Programme Area: Smart Systems and Heat

Project: Consumer Response and Behaviour

Title: Smart Energy Solutions – the Consumer Perceptive

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This report was prepared for the ETI by the consortium that delivered the project in 2013 and whose contents may be out of date and may not represent current thinking.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 report seeks to synthesise evidence from across the different strands of the Consumer Response and Behaviour project in order to improve our understanding of how consumers currently use solutions for heating and cooling the home, and for providing hot water, and how consumers might respond to different characteristics of future smart energy solutions. Evidence is drawn from the full range of sources across the project, including existing literature, qualitative field research and quantitative survey data.

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.

Smart Energy Solutions – The Consumer Perspective

Final Report

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

Context

This report represents the core deliverable for Work Package 5.8 Solution Characteristics and is a retitling of

D5.8 Smart Energy Solution Characteristics

to

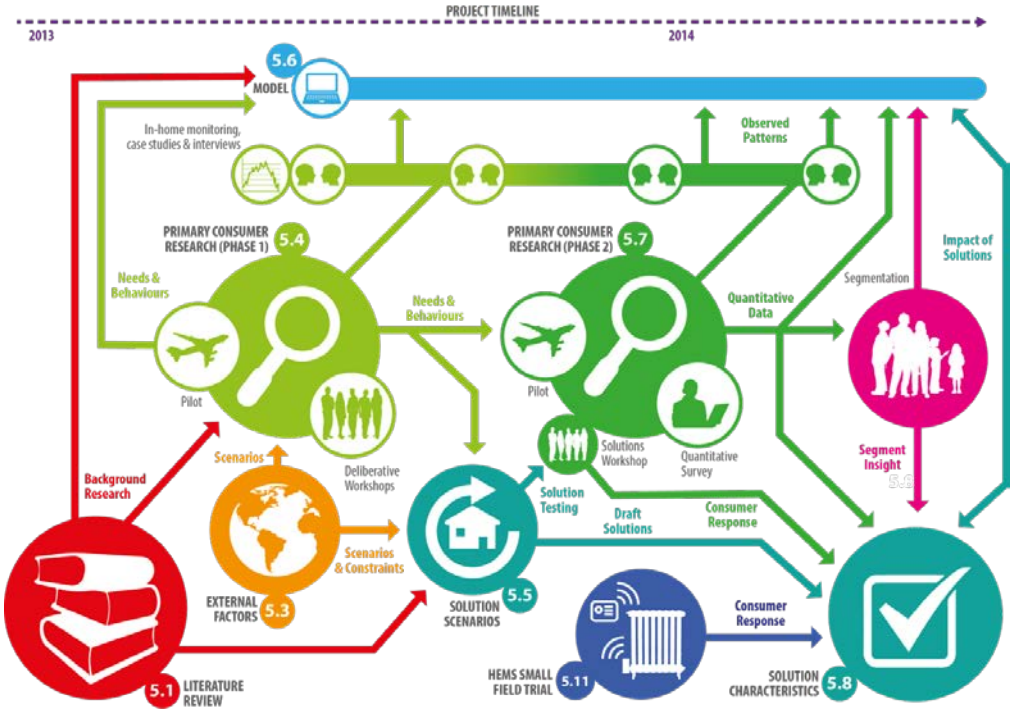
Smart Energy Solutions - The Consumer Perspective

This Report, *Smart Energy Solutions - The Consumer Perspective*, is one of the final deliverables of the Energy Technologies Institute (ETI)'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 the key 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.

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)** and details qualitative insights from workshops and interviews, and key case studies from the longitudinal in-home monitoring sample;
- *"Quantifying Heat Energy Needs and Behaviours"* - an output of **Work Package 5.7 - Primary Consumer Research (Phase 2)** and details quantitative insights from the mass survey into heat needs and behaviours and the resultant consumer segmentation;

- "*Modelling Insights"* - a key output of **Work Package 5.6 - Model** and details modelled insights into the impact of current behaviours and the impacts of changes to the household or energy system;

Executive Summary

This report seeks to synthesise evidence from across the different strands of the Consumer Response and Behaviour project in order to improve our understanding of how consumers currently use solutions for heating and cooling the home, and for providing hot water, and how consumers might respond to different characteristics of future smart energy solutions.

Evidence is drawn from the full range of sources across the project, including existing literature, qualitative field research and quantitative survey data as shown below.

Our qualitative and quantitative work led to a deeper and richer understanding of consumer needs, leading to categorisation of these five fundamental underlying dimensions of need.

- *Hygiene* – wanting to feel clean, keep the home clean and looking/feeling/smelling nice, keep healthy, and feel safe & secure. This also aligns with keeping a tidy home and the aesthetic appeal of the home.
- *Comfort* – being comfortable, feeling in control, and being able to rest and relax. This includes not being too hot or too cold but has broader connotations of being able to enjoy the home "comfortably".
- *Resource* – meeting concerns regarding the costs of energy and solutions as well as a need to reduce waste (or be more efficient). This category also aligns with needs related to environmental concerns as well as property maintenance and property value.
- *Ease* – doing what's easiest, keeping to everyday routines, habits and perceived norms. It represents convenience, simplicity and being able to get on with life without having to think too much about managing the heating
- *Other People* – looking after the needs of visitors and other members of the household, wanting to avoid arguments and be productive within the home, and concern for how the home and household appear to other people.

In this scheme, a sense of being in control falls in the *Comfort* dimension. A more general *Control* factor also has a cross-cutting role across all five needs, related to a desire to be able to enact

change (e.g. to control energy costs) by having authority over situations and technologies. We also found, in our qualitative work, that the way that people discussed control within the context of solutions raised insights that would be easier to convey in this report by separating it out from the *Comfort* dimension. As such, we have included “Control” as a sixth factor in this report, against which we present consumer insights.

Our qualitative work highlighted that although being warm in the home is universally important to consumers (with many suggesting that it is a "right"), the majority of consumers are typically able to meet their heat-related needs and, as such, day-to-day concerns about how they heat their homes are of low concern and low priority. Our quantitative work mirrored this finding by showing that 72% of people are always able to keep warm enough in winter. However, the 28% minority is significant and can be broken down as follows: 24% sometimes warm enough, 4% rarely or never; and 1% where it varies between household members.

We found, through both the qualitative and quantitative work, that consumers often employ complex and dynamic strategies for managing their needs (such as using primary and secondary heating systems in different ways combined with warm clothing, hot or cold food, etc.). In most cases it seemed that consumers were content with this multiple-method approach as it was adaptable enough to help cover a range of different need cases. As such, we found that consumers did not express considerable demand for an alternative solution.

Other barriers to change included lack of awareness of any problems with their system, lack of awareness of the cause behind any identified problems and lack of knowledge on how to optimise their current system. This last problem was often spoken of in terms of a reluctance to spend money on new solutions when they were not yet making the best of their current set-up.

We also found that installation of measures relevant to heating of the home was typically done in one of two situations: during a change of circumstances (including boiler breakdowns or changes in family composition) or as part of other home improvement works (e.g. an extension or major refurbishment). Very rarely, it seems, do UK consumers carry out works to their energy systems unless they have another purpose in mind (e.g. increasing space) or some external prompt.

However, this apparent low demand for new heat solutions is not insurmountable. Our research suggests that an approach to solution design that examines a full spectrum of household needs and considers how each component of a solution might impact these could lead to solutions that are more attractive to consumers. Furthermore, we suggest that solutions could present an attractive value proposition to consumers if they enhance or preserve the core needs of *Hygiene* (particularly health) and *Comfort* while also addressing other needs that currently may be unmet (e.g. if convenience is currently sacrificed in favour of reducing waste of energy).

Our quantitative work suggested that there are seven needs-based segments across the UK population. As such, one approach to solution design may be to consider designing solutions targeted at specific segments based on the needs that they feel the most. Our research has suggested that this may not be an effective approach for a number of reasons. Firstly, we found that needs are dynamic and variable within a household, meaning that many consumers may move between segments throughout the day. Secondly, the needs segments are based on quick responses (or surface-level perceptions) from our quantitative survey and, therefore, may not account for deeper needs that consumers are less aware of. In this case, solutions may be attractive at first, but may not be used effectively or otherwise enjoyed once installed. Finally, consumers are used to systems that allow them flexibility to manage their dynamic needs. The aforementioned complex control strategies allow consumers to respond to changes in household occupancy (e.g. when different people are at home), internal and external conditions (e.g. changes in the weather) and system conditions (e.g. if something stops working). Consumers seemed to speak highly of systems that were responsive to changing needs, both in the present and in the future (e.g. if the household changes or if they sell their home to a new family). As such, as detailed above, it is our recommendation that solutions should aim to meet a broad spectrum of needs and have flexibility of use built-in. Needs-based segments could, however, prove effective at the stage of *marketing* the benefits of a solution –

speaking to common, surface-level benefits that might encourage consumers to make a purchase decision.

In this report we consider, in detail, the evidence in relation to a range of different solution components and then highlighting the relevant insights according to different categories of core needs. Some of the most salient insights for each component are as follows.

