of the emerging user types and the requirements they have from heating controls. The user types emerge from an interaction between people’s attitudes to control, the home they live in, and their household. They provide a framework to consider different types of people and what they need. They are also useful in considering why participants were attracted to certain heating-control technologies, or aspects of them.

This research has not validated the user types and they should only be considered as a framework to aid thinking about approaches to heating controls and requirements for them. Southampton University conducted an analysis of temperature data captured across the 21 households that used the Joulo recorders to look for any similarities in temperature control that might exist among profiles of participants within the different user types[6]. They found strongest evidence of similarity among those defined as ‘Hands off’, and also to a lesser extent among those defined as ‘Reactors’. There were only one or two households in each of the other three types who had also been among the 21 using the Joulos, making further patterns hard to identify. Further research would be required to validate or refine these user types.

4.1 Rationers

“We only put the heating on if the baby is too cold to settle"



‘Rationers’ were defined by being at the extreme end of the spending-versus-comfort scale. They differed in terms of where they were on the other scales, and as a group were not defined particularly by their attitude towards space, their routines, or others in the household.

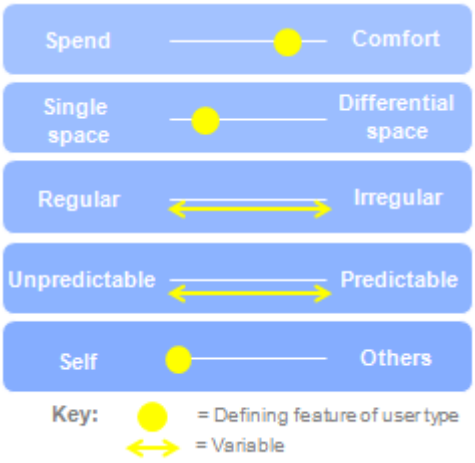
Their main priority was minimising spending; heating was rationed to a minimum. They had very limited income and may have used a pre-payment card which helped them control their spending. They used heating more to ward off discomfort than to achieve comfort.

‘Rationers’ were likely to control heating manually to be sure it was not on when they didn't need it. They could use an auxiliary electric heater to just heat the space they were in. They made extensive use of extra clothing and sometimes went to bed to keep warm.

[6] Data analysis conducted by Dr Alex Rogers, Agents, Interaction and Complexity Group, Electronics & Computer Science at the University of Southampton in April 2013.

4.2 Ego-centric

"My son finds it so hot that he keeps his window open"



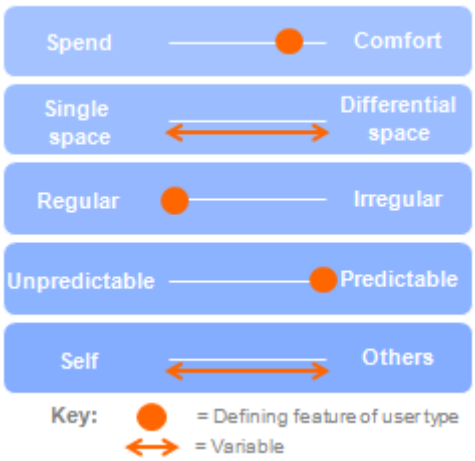
'Ego-centric' sat at the self end of the self-versus-others scale. They tended more towards comfort on the spending-versus-comfort scale and were more likely to consider their home a single space than a collection of separate spaces, especially if they lived in a smaller home.

Those who fell into the 'Ego-centric' user type operated the heating manually according to how they felt rather than using a timer. Their primary concern was for their own thermal comfort, whether they lived alone or with others. They were conscious that their subjective need for heat or cool could vary considerably.

Health was sometimes a factor in driving their attitude. Comfort was more important than spending although they may have been on a lower income. Their behaviours could create conflict with others who lived with them. They did not need a great understanding of their heating controls, and they did not give them much thought.