- **Controls and Feedback** – consumers are interested in control systems that help them meet their needs of *Hygiene* and *Comfort* in ways that are less wasteful, reduce energy costs, are more convenient or help to manage multiple needs within the home. However, there appears to be a tension between wanting additional control and having too much to manage, particularly considering difficulties in using existing controls. Consumers are wary of solutions that provide high levels of automation, too, for fear that they will be ineffective at managing unpredictable requirements.
- **Heat Delivery and Localised Heat** – the key feature that consumers seem to want from technologies that emit heat (including radiators, underfloor heating and secondary heaters) is responsiveness – having heat that is provided immediately when wanted and stopping heating when heat is no longer needed. Flexibility of control is also a key desire. As such, many consumers favour secondary heat technologies that provide rapid, directional heat that allows for intuitive control and for varying heat demands to be met across the household.
- **Centralised Heat** – consumers seem less concerned with the way that heat is generated than they are with the above scenarios of how it is controlled and how it is emitted, as well as how they pay for it. Boilers are the most common option for generating central heat and a "safe default" for consumers when it comes to replacing them. Some key barriers to changing these technologies include up-front costs, disruption of installation and any additional works required during replacement.
- **Hot water** – as with heat delivery, responsiveness is key, with consumers wanting a hot water system that can provide the required quantities of hot water quickly and as needed. On balance, combi-boiler systems are typically preferred because stored systems suffer from problems such as limited supply, requirement for a store that takes up space and time required to heat extra hot water.
- **Cooling** – technologies providing active cooling (including mechanical ventilation) in homes are not as widespread in the UK as they are in some other countries or, indeed, in cars and commercial premises. However, the literature review suggests that a number of factors (warming climate, aging population, better-insulated homes, etc.) will tend to increase demand for air conditioning in future. Up-front costs of such systems remain a major barrier compared to the perceived benefits that consumers might enjoy from domestic cooling systems. Enhanced solar shading combined with improved passive cooling behaviours (e.g. cross-ventilation, night purging, etc.) may be a more cost-effective and energy-efficient approach. For cooling by ventilation, natural ventilation through windows is typically preferred to mechanical systems, which consumers can perceive as noisy and/or ineffective.
- **Insulation and Building Fabric Improvements** – loft and cavity wall insulation installations are widespread, however consumers have come to expect that such technologies should be heavily subsidised or provided free of charge, potentially limiting the willingness to pay for other types of insulation such as solid wall or floor insulation (which may suffer additional barriers such as disruptive installations and impacts on building appearance). Double glazing is a more popular solution that consumers seem more willing to spend money on, possibly owing to additional benefits such as security, noise reduction and enhancing property value. Measures that can improve thermal performance of dwellings while retaining appearance of period features are often viewed positively.
- **Installation Process** – most consumers have recent experience of carrying out works to their home (e.g. decoration, extensions, work to the heating system, etc.) and this is typically done "bit-by-bit" or grouped with other works as part of a larger refurbishment plan, dependent on resources and disruption/convenience. Our research yielded no specific preference for either approach, partly due to the wide range of factors involved (cost, hassle, scope of works, time of year, etc.) The key feature of the installation process seems to be the trust that consumers place in

technologies, processes and people carrying out works, with many choosing to carry out works themselves or looking to friends and family before seeking out other trades. Consumers typically want to feel "in control" of works and oversee them in person, despite acknowledging the hassle that this might introduce.

- **Advice** – the two core characteristics of advice provision that commonly emerge from consumer feedback are independence and trust. Consumers want to feel that advice being provided is not biased by commercial interests and that it comes from a source that they feel is credible and trustworthy. Often the sorts of advice that consumers expect relates to resource (e.g. how to use less energy, save money or how long technologies will take to pay back the up-front investment through savings).
- **Paying for Energy** – In terms of energy consumption, consumers typically seem to be detached from their energy bills and consumption (particularly if they pay by direct debit) and seem reluctant to switch suppliers for a range of reasons (including hassle, lack of perceived impact and existing account debts/credits). In the qualitative research, consumers expressed concerns about specific payment models presented to them ("Paying for Comfort" and "Community Energy" – presented in more detail in the main report body), particularly if they thought there could be increases in their bills, a sacrifice of control over heating to a third party, or reduced reliability or quality of service.

The full report uses these insights to present a table-based assessment tool that could be used to evaluate a proposed system based on individual components mapped against each of the six need categories detailed in this report.

Contents

1 Introduction

1.1 Purpose of this report

This report seeks to synthesise evidence from across the different strands of the Consumer Response and Behaviour project in order to improve our understanding of how consumers currently use solutions for heating and hot water and how they might respond to different characteristics of future smart energy solutions.

Evidence is drawn from the full range of sources across the project, including existing literature, qualitative field research and quantitative survey data. These sources are described in Section 1.2.

Originally conceived as a further development of concepts developed in **WP5.5 Solution Scenarios**, this piece of work has been revised to deliver a more useful reference for the Energy Technologies Institute (ETI) by drawing together findings and presenting them, in a logical structure, in reference to a broader range of solution types, seeking also to provide ETI with a useable tool to evaluate solutions from a consumer perspective.

1.2 Key inputs

Figure 1.1 – Key inputs into this Report

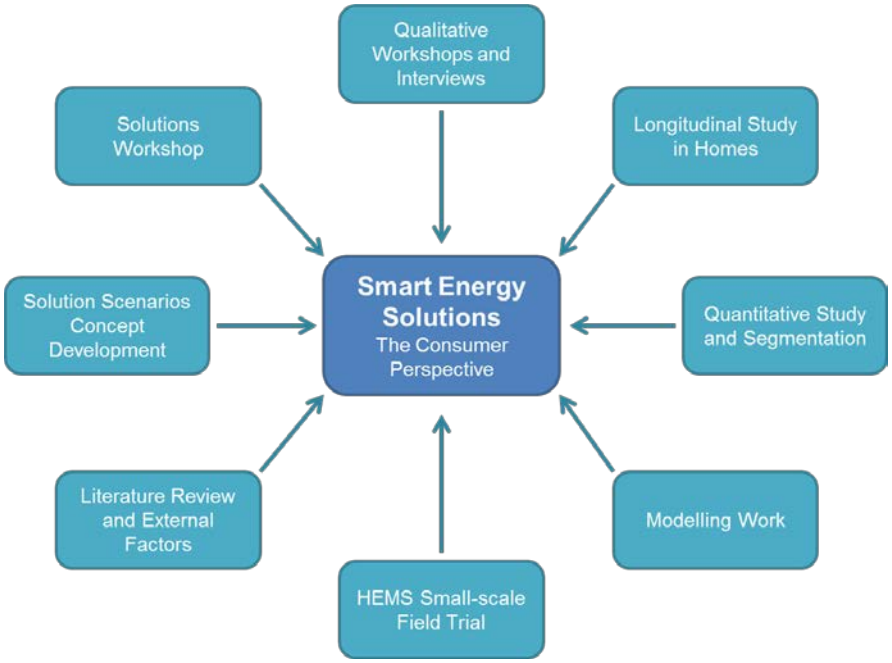


Figure 1.1 summarises the key inputs from across the Consumer Response and Behaviour project that have informed the findings in this report. Where appropriate, the report will seek to signpost the specific source of a finding.

The following sections detail the scope of each of these sources and how they have helped inform this analysis.

1.2.1 Literature Review and External Factors

As two of the earliest pieces of work within the Consumer Response and Behaviour project, the literature review and external factors review laid much of the groundwork for the project's understanding of consumer needs and behaviours related to heat.

The literature review sought to inspect the literature base to understand: the energy-related lifestyle services that consumers require (such as comfort or entertainment); the potential for changes to lifestyle; the preferred characteristics of their interactions with the energy system; the design features of successful consumer-focussed energy products; and the likely barriers to changes in technology and products.

The external factors review also inspected the literature but with a focus on the external constraints that impact how people use heat, specifically political, economical, social, technical, legal and environmental factors. The review aimed to improve understanding on how these factors currently impact consumers as well as how these factors might change between now and 2050.

The literature review has been particularly useful in this report to cross reference our findings against previous work - identifying if our findings contradict previous evidence. It has also been useful in this report to address any areas where evidence from our primary research may be missing (e.g. drawing on findings from ETI's Thermal Efficiency reports). The external factors piece has helped, primarily, to identify where some of our findings might change between now and 2050, particularly considering how and why cooling and ventilation are likely to become more important to UK consumers over the coming decades.

1.2.2 Solutions Scenarios Concept Development

The previous solutions-focussed element of the Consumer Response and Behaviour project was the Solutions Scenarios work, which developed six key consumer proposition concepts. These concepts considered solutions beyond the technologies involved but also to the full supply system that would best enable consumers to realise the benefits of each solution.

Figure 1.2 - Business Origami® Workshop

The concept development was rooted in the creation of personas based on the longitudinal sample of 30 homes (see section 1.2.5). Detailed summaries of six cases were drawn up (including details about the household, the property, existing system, attitudes, etc.) and draft solutions matched to their specific needs through an idea generation workshop carried out by ETI. These were then co-developed by the consortium and the ETI engineering team using Hitachi's Business Origami® process.

The resultant six solution concepts were:

- A Home Energy Management System (HEMS) focused on automation and providing health-related feedback on how to create a healthy home environment;
- A HEMS focused on its ability to be easily fitted (and removed) to an existing system featuring remote room-by-room control;
- A bespoke retrofit service providing a "one-stop-shop" for retrofit, from advice, survey to installation;
- Secondary heating technologies that could be controlled through a standardised wireless protocol and using remote, smartphone apps;
- A business model focused on providing a guaranteed level of comfort through the use of in-home sensors and provision of energy efficiency upgrades;
- A business model focused on a community-owned heat network and local area retrofit roll-out, with profits invested in the wider community yielding benefits in job creation and investment in local services and trades.

Originally conceived to be further developed in this later period of work, it was agreed with ETI to, instead, continue to test more basic elements of concepts with consumers rather than more detailed, thought-out concepts such as the ones developed at this workshop. As such the detail of these concepts is not vital to the understanding of the insights presented in this report.

Nonetheless, these concepts have provided the solutions workshop and longitudinal interviews with a wealth of material from which to draw out key prompts, probes and lines of enquiry.