4.3 Hands off

"If I want it 20 degrees in winter, I want it 20 degrees in summer too"



'Hands off' tended more towards comfort on the comfort-versus-spending scale, with regular and predictable routines. Consideration of their home as single or differential space did not define this user type; nor did their attitude towards self versus others.

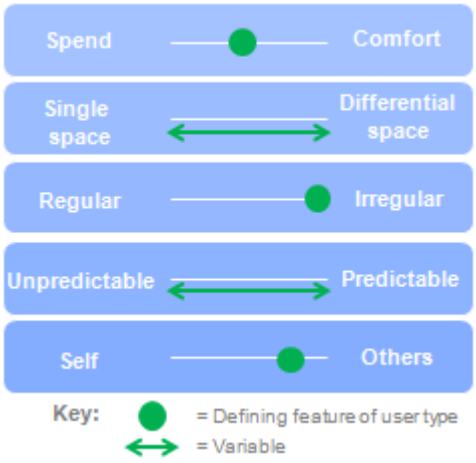
Occupancy was reasonably regular and predictable for those in the 'Hands off' user group. They didn't want to think about or interact with their heating unless they had to. They wanted to be warm when they were at home, and were well served by controls that allowed programming of different temperatures for different times. One in this group who didn't have a timer kept the heating on constant with their thermostat set to 18, rarely adjusting it.

They could struggle to make changes to their controls if they needed to because they didn't interact with them regularly; it may have been some time since they or someone else programmed the controls.

4.4 Planners

"I like to interact with the controls... I like to have a little bit of control"

Planners sat in the middle of the spending-versus-comfort scale as they tried to juggle what they are spending on heating and the comfort of everyone in the household. They were more towards regular than irregular, and were variable between predictable and unpredictable. They tended more towards others on the self-versus-others scale.



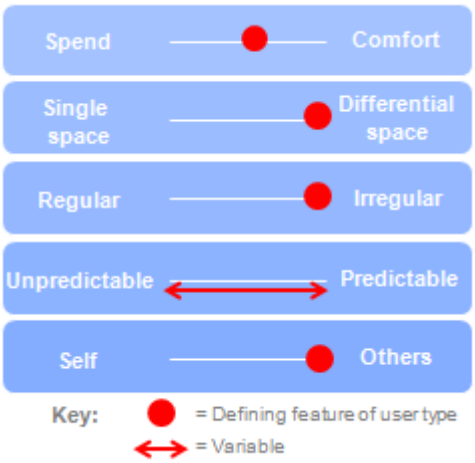
Planners thought ahead about when they needed it warm and when they didn't. They could have irregular routines and tried to proactively manage heating. They tried to avoid using the heating when they didn't need it, and they made relatively frequent anticipatory changes to their timer settings, and sometimes to TRVs.

Planners could consider the weather forecast in their forward planning, and they planned for the household, not just themselves. They were helped by analogue, clock-style timers with high visibility of settings, but if they had a digital one they had to learn how to change time settings which could discourage more frequent changes. Planning could be undermined by another member of the household – for example a teenager – overriding settings.

4.5 Reactors

"If I see snow outside, I turn up the heating"

Reactors often sat in the middle of the spending-versus-comfort scale, attempting to find a balance between being comfortable in a larger house, while keeping spending under control. They tended to view their home as having lots of differential space (i.e. several zones). As family households they often had irregular routines, which varied in predictability, making it more difficult to plan their heating needs. They tended to react to situations regarding their heating. They often considered others in the household more than themselves.



Reactors tended to live in larger homes where some rooms felt warmer and some felt cooler. They were mostly family households including ones where children had left home. They reacted to external and corresponding internal variations in temperature and struggled to achieve comfortable temperatures without frequently adjusting time periods, thermostat settings, using override, auxiliary heating, or adding layers of clothing or using blankets.

Someone was often in during the day, perhaps working in a cold extension home office. When home alone they could choose to heat the room where they were. They may have had rooms or floors that were unused for periods of the day, or longer.

5. Main findings: prioritisation of requirements

As described in 3.7 a ‘long-list’ of requirements was inferred from the in-home sessions. Often these were not articulated by participants, but emerged from discussion and observation. Workshop participants prioritised these requirements by indicating their relative importance.

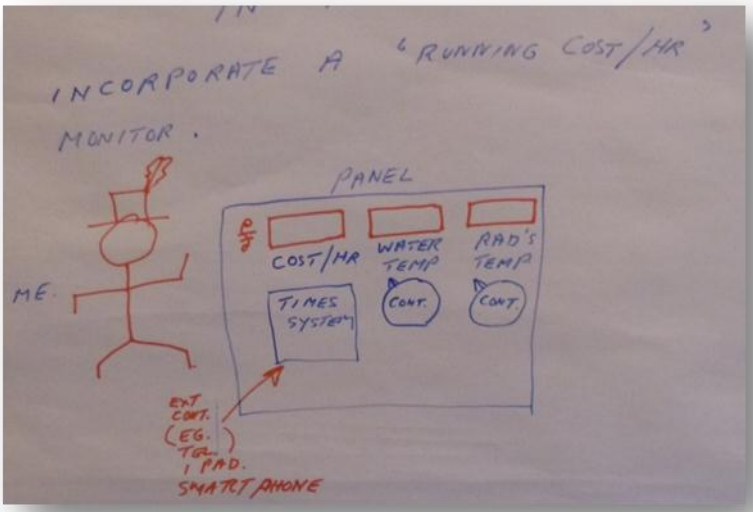
Monitoring and controlling spending appeared to be most important as represented by the first and third-ranked requirements, followed by centralised zonal control, ability to turn heating on remotely before returning home, and then clear and permanent display of times and temperatures set, as well as a simple means of turning the heating on and off, and rapid warming. Requirements that came out as high in the workshops were not surprising to the research team who had previously conducted the in-home, in-depth interviews.

Requirements that were rated high priority are shown in the table below. Those that were rated medium or low priority appear in appendices *F- Requirements overall prioritisation list* and *G - Requirements by user type* which accompany this report.

Rank	Requirement	Priority based on votes
1	See how much heating is costing you	High
2	Ability to set different temperatures at different times for different rooms – all from one central panel	High
3	Understand savings that can be made by making adjustments to settings on the heating controls	High
4	Ability to remotely turn on heating before returning home	High
5	Clear and permanent display of times and temperatures set	High
5	Simple way to switch the heating on or off	High
5	Rapid warming when turning the heating on	High

High-priority requirements were also reflected in participants’ ‘ideal’ designs created in the workshops. The ‘ideal’ design below shows a control panel that would incorporate a running cost-per-hour monitor.

5.1 Summary of needs by user type



Section from workshop participants' 'ideal' controls

- 'Rationers' particularly cared about spending and their requirements reflected this; they cannot afford to go over budget.
- Being able to control heating from outside the home particularly resonated with the 'Ego-centric' user type, who are focused on their personal needs.
- Visibility of the current settings appealed to 'Hands off'; they could see if everything was working optimally and leave it well alone.
- Ease of on-the-fly adjustment (e.g. not needing instructions) was important to 'Planners' as they interact with the controls more frequently.
- Reactors saw zonal control (ability to control times and temperatures in different rooms from one panel) as helpful to achieving comfort in larger homes, while minimising waste.