1.2.3 Solutions Workshop

Building on the solution concepts detailed above, the solutions workshop opted, rather than testing the concepts themselves, to extract some of the core features of control or retrofit solutions and create ten simple vignettes (narrative stories plus drawings) to gain consumer feedback on these basic elements. The solutions workshop focussed on the benefits and challenges that consumers face with their current systems and presented the vignettes in the context of these.

Figure 1.3 - Solutions Workshop

Using a "deliberative workshop" format, the one-day session featured 30 members of the public, sampled against emerging insights from the wider project in terms of decision-making types as well as different experiences with making home improvements. After a plenary session, the group was divided into three groups of ten participants to engage in a structured group discussion. The morning session covered controls while the afternoon covered retrofit.

The workshop was designed specifically to feed into this report and is, therefore, a crucial source of insights into consumer response to specific solution elements.

1.2.4 Qualitative Workshops and Interviews

As one of the earliest pieces of fieldwork in the project, the qualitative workshops followed a similar "deliberative workshop" format as detailed above, but focussed instead on consumer needs and behaviours. Four workshops in total were held in different locations throughout the country, featuring 160 members of the public in total.

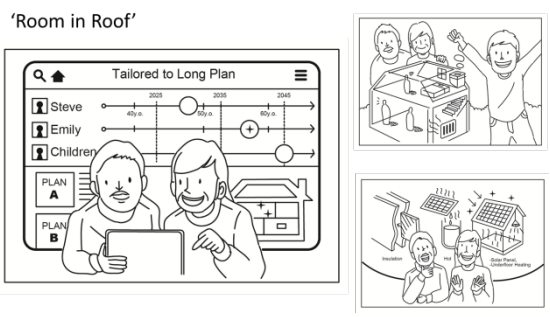
The outputs of this workshop helped inform some of the earliest insights into categorisation and interactions of consumer needs and behaviours, which much of this report is based on.

A series of qualitative interviews were also held with members of the public covering groups that were difficult to recruit for the workshops, who represented special interest groups. These included people in highly insulated homes, those with heat pumps, those with communal heating and those in fuel poverty. Relevant insights from these particular groups are a crucial input, particularly those where people are living with some of the solution elements that are being considered as part of a future smart system.

1.2.5 Longitudinal Study in Homes

From the qualitative workshop participants, a smaller sample of 30 participants were selected to participate in a longitudinal, one-year study of how people use energy in their homes. Four interviews were carried out throughout the year with each household, focusing on how needs and behaviours change throughout the year as well as discussing different aspects of smart solutions. At the final

Figure 1.4 - Solution Vignette



interview, participants were presented with a selected pair of vignettes from the full set used in the solutions workshop to gain further insight into consumer response to these.

In addition to the qualitative interviews, each home was fitted with a system of monitoring equipment to gain quantitative feedback on energy usage, internal environment and behaviours. The monitoring provided a vital basis for gaining a deeper understanding in how consumers currently interact with their systems, particularly in the complex control strategies and workarounds employed by the majority of households.

The final interview also included a technical co-interviewer who provided participants with bespoke energy tips based on the accrued understanding of people, property and energy systems. Consumer response to these tips were very positive and have informed some of the aspects of this report related to advice provision and consumer response to specific elements of the advice.

1.2.6 Quantitative Survey and Segmentation

Building on the insights into consumer needs and behaviour from the qualitative work, a large quantitative study of British homes was carried out with an aim to quantify insights related to needs and behaviours, targeting 2500 homes in the general public. In addition to a typical CAPI survey, the process included interviewer observations of existing systems.

The quantitative study has been useful in providing quantified statistics to support insights throughout this report, and validating assumptions from the qualitative work. The survey also helped better understand the prevalence of different needs and, in conjunction with the qualitative work, help achieve a better, consolidated understanding of consumer needs, through which solutions can be designed.

The results of the survey also yielded the development of a segmentation of consumer needs, with the hope that the segments may support the targeting of specific solutions at specific consumer groups. The results of the segmentation suggest that there is too much variation in typical sociodemographic or technological characteristics by which these segments could be defined, and that such characteristics would be poor indicators of consumer needs and likely response to specific solutions. However, the breakdown of needs is still a useful tool for understanding which needs are often felt in conjunction with each other for specific segments and is a useful part of the wider aim of using consumer needs to design desirable solutions.

1.2.7 Modelling Work

Utilising the data from the longitudinal study and combining this with modern building physics models has yielded an approach to better represent the way that consumers might interact with their systems. The modelling insights focus on better understanding how different energy behaviours interact with energy systems to result in different energy usage and create varying internal environments.

The modelling work has also aimed to understand the difference between consumers' desired environments and actual environments, highlighting the key opportunities for solutions to help consumers achieve a desired environment more consistently.

Finally, it has helped understand the impact on energy usage of changing the household or changing elements of the system, allowing some solutions to be evaluated according to this potential impact.

1.2.8 Small-scale HEMS Field Trial

Later in the project, a small, rapid field trial of two different smarter heating controls was commissioned by ETI. Intended to provide rapid learning, this study took a sample of twelve homes and installed a system that either focussed on remote control of heating or wireless zoning.

While the small, unrepresentative sample, limited timescales and limited depth of the study make it difficult to draw meaningful conclusions about the wider impacts and consumer responses to similar

smart controls, the study provides a rich source of case studies into how consumers use such controls and help illustrate a number of lessons into good practice in the design and installation of future controls.

1.3 What is a Smart Energy Solution?

A Smart Energy Solution, within the context of this project can be considered as any technology, or system of technologies, combined with suitable enablers and infrastructure, that enhances the consumer experience of energy. Crucially, it is not sufficient to look purely at technologies like intelligent controls or heat pumps; a true smart solution must consider the full user experience, including aspects such as the advice required to use it effectively, the installation process and the wider non-energy benefits that the solutions can bring to consumers.

This project aimed to gain a better understanding of consumer needs and behaviours in the context of their current home energy systems and, through this, to better understand their requirements to design better solutions. A secondary aim was to gather evidence on consumer response to solution elements. This evidence is presented in this report.

An assessment of our successes and limitations in terms of meeting these aims is presented in Chapter 14.

2 How this report is structured

The Consumer Response and Behaviour project is a large-scale programme of mixed-method research that has produced a wealth of data and insights. The scale and complexity of many of these findings makes interpreting the insights a significant challenge, particularly in usefully applying these to future design of solutions.

This report will therefore aim to summarise and simplify the insights from the project in the following structure:

- **Establish the baseline perspective** - How do consumers currently view solutions to provide heat and hot water, in general? How important are they to consumers? Are consumers willing to change their systems? What are the key challenges? What needs are solutions meeting or not meeting? How are they used? How does this impact the way we should think about designing solutions for consumers? [Chapter 3]
- **Consolidated evidence of consumer response to aspects of solutions** - A series of chapters bringing together the insights from across all areas of the research project, highlighting how needs drive response to specific elements of solutions. This will include:
    - Control and Feedback
    - Heat Delivery and Localised Heat
    - Centralised Heat Generation
    - Hot Water
    - Ventilation and Cooling
    - Insulation and Building Fabric Improvements
    - Installation Process
    - Advice
    - Paying for Energy

    Each chapter will be concluded with a summary of key findings ordered according to the relevant consumer need category. [Chapters 4 - 12]
- **Consumer-led solution assessment for solution designers** - An assessment framework that solution designers can use as a way of interrogating potential solutions, assessing them from the consumer perspective, with worked examples. [Chapter 13]

3 The Baseline Perspective

- Being warm in the home is universally very important to consumers. However, as the majority of consumers are able to usually achieve this requirement, day-to-day concerns about the *means* of being warm are generally of **low concern and priority**;
- Most consumers are able to meet their fundamental heat-related needs of comfort and health with their existing systems, often through the use of normalised, complex **control strategies** or "workarounds";
- There are a number of barriers to consumer take-up of solutions emergent from our work, including **lack of awareness of a problem**, **lack of awareness of the source of problems**, **lack of knowledge on how to optimise current system** and **no strong dislike of the current system**;
- When consumers *do* make changes to their system, this is typically **in response to a change in circumstances** (e.g. boiler failure or household changes such as the birth of a child) or **as part of other works** (e.g. installing a new boiler when replacing a kitchen or refurbishing the home);
- To make solutions more attractive to consumers, they should be designed around **consumer needs**, focusing first on preserving/enhancing existing standards of health/hygiene and comfort, then aiming to better meet other needs such as convenience, cost or harmony in the home.

Before detailing specific insights related to different components of a solution, there are a number of overarching findings that impact how consumers perceive solutions and how, in response, we should consider the design of solutions.

This chapter summarises some core findings from other reports, particularly the final qualitative report **What people need and do that involves heat energy** and the quantitative report **"Quantifying heat energy needs and behaviours"**.

3.1 How important is heat to consumers?

Across all areas of our research, the significant majority of consumers revealed that thinking about how they heat their homes was **not a significant day-to-day concern** for them. Thinking about heating their homes is of a low priority when compared to other daily priorities (high priority concerns vary between consumers, but heating is typically low).

"Life gets in the way… It's not your uppermost thought is it - the control of the heating in your house? Day-to-day problems take over, really."

- Solutions Workshop Participant

Another finding was that many people view being warm in their home as **"a basic right"** and are strongly protective of the preservation of this right. This is most apparent when considering the impact of either an energy price rise or a drop in household income - in either case, effectively raising the percentage spend on energy - the most common stated response is to make sacrifices in other areas, rather than taking steps to reduce energy consumption. A commonly held view is that "it costs what it costs" with consumers viewing their energy spend as a fixed requirement, similar to council tax or a mortgage, rather than something that they can impact by their own behaviour or choose to vary. This can be shown to stem from consumers' inflexibility to accept a change to their fundamental requirements of being warm in their home.