6. Smarter heating controls: reactions and analysis

6.1 Reactions to concepts

6.1.1 Automation

Automation was seen by some to be an effective way to cut down on heating costs. *"If it learns your patterns then it should save for you, no need to remember to turn heating down: I like the idea of the system turning down rooms not being used during the day" Female, 54, family.*

However, not many saw this potential, and it was difficult to overcome concerns around trust. Others with less regularity in their lives were more doubtful of the benefits. As many did not have predictable lives this was a common reaction. They did not believe that automation could work for them. *"If you have a routine then fine, but my days vary so much I'm not sure it could work" Male, 36, family.*

Others still were anxious of relying on technology. "*Too high tech, there's more to breakdown" Male, 81, retired.*

6.1.2 Remote control

Remote control was spontaneously suggested by some participants during the in-home interviews. This came up when discussing current problems with their heating, and what would be their ideal controls. *"It would be nice to set from my phone, if I'm on my way home I would flick the heating on, like the Sky Plus recorder" Male, 36, family.*

It was seen as less relevant by some who stayed mostly at home. Those people felt the benefit was primarily the ability to adjust the heating when out of the home, and as this did not apply to them, they felt they would not use it a great deal. *"Not for us as we're at home a lot" Female, 54, working.*

For others, however, the main benefit could be the convenience of using it at home. Some could relate to lying in bed, wishing they could adjust the heating without getting up. A few with health issues (especially mobility issues) who controlled the heating manually also saw this benefit. *"I'm more interested in remote control so I can do it from the sofa" Female, 54, family.*

6.1.3 Zonal control

Zonal control was also mentioned by a number of in-home participants. Part of the attraction lay in convenience. As described in section 3, people reported avoiding using TRVs due to their distributed location and the perceived hassle of going around turning them off and on. Zonal control that combined the ability to fine tune heating, with the increased convenience of central control was attractive to many. *"It would work perfectly in our home, working at different times for*

different temperatures" Female, 64, working. "A panel where all is visible at any time, to have a setting for my daughter's room, for my room, for the TV room" Male, 68, retired.

6.2 Matching concepts to user types

Through analysis of the in-home interviews, ranking of concepts by participants in the workshops, and analysis of ideal designs created during the design exercise, researchers matched the concepts to user types in terms of what those user types appeared to want. The table below presents the preferences identified. Remote and zonal controls had broad appeal except to 'Hands off', while automated controls appealed only to 'Hands off', and not to other user types.

User type	Automated controls	Remote controls	Zonal controls
Rationers (n=5)	No	Yes	Yes
Ego-centric (n=12)	No	Yes	Indifferent
Hands off (n=12)	Yes	No	No
Planners (n=8)	No	Yes	Yes
Reactors (n=25)	No	Yes	Yes

'Rationers' were reluctant to relinquish control in case they ended up spending more. They saw too great a risk in having technology control their heating; and for this reason automation did not appeal to them. Requirements rated highly by Rationers included a simple way to turn heating on or off that would also be addressed by remote and zonal control. Appeal of zonal control came from the ability to only heat the space they were using.

'Ego-centric' were more self-oriented and felt that only *they* knew when they needed more or less heat. They voted for a remote way to turn heating on before returning home and a simple way to switch the heating on or off. They also voted for the ability to set different temperatures at different times for different rooms – all from one central panel. It was not so clear that zonal control would have appeal to this type.

'Hands off' by their nature preferred not to think about, or interact with, their heating controls. This would suggest that automation would appeal to them, and they were indeed the only user type where several participants ranked it as their first-choice concept.

'Planners' had irregular routines so felt automation was not suitable for them. Planners were interested in a simple way to switch heating on or off, the ability to set different temperatures at different times for different rooms from one central panel, easy access to heating controls in the home and the ability to remotely turn on heating before returning home.

'Reactors' had irregular routines that could also be unpredictable, so again automation was not popular. They were particularly interested in the ability to set different temperatures at different times for different rooms from one panel. They also voted highly for the ability to turn the heating on and off remotely. They wanted a simple way to turn the heating on and off as well as easy access to the controls implying both remote and zonal control would have appeal.

6.3 Requirements not met by the different smarter heating controls

A number of key requirements were not met by the smarter controls concepts as they were described to participants. Most notable are those focused around cost. 'Seeing how much heating costs', and 'understanding the savings that can be made by making changes' were voted for highly overall. 'Understand the cost of heating by the hour', 'knowing whether it's more expensive to have gas central heating on or just heat the room up that's being used with an auxiliary heater', and 'being made aware of a higher spending than normal' were also among the requirements not met by smarter heating controls.