While these two findings may appear to be contradictory, the subtle difference between them is that the first relates to the *means* of getting warm, where the second relates to the *ends* of *being* warm. As such, while being warm in the home (the ends) is of key importance to consumers, the means by which they achieve this are of little day-to-day concern.

This highlights another important finding from across all research areas in the project - in the majority of cases **consumers are able to meet their heat-related requirements with their current systems**. 72% of households reported that their current strategies for keeping warm achieve their aims, 23% reported "sometimes" and only 4% reported "rarely/never". In many cases, they achieve this through the use of highly specific, often complex control strategies (or "workarounds") to make their systems work for their household's specific needs. On average, consumers utilise a combination of five methods to keep warm in their homes - most commonly a combination of all four of: use of heating systems, controlling where heat goes (e.g. closing internal doors), retaining personal body warmth (e.g. putting on a jumper) or heating the person (e.g. hot water bottle). These workarounds can be due either to a failure to fully understand/utilise the control capabilities of the existing system or a fundamental failure in the system itself to meet the needs of consumers. This finding, and the high diversity of different control strategies observed across all research areas, highlight the **high adaptability of consumers** to make a system work for them in order to keep them warm. This also highlights the significant finding that the seemingly infinite combination of people, property characteristics, system characteristics and associated workarounds ensure that **no two combinations are the same - all cases are different, sometimes only slightly, sometimes significantly**.

In the previous paragraphs, we have focussed on the goal of "being comfortable". However, in the course of our research, we have found that this requirement is part of a more complex and sophisticated suite of consumer needs. The work has also highlighted that needs work in a hierarchical fashion with **health** and **comfort** always at the core i.e. health and comfort needs must generally be met before focusing on other needs. As such, it can be stated that consumers' needs to be healthy and comfortable are, as above, generally met through the use of existing systems and their control strategies, which may lead to necessary trade-offs in other need areas (such as convenience or cost).

The key consumer needs and example hierarchy are detailed in Figure 2.1 and 2.2. A further key insight from the consumer research is that needs tend to manifest along a dynamic continuum where a consumer can move back and forth as dictated by their current circumstances. Once a more central need is met, consumers can move to focus on meeting more peripheral needs and are often less consciously aware of the need that has been met.

Figure 2.1 Consumer needs

Figure 2.2 Prioritisation of needs

The quantitative research reached a similar conclusion in terms of the groupings of needs, instead concluding with five core dimensions of need. It should be noted that the qualitative needs emerged from a detailed, in-depth, longitudinal exploration of needs over a year, whereas the quantitative needs represented a quick response of consumers in the context of a quantitative survey. As such, where the needs above can be seen as deeper, underlying needs, the quantitative needs are more "surface" and at the forefront of consumers' minds when discussing heat energy:

- **Hygiene** - typically using heating and hot water for the purpose of cleaning and looking after personal health. This also aligns with keeping a tidy home and the aesthetic appeal of the home;
- **Comfort** - typically more related to needing to be warm or otherwise enjoy the home "comfortably". The quantitative factor analysis also suggested that *Control* as a need, falls into the category of comfort - perhaps because consumers conceive their control strategies in the home in terms of how they can make the home more comfortable;
- **Resources** - as with the qualitative work, this comprised concerns regarding the costs of energy and solutions as well as a need to reduce waste (or be more efficient). This category also aligned with needs related to environmental concerns as well as property maintenance and property price;
- **Ease** - typically related to a need for convenience but also a need to conform with others as well as reliance on routines and habits;
- **Other People** - Again, similarly to the qualitative categorisation of "Relational Dynamics", this need focuses on how other people within the home impact the way that consumers use heat as well as a need to manage the needs or visitors (e.g. hospitality).

After consideration of the best model of needs to take forward into this report, it was decided to use the quantitative need structure (as this typically encompassed much of the qualitative needs) but to separate *Control* out as a distinct need from *Comfort*. Particularly in the context of solutions, this is seen to be a key consideration for consumers, particularly in terms of the depth and format of the control that they might have over their systems, the processes of acquiring new technology and the way that they pay for these.

In both cases, these changes are made to serve the purpose of better understanding needs in the context of solution design.

3.2 Are consumers willing to change their system?

As previously noted, consumers are generally able to meet their core needs of **health** and **comfort** through the utilisation of their existing system, supplemented by workarounds where necessary. Where new technologies might, in theory, allow them to meet these needs more easily or efficiently or with fewer workarounds, consumers still seem to be reluctant to make changes to their system (even when they are *able* to change - i.e. they are not subject to specific barriers such as property ownership, excessive upfront cost, etc.). Our research suggests a number of influencing factors, including:

- **Lack of awareness of system shortcomings** - particularly with people who have been living with the same system for a number of years, where the experience of the system has become normalised and they lack a tangible reference point of how the system could be different or improved;
- **Unsure of the source of the problem** - where consumers are aware of an issue (such as a particularly cold room) but lack the knowledge to identify the cause and, therefore, lack confidence in selecting an appropriate solution;
- **Unsure of how to optimise** - where consumers are aware of the presence of an issue but believe that improved utility of the existing controls and behaviours could improve the situation.

This belief in unrealised optimisation is a barrier to investment in a technical solution as consumers feel they could achieve improvements at no cost (financial and other costs such as hassle, time spent finding a solution and installer, etc.);

- **No strong dislike for the system, on balance** - as most consumers find their system meets their needs there are generally a number of positive things that they can identify that might serve to balance out negatives, which are often viewed as "frustrations" rather than serious issues.

There are two further common patterns of logic related to resistance to change and which underpin many of the above points. Firstly, the fact that the current system (with workarounds) generally works for most consumers often means that they don't see a strong need to make a change - or **"if it ain't broke don't fix it."**

Secondly, as many view being warm (and thus being healthy and comfortable) as a fundamental right, there seemed to be an undercurrent of **resentment at the idea of going through effort to make a change to the means** in which this right is provided, in some instances.

When changes *are* made to the heating system this is generally in one of two scenarios[1]:

- **In response to a change of situation** - this can further be broken down into planned and unplanned (or crisis) responses. **Crisis responses** are a particularly common reason for a change to many heating technologies such as boilers when they break down. Crisis responses are often made rapidly and regularly resort to defaults - like-for-like or similar solutions to what needs replacing (e.g. a standard boiler may be replaced with a more-efficient condensing boiler) . This also applies to controls, for example one case of the longitudinal sample (N1) recounted the time when his thermostat broke - when his maintenance provider arrived he opted for a like-for-like replacement rather than a more expensive solution offering remote control that he later realised he would have liked. Planned responses are often more carefully considered, as consumers generally have more time to make a decision. These are typically responses to changes that can be characterised as **life transitions**, such as having a child or retiring. Consumers will typically attempt to adjust their existing control strategies of their existing system before turning to a technological intervention, but may be more receptive to considering unfamiliar solutions than in response to a crisis;

- **As a secondary part of other works** - the other common time when new technological solutions are installed in consumer homes is as part of **wider home-making activities** where consumers are making changes such as adding an extension or refurbishing a kitchen. Such changes can be characterised either as changes that are driven by a functional use requirement (e.g. more space needed) or a desire to personalise the home as an expression of identity. In either case, the primary focus is rarely on heat, and heat-related technologies may only be installed due to a requirement (e.g. Building Regulations) or as an afterthought.

In either scenario, installation of heat solutions are rarely driven by the desire to change the way heat is used in the home.

3.3 How can solutions better appeal to consumers?

The previous sections have highlighted a number of challenges to the uptake of smart energy solutions. Particularly that a) most consumers perceive that their current system of technologies and

[1] These findings are broadly aligned with the findings of DECC's "More efficient heating study" which concluded that system breakdowns were the most common trigger for replacement, with 61% of people replacing because the boiler had broken down or was at the end of its life and 13% as part of wider refurbishment works. Our longitudinal study suggested, however, that there was more evidence for life changes impacting a decision on changing system than the DECC support suggests. This may be explained by the difference in sample or otherwise method variation (quantitative versus qualitative) where life changes could be a less "front-of-mind" trigger for consumers that is more likely to emerge through depth, longitudinal interviews over a rapid quantitative survey.
(https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/191541/More_efficient_heating_report_2204.pdf)

control strategies meets their core needs of comfort and health albeit often at the expense of other needs such as cost or convenience; and b) that the status quo of installing energy upgrades is generally in response to a technical failure or as an add-on to other homemaking activities.

For the first point, evidently, the key to designing more attractive solutions is to create solutions that are benchmarked against the current system's ability to meet the core needs of comfort and health (seeking to preserve or enhance this level), while addressing the wider needs that are currently sacrificed to achieve these.

For the second point, solutions should, in the first instance, seek to be compatible with existing market channels – end-of-life replacements and homemaking activities – to maximise exposure to willing consumers. Creation of a new market for installation of smart heat solutions is not out-of-the-question, but our research suggests that this will be a significant challenge and one that will require a step-change in consumer attitudes.

Another way to consider solutions is in terms of the way that consumers *experience* them, both in reality and in their perceptions, rather than focusing on the technical capabilities of the solution. This experience must be considered more widely than the heat- or energy-related properties of the solution and, instead, be assessed against the wider impacts that the solution might have on their needs. External wall insulation, for instance, may reduce the U-value of a wall, but the experience for the consumer is not just limited to the improved thermal performance and associated cost savings - it also potentially includes a change to the appearance of the building, a perception that this may negatively impact property value, a perception that neighbours or visitors might think differently about them, a loss of conformity with surrounding homes, concerns about poor workmanship, etc.