Some other requirements that may not be met by smarter heating controls include:

- Feel confident that temperature will always be right for babies and young children.
- Being made aware of when control settings are not working as efficiently as possible for routines and occupancy patterns.
- The system working out the best compromise temperature to suit different people with different preferences in the home.
- Knowing how far ahead heating needs to be turned on to achieve a particular level of warmth at a particular time.
- Heating to take account of different personal needs and rhythms.

6.4 Opportunities for smarter heating controls to save energy

'Wasteful' behaviours can occur when energy is expended on heating with no benefit to the occupants. Such behaviour would include heating the home when it is not occupied, but not heating it to a high temperature if this is desired by the occupants. Throughout the research a number of potential 'wasteful' behaviours were identified. These are behaviours that can occur. It does not mean that they always do. They can be categorised as follows:

6.4.1 Forgetting

- To turn controls back from Constant to Timer after switching to Constant between timer periods.
- To turn controls from On to Off if controlling manually.
- To turn off radiators in guest rooms after a guest has left.
- To readjust the timer to new routines of occupancy.

- To change the timer back after setting it for an early start.

6.4.2 Excessive ‘caution’

- Turning heating on ahead of time – in a room or the whole home – not realising less time is needed to achieve target temperature.

- Overheating the home when away because of concerns about pipes freezing or pet welfare.

6.4.3 Heating too much space

- Heating spare/ unused rooms.

- Heating rooms that are not currently being used.

6.4.4 Over-heating home

- Heating whole home at too high a temperature to achieve right temperature in one place or for one person.

- Turning up thermostat higher than needed to ‘accelerate’ heating.

6.4.5 Use of auxiliary heaters

- Heating one area with an electric heater instead of using central heating (with zonal control).

- Boosting or accelerating the temperature of a specific area with a particularly inefficient heater.
    - Using a hairdryer to warm up a bed.

    - Turning on the oven to heat up a kitchen in the morning.

6.4.6 Non communication between household occupants

- Someone switches heating from Timer to Constant but does not tell the person who might otherwise manage the heating, so it does not get switched back to timer and remains on for longer than desired.

6.4.7 Leaving heating on when out of the home

- Not turning heating off or down when going out.

6.4.8 Non fine tuning of timer

- ‘Failure’ to fine tune timer for example when going to bed early or getting up late.

6.5 How smarter heating controls might address ‘wasteful’ behaviour

Automation could have the potential to mitigate more of the identified ‘wasteful’ behaviour categories than remote or zonal control. As such, a paradox existed that participants wanted to save money and avoid waste, yet they were mostly more interested in remote and zonal controls than automation. The findings suggest that the technologies participants are attracted to may actually do less to mitigate ‘wasteful’ behaviours and so save them money.

Section 3.2 highlighted that there can be confusion about efficient use of heating. The requirements that appealed to them most did not necessarily address 'waste', but more the symptom of it which was cost. Because people could be unsure about how to minimise waste they seemed to be looking to make more informed choices based on better spending feedback and greater control of their heating system, rather than ceding control to the system. This may explain why automation expressed as a requirement received very few votes.

6.6 Ideal controls

So far in this report the concepts have been analysed separately. From the 'ideal design' exercise that took place during workshops', it was clear that participants wanted to incorporate various aspects of the technologies. Remote and zonal control could be combined, perhaps with automation as more of an optional layer so that users could try it out and build trust in it over time. While some might ignore automation altogether, it would give people the opportunity to experiment and see automation in action, without having had it imposed on them.

This research also suggests that ideal controls would allow users to monitor the spending consequences of their use of heating and make informed decisions accordingly. This was expressed as understanding the cost of heating by the hour, or being able to understand the spending implications of certain actions. For example, if the radiator was turned off in the spare room, how much this would save.