The consumer experience, both perceived and actual, is more complex than the energy-related properties of solutions. Therefore, solution design should take a more holistic view of how solutions can impact, positively and negatively, on consumer needs.

The following chapters detail how different elements of solutions impact on the consumer experience and provide evidence for how consumers may respond to these.

4 Controls and Feedback

- There is evidence that, while widespread and in most homes, many consumers have **difficulty in correctly using common control systems** such as thermostats, programmers and TRVs;
- Consumers are interested in improved feedback on the operation of their systems, although their interest is typically **based on comparisons** (e.g. energy consumption against an average benchmark, temperature against a dwelling average and humidity against thresholds for mould and condensation);
- Remote control is a **widely popular solution**, with many consumers anticipating benefits of being able to control their heating through a smartphone app or similar touchscreen display;
- Automation is favoured by some consumers but presents **a number of consumer concerns** typically related to the perception that automatic systems would be ineffective at capturing the varying routines and demands of the household;
- Zoning is another popular concept, with consumers noting **a range of benefits** that spread across all key need groups identified in Chapter 3. However, some concerns exist around the potential **complexity of trying to manage controls in multiple rooms**. Modelling work also suggests that the actual benefits of zoning may be limited due to internal heat transfers and occupant behaviours, particularly the opening of internal doors.

Controls are one of the most immediate and consumer-facing elements of a heating system. When available and when used correctly, they provide consumers with the ability to make whatever system they have respond to their specific needs. They also allow for changing needs (be these temporary, permanent, rapid or gradual) or different households to be catered for, by the same system, in a dynamic way. Put another way, controls have the potential to allow users to balance the operation of their system according to their personal prioritisation of all of the key need groups, and revise that strategy according to a dynamic shift in those priorities. As such, effective controls should be at the heart of any solution.

Effective feedback where consumers are provided with the information that they require to make informed decisions about their control and use of heat energy, also serve to assist consumers in meeting the full range of their needs.

This chapter examines the evidence relating to specific types of potential control systems and how this relates to meeting specific needs. The focus is on controls related to heating space rather than cooling or hot water. Controls for cooling are omitted specifically, due to very limited evidence available. Hot water control is omitted as many of the features that consumers wanted to change relate to the output, rather than the way it is controlled (See Chapter 7). However, the majority of the insights that inform solution design for controls and feedback in this chapter would equally apply to controls that include hot water and cooling.

4.1 Current controls and feedback

By far the most common types of current control systems in homes are room thermostats (75%), programmers (86%) and thermostatic radiator valves (or TRVs) (84%), with 63% of homes having all three types of device.

Room thermostats are typically mechanical (63%) and only installed in one place in the house (92%), typically the hallway/landing or living room (67% and 27% respectively - 94% in total).

Programmers are typically digital (63%) and also only installed in one location (98%) - usually in a visible location although 30% are enclosed in a cupboard.

Despite their widespread prevalence, there is evidence that consumers struggle to understand these controls and use them, as designed, to optimise their internal environment. A common finding from the longitudinal study (as reported by participants) was that often one person in the household takes full responsibility for adjusting the controls, with other household members either discouraged from interacting with them or lacking confidence in how they work. There was wide observed and reported variation in this, with some households finding that certain controls (e.g. thermostats) are used by multiple occupants and other controls (e.g. programmers) only by one. Similarly there were instances where usage was divided based on functions of control (e.g. multiple household members using a programmer's boost function but only one person adjusting the schedule). There was no discernable pattern in the evidence as to whether certain controls were more or less likely to be operated by one or many household members.

Despite this, even the people who interact with their controls regularly fail to make full or correct use of them. This seems to be due to a failure in understanding either **what the control does** or **how to use it**, or indeed both of these. To illustrate this two of the most common controls - thermostats and programmers - are considered, along with respective findings from the qualitative work:

- With thermostats, people often lack a full understanding of **what the control does**. While they understand that it can control the temperature of the room, a common misconception is that it does this by varying the output temperature of the boiler, rather than by turning the system on and off according to the ambient temperature. This misunderstanding results in a number of interesting behaviours:
    - Using a thermostat as an on-off control, turning it up to maximum when they want heat and turning it to zero when they are too hot. Many participants mentioned listening until they heard the "click" to know that the heating had come on;
    - Using a thermostat to heat the room up more quickly. A common belief seems to be that when a room is too cold, it will be heated more quickly by temporarily raising the set point temperature a few degrees. Interestingly, many maintain a default thermostat setting in the region of 18-22˚C despite this;
    - TRVs are regularly used in both of the above ways;
- With programmers, people often lack a full understanding of **how to use them**. Throughout the study we did not come across anybody who failed to understand that a programmer sets times for the heating system to be on or off, and automatically manages this, but many confessed that they did not know how to change the settings. The variation in programmers available is significant, with no standardised terms or symbols (e.g. "Boost", "Comfort+", "+1" all in use for the same function). Furthermore, many programmers seek to minimise screen size and numbers of inputs, making it more difficult for users to successfully and confidently operate the device. Many consumers feel that to operate their programmer they need to locate and use an instruction manual, which is often deemed to be too much effort. The result is that, even when programmer schedules fail to match occupancy patterns, consumers become accustomed to the set times and compensate by using the common "boost" or "advance" settings, sometimes on a daily basis.

When respondents from the quantitative study were presented with a range of potential improvements to the current way that they control their heating, **65% indicated that they would like a change**. While, for 9% of respondents, the change was in preferring more automation so they would not have to think about controlling the heating, the remaining 56% expressed an interest in enhanced levels of control. However, there was no overarching feature that people seemed to want. The most common desired features were to control "temperature in each room" (23%), "heat rooms more quickly" (23%) and control "remotely from outside the home" (19%).

Those who did want more control seemed to align to specific household types. For instance, **desire for more control was strongest in households with children**. This further breaks down to show that families with a pre-school child desired more control over temperature, room-by-room whereas

those with children that were all old enough to be in school showed a preference for improving control over the timing of heating. This finding supports some of the qualitative findings that highlighted that households with pre-school children tend to prioritise health and comfort (and thus, maintaining a warm and healthy environment at all times) at the expense of all other needs. Those with older children generally find that their comfort and health needs are more readily met and can therefore focus on needs related to reducing cost and waste (a key benefit of improved control over heating times).

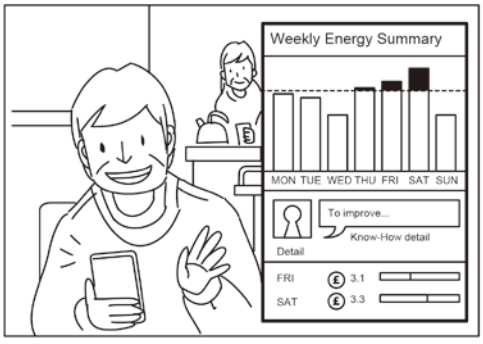
Households with **single occupants** and those where **all members were over the age of 60** were the two groups that stood out as those **least likely** to want additional control, with 53% and 59% respectively wanting no additional control or less control (more automation).

In terms of current feedback on energy usage, consumers are generally faced with very limited options. From the qualitative work, these include:

- **Perceptions of the current environment** - how warm, cold, dry or stuffy the current internal environment feels is the dominant way that all consumers have to make sense of how their system is performing. For example, placing a hand to a radiator is often the only way to tell if the radiator is currently on;
- **Digital displays** - in terms of heating these are often limited to digital thermostats, which are only present in 35% of homes and, in most cases in a single non-living room (i.e. a hallway or landing). These typically will only ever provide current set point and current actual temperatures, system on/off status as well as otherwise less-useful information in terms of energy use. Any displays related to energy consumption are typically connected to electricity usage, not gas usage (except a very small minority in smart meter trials) leaving no display that helps users make real sense of consumption of heat and hot water;
- **Meter readings and bills** - consumption over a period of time can be gained by meter readings and information provided on bills. However, this data is insufficient to help consumers make informed changes to behaviour as it is impossible to relate periodic consumption of this kind to specific usage cases and behaviours. Consumers also typically struggle to make sense of energy bills, finding that kWh are confusing and meaningless, with the only meaningful figure being the total cost.

There is clearly an opportunity to provide consumers with an improvement on these sources of information to support their use of controls to improve their experience with their systems. These will be discussed in the following section.

4.2 Feedback



Feedback can support consumers to identify potential changes, motivate them to change behaviour by informing them of the impact of different behaviours, and make it more convenient to understand how they use energy in the home.

Participants at the solutions workshop and in the longitudinal study were presented with a vignette focusing on a slightly more advanced form of feedback, where consumption information and basic advice were provided via a range of media, including tablets and smartphones.

Types of information that different people responded positively to include:

- Real-time and historic consumption (although there is disagreement over the best way of presenting this - kWh, cost-equivalent, or other. CO2 equivalent is generally poorly valued);

- Current environmental data - e.g. temperature and humidity - both internally and externally;
- Appliance-specific data - what is on and what is it consuming?;
- Target-related or benchmarked data - how does current usage compare with a pre-defined target or how does it compare to the usage of other, similar people?;
- Tariff data - particularly of interest to those who are on variable rate tariffs such as Economy 7;
- Behavioural recommendations - simple suggestions based on observed usage for how to save energy. Some also suggested that a way of keeping track of how much adopted behaviours had saved;
- Upgrade recommendations - less popular than behavioural recommendations, but some people were interested in a system that was able to point to specific upgrades and expected, quantified savings;

Further to this, the qualitative study featured in-home monitoring, which generated data and graphs on which to base qualitative lines of enquiry at interviews. Consumers were also shown the graphs and data at these interviews. Typically, the types of data that consumers seemed to value from the monitoring included:

- Energy consumption data when compared to a baseline - i.e. to identify whether they were high, medium or low users;
- Humidity data in the context of when it was at levels that might encourage mould growth and impact on health. Otherwise, humidity data rarely provoked interest;
- Temperature data in helping to identify which rooms were warmer or colder than others. While there is no direct evidence for the reason for this, our interpretation, based on wider qualitative interactions is that this was generally either to help them identify areas where they should amend their control strategies (e.g. by altering TRVs) or to confirm their perceptions (e.g. to confirm their belief that a certain room is colder).

It should be noted that these are all "comparative" by nature - i.e. consumers were less interested in absolute values of data but only when used to compare the readings to a baseline, be that in terms of other people, other rooms or thresholds for mould growth.

"I can't keep on top of all of that, it's like a day job."

- Solutions Workshop Participant

Most participants expected that feedback should be integrated with control systems to get the most benefit, rather than as a separate device, such as an IHD.

The presentation of information via a smartphone or tablet "app" had wide appeal, across a broad spread of demographics - this was true for most aspects of control or feedback.

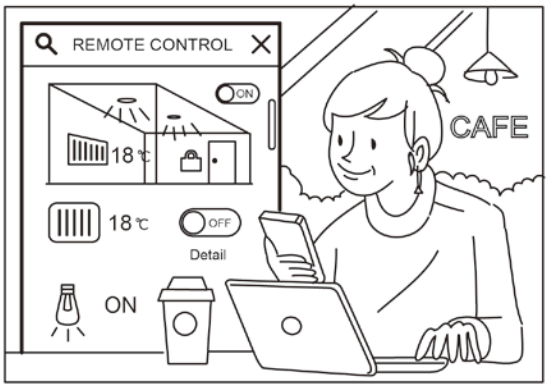
Improved feedback taps into a range of needs. Qualitative participants felt that it would provide them with a better ability to control their systems to help them reduce cost and reduce waste. They also felt that such systems could help reassure them when they were behaving efficiently (such as not engaging in wasteful behaviours), giving peace of mind and comfort. The key challenge in providing effective feedback devices is in making the information convenient and easy to act upon.

4.3 Remote Control

The concept of remote control of heating, via a smartphone app or (less-popularly) web dashboard, was one of the most widely appealing elements of a future smart heating solution, when presented as part of qualitative research activities. To those that were presented with a simple vignette (in both the longitudinal study and solutions workshop), they felt that it was a simple and straightforward idea. As

with the concept of feedback, consumers presented a variety of ways in which remote control of their system could help them. These include:

- Avoiding coming home to a cold home by turning the heating on remotely, increasing comfort;
- Avoiding wasting heat by turning off the heating when away from the home;
- Ease of ability to change system settings to meet changing routines;
- Increases overall control, making it easier to save money;



The small HEMS field trial included people with all of these expectations of the benefits that remote heating control could bring. However, despite the first two expectations (listed above) being the dominant pre-use anticipated benefits, the trial suggested that the third benefit (Ease of ability to change the system settings) was the most widely realised when in-use. The research suggested that this is due to users being less mindful of their heating system when out of the house - either forgetting to activate the heating on the way home or forgetting to turn it off when they were away. Conversely, the increased functionality and usability of the programming/scheduling functions was not seen as important a benefit before use because participants were either partly unaware of the inconvenience of their current programmer or because they could not fully anticipate how they would use the new user interface.

This highlights an important insight that sometimes the perceived benefit that will attract a consumer may not be the same as the benefit that they realise throughout the use of the solution. Solutions should therefore be designed with both in mind, although marketing may want to be focussed towards the perceived benefits that may be more closely aligned to consumers' front-of-mind needs.

Despite being popular with most consumers in the context of the qualitative work, there was some noticed variation across the population. Only 19% of respondents were interested in controlling remotely according to the quantitative survey. These respondents were more likely to have at least one child (25-26%), live in a household of three people (27%) and be in the highest quartile of income (34% compared to 11% in the lowest quartile).

Returning to the mismatch between the generally positive response from the qualitative respondents and the lack of interest from the quantitative sample (81% not interested in remote control), there is an argument that the difference in the way that the idea was presented could be an important factor. Whereas the quantitative sample were presented with a brief item in a list - "being able to control the heating system remotely from outside the home" - the qualitative sample were presented with a richer vignette, presenting some of the potential benefits of remote control. The quantitative response can be said to be an immediate front of mind response to a feature, whereas the qualitative response was likely based on a more considered assessment based on relating to the potential benefits of that feature. This distinction is important in the way that solutions like remote control are presented to consumers.

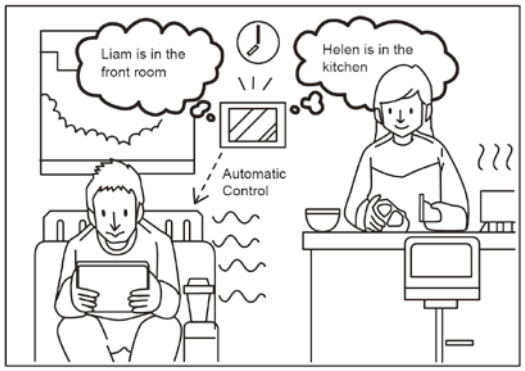
In general, consumers in the qualitative work expected remote control to function through a well-designed app, offering them the ability to easily set up schedules and providing them with simple feedback as to the functioning of the system.

They also expected the system to have a manual override such as a wall unit in place of the thermostat that would allow them to control their system in the absence of power or network downtime.

Crucially, when asked about data security concerns (such as hackers gaining access to heating settings or records of when it had been turned off for extended periods of time) respondents generally seemed unconcerned - suggesting that there are so many things that are done online now, with data generally being securely managed that there is no reason to worry more about adding an element like this to the Internet.

4.4 Automation

The concept of automation covers a wide range of control cases. Common controls such as a thermostat and programmer both perform automatic functions in activating or deactivating a heating system on the user's behalf. There is evidence that most consumers are satisfied with using these types of automatic controls whether or not they understand how they work. Programmers, in particular, are generally relied on, when present, to operate a heating schedule. Thermostats are often misused, either partly or completely, with consumers most commonly believing that a higher set point will heat a room more quickly and others using them as an on/off switch. However, in the first case, consumers will still often set a thermostat to a set point that they are happy with and allow the thermostat to regulate the temperature with little user input.



These types of automatic controls can be characterised by the fact that they obey a user-set instruction, only deviating when the instruction is changed by the user. Increasingly, though, modern controls are integrating intelligent/smart features that allow controls to be varied by the system in response to patterns of user behaviours, passive signals from consumers or external weather.

Of all the control features presented in this chapter this sort of automation is the one that presents the most concerns to consumers across both the quantitative and qualitative research activities. In general, the key concerns with automation relate to a perceived sacrifice of control and a lack of trust in a system to be able to effectively learn behaviours that consumers perceive to be unpredictable.

When qualitative participants (longitudinal study and solutions workshop) were presented with a vignette detailing a system that is sophisticated enough to determine whether people are in the home or not, and even in which room they are in, response was sceptical with some consumers being wary about installing a large system of sensors throughout the home both in terms of privacy and perceived cost of a system with multiple components.

"It feels a bit 'Big Brother'...it's taking the control away from you, isn't it."

- Solutions Workshop Participant

Perhaps unexpectedly, the people that were more interested in increased automation, according to the quantitative work, were singles over 60, where they were typically the group least interested by other controls that required more user interaction. Larger households were also more interested than smaller households.

For automation to be widely accepted by consumers, they stated that they would need assurance that control ultimately rests in their hands and that any changes made by the system through intelligent learning would be authorised by them. However, many participants agreed that if they are still required to authorise changes then that defeats the purpose of automation in reducing the hassle of having to think about heating.

4.5 Zoning

Zoning is the idea that different rooms or spaces within a home can be controlled to have a different environment and regulated to better match the different uses of different spaces, by different people and at different times.

The most common existing zoning controls are TRVs (present in 84% of homes) but there is evidence that these are poorly utilised. Many participants from the qualitative study found these inconvenient, often out-of-reach (behind furniture or in hard-to-reach corners) and in almost all cases only allow thermostatic control, rather than timed to match different patterns of occupancy. The insight that people often fail to understand the principle of thermostatic control further compounds this, with TRVs often used as if they were standard on/off valves. This may explain why, despite only 16% of people being without TRVs, 23% responded that they would like more control over the temperature in each room (i.e. many people with existing zoning controls (TRVs) still feel that they would like more control over this aspect).

The smart concept of zoning presented to workshop and longitudinal interview participants included wireless control over different heating emitters from a centralised control panel or portable smart device (e.g. a tablet computer) which allowed different zones to be controlled at different times. Along with the "remote" concept, zoning was the most popular with this sample. By considering the needs addressed by such a system it is easy to see why it appeals as it has the potential to improve the experience in each of the six categories we have identified:

"To be able to monitor and control the temperature in the nursery and then in the playroom and then in the living room all simultaneously via an app or a tablet while I'm watching television rather than having to keep an eye on the baby monitor to tell me the temperature, that would give me peace of mind that my daughter and the new baby are at a comfortable, optimum temperature for them to sleep."