Furthermore any design should incorporate good principles of user centred design to ensure good visibility of current settings and allow for a simple relationship between adjustments to settings and the display of these settings.

6.7 Saving energy through smarter heating controls

This research cannot confirm whether smarter heating controls would or would not result in energy savings. All participants were interested in either saving money, or reducing wasted expenditure, both of which entail reduced energy use. People are likely to respond well to the message that smarter heating controls could help them maintain or even improve comfort, and save money. Zonal control had broad appeal and it would make it easier for participants to reduce heating in parts of their home not currently being used. They would need to be certain that that turning heating down in some rooms would save them money, and not all were sure about this. It is therefore likely that zonal control would result in energy savings.

It was notable that participants prioritised use of remote control to turn heating on ahead of returning home over using remote control to turn heating off after leaving home. This could imply remote control might increase rather than decrease use of energy in some circumstances. However, it is also possible that this facility might encourage people to turn their heating off or down when they go out knowing they can turn it back on or up before they return.

Participants were interested in getting more information about the cost of their heating behaviours so they could make more informed choices. A retired participant taking part in one of the workshops described how if he realised that the saving he was achieving by not heating his top floor was only minimal then he might be inclined to heat it after all. So it is possible in some circumstances that providing such information could *increase* energy use if the extra cost is perceived to be small.

6.8 Adoption

As well as scepticism around automation, there appeared to be two potential barriers to participants acquiring smarter heating controls. The first of these was that participants could believe there were bigger energy priorities in the home to address, such as single-glazed windows and poor insulation. The second was that most wanted to know the cost-benefit before they made a purchase. Often they had unrealistic expectations about payback time, expecting to see savings after a year, especially older participants. There was an intriguing suggestion that new heating controls could be bundled into energy packages like mobile phones are currently.

7. Conclusions

7.1 Emerging user types

The research findings have emphasised that households are different, and this is no more so than when it comes to considering how households use their heating systems. This research posits five different heating controls emerging user types. It is suggested that these be considered as a framework to aid thinking about future approaches to heating-controls and their design. People's lives and needs differ and the closer heating controls come to matching the lifestyles and needs of different users, the more likely they are to be welcomed by them.

7.2 User needs

The research was conducted to identify user needs for heating controls. From the requirements that have been inferred, four stand out as having particular importance: monitoring and controlling spending; being able to control times and temperatures in different rooms from one central panel; remote control to turn heating on before getting home; improved visibility of the system state.

Monitoring and controlling spending appeared to be important for many but is not currently incorporated into smarter heating control concepts. Some requirements were more associated with particular emerging user types than with others suggesting that there is no one-fits-all best solution to heating controls design.

7.3 Reactions to smarter heating controls concepts and implications for ideal controls

Automation only really appealed to 'Hands off'. Overall there was some scepticism that automation could work out what's best for householders, but analysis suggested it could help people reduce 'waste'. As reducing 'waste' and so minimising spending emerged as a key desire, it suggests that automation is potentially a good solution. However, participants struggled to envisage how automation would work for them; this was not a problem with zonal and remote controls.

Participants could also be confused about waste or whether their behaviours were 'wasteful' or not. Even though automation might be the most effective in reducing waste, participants would not necessarily choose it.

Remote control seemed particularly relevant to 'Ego-centric', but the appeal was more about turning heating on before getting home, rather than turning it off after leaving home. Because of

this, remote control could potentially increase energy use in some situations, but it could also be used by those who forgot to turn off their heating or those who do not know when they will be returning so leave their heating on to be sure their home is warm on return.

Zonal control had relevance for most, but particularly for ‘Reactors’ who tended to live in larger family homes. Zonal control would help them manage their use of heating while maintaining or improving comfort.

Remote and zonal control could perhaps be combined, with automation as an optional layer so that users could try it out and build trust in it over time. Ideal controls would also allow users to monitor the spending consequences of their use of heating and make informed decisions accordingly.

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