- **Hygiene** - particularly with homes with young children, the idea of being able to maintain a healthy temperature for infants or those with special heating needs is particularly attractive;
- **Comfort** - a system that allows the balancing of temperatures in different rooms, meaning that each room is at the right temperature at the right time is universally attractive;
- **Resources** - almost all of those presented with the concept recognised the ability to optimise a system to reduce waste by not heating unused rooms;
- **Control** - many participants felt that this concept represented the most sophisticated and customisable way ("ultimate control" as one workshop participant called it) to make a system match the changing needs of a household, with the flexibility to easily alter settings as and when needed;
- **Ease** - whereas many people find TRVs inconvenient to operate, requiring you to go to each individual radiator whenever you want to make a change, the ability to control them centrally from a single interface was viewed as much more convenient. The ability to set different heating times for different rooms was also seen as a very convenient way to manage heating;
- **Other People** - whereas many consumers complain of different, personal ideal temperatures between household members, one appeal of zoning is the ability to create environments that suit different members of the family within the same home.

Despite its broad appeal, in this format, there were a number of consumers in the qualitative and quantitative samples who were less keen on zoning than other control types and some who pointed to aspects that would put them off.

Typically, single-occupant households were less interested in zoning than others. This is partly to be expected due to the correlation between household size and number of rooms. Many people who lived alone felt that because their home was so small, and they tended to use all the different rooms, their needs were met, so zoning was less important to them.

Another significant issue with zoning is a potential consequence of one of its key benefits - the high level of control and, therefore the perceived complexity that that would bring. Participants at the workshop and the interviews noted that they didn't want to have to think in that much detail about setting up different heating times for every room and were put off with the idea of having too much control. This complexity was realised, also, by some of the participants of the HEMS field trial where a system similar to the one detailed above was installed.

Beyond the challenges related to the user experience of zoning control systems is the question of how effective a control system such as this can be at helping consumers achieve the benefits they anticipate, particularly in terms of creating different environments in different rooms.

Evidence from the modelling work and the longitudinal study suggest that, for many homes, zoning may prove difficult to fully realise. A key reason for this is that, despite wanting to create different environments in different rooms, many consumers like to keep internal doors open. The qualitative sample, albeit small, suggested that a significant number of people like to keep internal doors open, based on reported behaviour and interviewer observations (internal doors were not monitored as part of the study). Reasons for this included the ability to talk to people in different rooms, allowing pets to move about, natural light reaching internal rooms and the general sense of the home as a whole rather than divided areas. Crucially, these are all valid reasons that provide benefits to consumers who may be unwilling to change their behaviours to support more effective zoning.

Modelled data suggests that this desired behaviour (keeping internal doors open) significantly reduces the ability to create separate zones. Furthermore, even with doors closed, the model has shown that internal heat transfer between rooms (e.g. through walls and floors) can limit the efficacy of zoning. This was observed in the HEMS trial too, where monitored data showed that even when the heating patterns were changed significantly between rooms, the internal environments showed less of a differentiation than might have been expected.

The modelling data also highlighted a potential risk that zoning could increase the risk of condensation and mould. By reducing the temperature in a space, relative humidity is likely going to increase. Higher relative humidity and cooler surfaces (e.g. walls and windows) increase the risk of moisture condensing onto these surfaces and causing mould growth. Mould growth can increase the concentration of mould spores in the air, which in turn can cause respiratory issues in people. As such, an unintended consequence of zoning could potentially be to create a less healthy internal environment.

4.6 Needs-Focussed Summary

It should be noted that many participants at the workshop and in the interviews naturally expected that the best control system would take elements from all of the concepts presented, even when not presented with all the concepts (e.g. in an interview when only the concept of zoning was presented, respondents, unprompted, mentioned that it could be even more useful if the system was able to be controlled remotely or was capable of learning or performing tasks automatically to reduce some of the burden of "too much control"). As previously mentioned, an effective and attractive control system will address a spectrum of needs and enhance the experience across the board. Here, we summarise learning against each core need category for control and feedback.

4.6.1 Hygiene

Controls that enhance consumers' ability to maintain a healthy environment in all rooms (and particularly in the rooms of more vulnerable people, such as infants) are appealing. Aesthetic appeal of controls and feedback devices is also important for consumers. Effective feedback that helps warn consumers of an unhealthy environment and advise them on the best settings to maintain healthy conditions are also of interest. Controls should not increase any risk of degrading the health of the internal environment (e.g. zoning leading to mould growth).

4.6.2 Comfort

Controls that better enable consumers to achieve desired levels of thermal comfort at all times are of interest. Controls that allow for flexibility in the achieved standard of comfort (as comfort needs change) are also beneficial. Enabling users to vary internal environment according to different household members' desired environment is also of interest. Controls should be wary about requiring changes that impact on positive enjoyment of the home (such as open internal doors).

4.6.3 Resources

Controls are an important way of allowing consumers to manage their energy consumption and, thus, their costs. They also can allow consumers to be less wasteful, through features that minimise heating spaces when they don't need to be heated. Feedback that helps provide live and historic information on consumption and allows consumers to identify wasteful behaviours or unnecessary appliance usage is also a valuable tool in helping consumers achieve their resource-related needs.

4.6.4 Control

Controls that enhance the ability of consumers to match their actual environment to the desired environment and adapt that easily and flexibly are key. Feedback that provides the best possible live information to consumers is also vital in giving them the ability to control their system. However, with both feedback and control, there is an important balance to be struck between the right level of information and controllability with information overload and overly complex controls that could put consumers off.

4.6.5 Ease

Controls that are conveniently located and simple to use are key. The best controls will take into account the varying types of user by providing a simple, intuitive user interface for those that may struggle with technology while allowing those consumers that are more technically-minded to create an optimised control solution for their home. Consumers are often particularly interested in using portable devices such as tablet computers to control their systems.

4.6.6 Other People

Controls that enable the needs of multiple people in a home to be met are of particular interest to larger homes. Zoning, for instance, has the potential to create different environments in accordance with different occupants' preferences.

5 Heat Delivery and Localised Heat

- The dominant theme emerging from research related to how people receive heat is **responsiveness**. Consumers seem to want to be able to have heat immediately when they want it and turn it off when they don't. It can be suggested that many secondary heat sources (e.g. fan heaters, fires, etc.) appeal for this reason;
- Radiators are the most common form of heat delivery in UK homes, accounting for 87% of cases. Consumers find them familiar and generally effective, but some concerns include **space requirements, aesthetics** as well as perceived **"dryness"** are common;
- Storage heaters have mixed appeal, but a common theme is that consumers would prefer radiators due to **limited control** and **responsiveness**;
- Underfloor heating appeals to many consumers, including those that do not have it. However, those that *do* have underfloor heating often experience problems around **responsiveness** and **cost;**
- Secondary heating technologies are used widely in UK homes, and for different purposes. Consumers often find that they provide an **effective way of managing multiple types of needs** in a flexible and responsive way making them a popular component of many household control strategies.

In all but the most well-insulated properties, heat is required to be generated by a heat source to keep people warm. In centrally heated properties and those with communal heating, this heat must be transferred to an output, or connected series of outputs, that "deliver" this heat to the end user (e.g. radiators or underfloor heating).

Traditionally, primary heating (central heating, for the majority of homes) is considered separately from secondary or localised heating (portable heaters, wood-burning stoves, electric blankets, etc.) as the system is characterised by the *source* of the heat. Our research has shown, however, that a significant proportion of the population makes use of both primary and secondary heating as part of an integrated strategy for meeting their needs. As such, it is helpful to consider the elements of the system that *emit* heat, both primary and secondary in tandem, to better understand what consumers get out of each and how they like to receive heat. To consider it another way, consumers seem to be more interested in the way that they experience heat than what produced it in the first place - be that a boiler, heat pump or communal biomass furnace. The consumer perspective on the characteristics of centralised (i.e. boiler, communal heating, etc.) technologies that *do* impact consumer choice (beyond the characteristics of the heat output) are discussed in Chapter 6.

This chapter considers the insights from our research into the way that consumers interact with and perceive solution elements that emit heat.

5.1 Radiators

In the UK, homes with radiators represent 87% of the population and in general, consumers view radiators positively. There is also evidence that those without radiators have experience of radiators, either from a previous home or from homes of friends or family and often state that they would prefer a home with central heating and radiators.

Radiators seem to appeal for a number of reasons. When deployed effectively (i.e. correctly sized and balanced) they provide a way to heat a room and maintain a stable temperature effectively and affordably. They also enable consumers, where appropriate, to avoid heating unused rooms or heat to a lesser extent using TRVs (although, as per our previous chapter on zoning, it seems more common that people will use TRVs as standard valves, having radiators either "on" or "off").

The ubiquity of radiators can also be seen as a benefit. As most people are familiar with heating spaces using radiators they are trusted and provide consumers with the confidence to heat their spaces.

There are other benefits to be noted from the use of radiators - most commonly the use of radiators to dry or warm clothes. This is most evident in the widespread use of towel rails in bathrooms that serve as a radiator but provide consumers with warm and dry towels when they get out of the bath or shower (and are potentially more likely to be cold). These benefits speak to the top consumer needs of hygiene/health and comfort and, as such, should not be underestimated when designing solutions that may not provide consumers with this utility.

As popular as radiators are, there are a number of issues with them as raised by consumers in our qualitative research.

- **Responsiveness** - Consumers acknowledged that radiators are relatively quick to heat up or cool down, as required, but that the delay (typically around half an hour) means that there are times when rooms are too cold or too hot, with consumers having to wait for the room (or the radiator) to reach their desired temperature, being uncomfortable in the process. Many consumers will turn to "workarounds" to overcome this delay, such as using secondary heat when too cold or opening windows when too hot. A desire for radiators that would provide heat "when wanted" or "instantly" was a frequent finding from respondents. This was repeated in the quantitative study with 23% of people saying they would like to be able to have more control over how fast they could heat their rooms;

- **Space** - Some consumers recognised that one drawback of radiators is in the impact on the usable space in a room. Apart from the space taken up by the radiator itself, the location of a radiator is, in most cases (although not all), understood to dictate that it should not be obscured by furniture/furnishings. This limits the way that rooms can be arranged or the amount of furniture that can be placed within a room - something that those with experience or underfloor or warm air systems seem to be more aware of;

"They're a waste of space. I'd rather they looked cooler, were hidden or just have underfloor heating."

- Longitudinal Study Participant M5

- **Aesthetics -** Some consumers also noted that radiators are "ugly" or not particularly nice to look at, expressing a preference for "hidden" solutions like underfloor heating;

- **Dryness -** A common belief is that central heating makes the air "dry", thus aggravating skin problems or drying out the mouth or throat. Our monitoring data suggested that this was not the case, with most radiator-heated homes experiencing moderate to higher levels of humidity (typically upward of 50% RH) or sometimes actually being too humid (over 80% RH) and at risk of condensation and mould[2]. Indeed, the "driest" home in our monitoring sample was with a home with underfloor heating rather than radiators. This highlights the fact that consumers may hold, and share, ideas about a solution element that do not match with observed data. However, these perceptions are still of vital importance to consumer uptake and must be considered accordingly;

- **Safety -** Typically a concern only with parents of young children or otherwise those with vulnerable household members - there was a small concern of risk of scalding on hot radiators. Where this did arise, however, it seemed to be a small concern that participants were able to manage (although rarely by reducing the system temperature on the boiler).

[2] A basic principle of relative humidity is that as air temperature rises, relative humidity falls as the air's capacity to hold water increases. With homes that heat all rooms to high temperatures, this means that humidity will drop as the space warms. The only potential additional factors specific to radiators that could cause dryness are related to convection currents and air circulation that could propagate dust and dry skin through air movement. However, these effects are expected to be relatively small. Indeed, these effects would be expected from other heating systems such as storage heaters. Notably, the complaint of dryness from radiators came from one longitudinal participant with storage heaters who believed that a benefit of storage heaters was that they don't dry the air like radiators.

Radiators can be said to meet most consumer needs for delivery of heat, particularly Health/hygiene and comfort. Where they do fall short appears to be in responsiveness (reduced convenience and control and temporary reduced comfort), impact on the use of the home (limited placement of furniture and aesthetic concerns) and some small health concerns (dryness of the air and potential scalding). All of these concerns, however, appear to be managed by the majority of consumers through workarounds or acceptance due to the perceived outweighing benefits or the perceived lack of an alternative.

5.2 Storage Heaters

Electric storage heaters are a common heating solution when consumers are in properties without a gas connection (although, crucially, not necessarily in an "off-gas" area) and exist in 8% of our surveyed homes and across three homes in the qualitative sample. They work by electrically heating a thermal store contained within the heater, usually overnight on a reduced electricity rate, and slowly releasing that stored heat over the course of the day.

Despite the different source, different operation and different configuration (i.e. room-by-room rather than a central heat source), storage heaters are analogous to radiators - both are solutions that radiate heat from a fixed point in each room. As such, many of the previously noted benefits and drawbacks to radiators similarly apply to storage heaters. Where they differ are as follows:

- **Control**[3] - All of our qualitative participants with storage heaters noted that the nature of storage heaters prevented them from controlling their heat effectively. Similarly, our quantitative survey revealed that those with storage heaters were more likely to want additional control. Participants described the experience as wasteful, providing heat when they didn't need it and often "running out" before the end of the day. In one case, a participant felt that on warmer winter days, the storage heater would cause her living room to overheat, and result in her spending more time in her bedroom or opening a window[4]. It was felt that storage heaters were poor at accommodating changes in the external temperature and that manually adjusting them by "predicting the weather" was impractical. Controls mounted on the heaters were typically poorly understood by participants, who blamed the installers for not explaining how they worked;

- **Responsiveness** - related to the above is the lack of ability to use storage heaters to respond to unexpected periods of need, particularly when too cold. All of our qualitative participants with storage heaters compensated for this by using secondary heating - typically plug-in heaters although, in one case, replacing a storage heater with a fixed electric heater in one room;

One person expressed a benefit for storage heaters over radiators - that she felt that storage heaters provided a "cleaner heat" without the dryness caused by central heating. Again, the monitored data in this property did not suggest that this was the true case, but the consumer perception remains.

Those with storage heaters typically stated that they would prefer central heating with radiators as they felt that they would be less wasteful and easier to control.

5.3 Underfloor Heating

Underfloor heating exists in two main forms - water-based or electric. Water-based systems are typically fed from a heat source such as a boiler, typically at a lower flow temperature than might be expected from a radiator-based system. Electric systems are based on heating elements looped underneath the main floor covering.

[3] Storage heaters typically have two controls - *input* and *output*. *Input* controls the maximum temperature that the storage medium can reach during an overnight "charge". *Output* controls the release of the stored heat. Higher output settings will release more heat but deplete the store quicker. Numbered settings on both input and output are often arbitrary numbers (e.g. such as those found on electric hobs or toasters) and require user trial and error for effective use. They also require users to be effective at predicting the required heat for the following day rather than responding to immediate needs.

[4] In one case, though, the participant expressed reluctance to open a window to cool down as she felt this would be wasteful as she had "already paid for the heat".

Underfloor heating is currently in a minority of UK homes although our evidence suggests that it is becoming more popular. Many of our qualitative participants (workshops and longitudinal study) without underfloor heating expressed a desire for it. Furthermore, those that had installed underfloor heating had often done so within the last few years.

The perceived benefits for underfloor heating (from those without it) were that such systems allowed for more flexible use of rooms (due to no radiators), aesthetically pleasing spaces (again due to lack of radiators), cheaper operation and the pleasant sensation from walking barefoot on a warm floor.

Conversely, those *with* underfloor heating (six out of thirty in our longitudinal sample - although four of these were only in part of the house such as a kitchen or conservatory. Only two cases had underfloor heating throughout; both being flats) were less positive, highlighting two main problems with it:

- **Responsiveness -** consumers with underfloor heating often complained that the system was much less responsive than radiators, in some cases taking days before the floor was warm enough to keep the house warm - there was no perceived way to vary the heat output rapidly enough to meet changing needs;

"Aesthetics is important, but not at the expense of comfort."

- Longitudinal Study Participant N25

- **Cost** - despite the above perception that underfloor heating would be cheaper, all those in our longitudinal study with underfloor heating felt that it was an expensive system to run and, in some cases, would sometimes avoid using it in favour of secondary heating (used as a "top-up").

It is worth noting that none of our participants mentioned that the underfloor heating had removed a way to dry clothes (as in the case of radiators).

In general, underfloor heating appears to be more popular with those that *haven't* installed it than those that are living with it. This may be because the perceived benefits are more tangible than the drawbacks. However, it should be noted that despite participants raising complaints with the system, in most cases there was no suggestion that they would prefer to revert/replace with a radiator-based system.

5.4 Warm/Forced Air

Warm air, while popular in other parts of the world (e.g. two-thirds of Canadian homes are heated by forced-air systems), is not widespread in the UK - only 1% of our survey sample were heated this way. Air is typically heated by a boiler and then forced around the house via ducts leading to vents in the floor, walls or ceilings. Such systems were popular during the 1970s but, in most cases, have since been replaced with a radiator-based central heating system.

Only one of our qualitative sample had a warm air system, as such there is little we can directly conclude from this single case. However, some insights from this case are relevant when compared to some of the other solution elements discussed in this chapter.

The participant described the differences between the forced air system and his prior experiences with radiator-based systems as:

- **Responsiveness** - the warm air system provides heat "pretty instantly" and the respondent finds that the house can be heated to a warm temperature "within 5 minutes" - faster than a radiator-based system;

- **Control** - while the respondent noted that it was possible to choose which rooms to heat by opening or closing vents, he said this was "a bit of a pain", particularly for the vents in the ceiling, which required standing on a chair or stepladder to reach.

Overall, the participant stated that he would prefer a radiator-based system as he felt it would be easier to control using TRVs, but also because it was familiar to him, having been the system he had "grown up with".

5.5 Secondary and other localised heat

Secondary heating is a blanket term that can apply to many different types of heating that are generally thought of as *in addition to* the primary heating and often thought to be used during specific times of need (such as particularly cold weather or primary system breakdown). However, our research suggest that in many cases, "secondary" heating forms an integrated part of consumers' day-to-day heating strategies.

For the purpose of this section we will consider secondary heating and localised heat to include portable heaters, fixed gas burners, electric "fires", ovens, wood fires and heating the person directly (e.g. through hot drinks, hot water bottles or electric blankets). The common thread of these is that they provide rapid heat in a specific location chosen, on-demand, by the user, as opposed to heating the whole home.

5.5.1 Common Themes

Across the different types of heaters discussed in this section there are a number of common themes that emerged across the qualitative sample as to the reasons why they make use of secondary heating or localised heat:

- **Responsiveness** - many participants felt that secondary solutions, particularly portable heaters, provide the best way (available to them) of getting warm quickly when the primary system is not used or not supplying enough heat. Some participants would use portable heaters in bedrooms to heat rooms rapidly in the morning when waking up;

- **Control** - most participants felt that secondary heaters were simple and very easy to control - in most cases, simply being on or off whenever they need heat and, in many cases, varying the heat output by adjusting a dial or adding more fuel;

- **Cost** - a common view emerging from discussions with users of secondary heating was that this was a cheaper way to keep them warm - by not heating a whole house and only having the heat on when/where they need it, they are saving money. There is evidence that, in some cases, this is true, although our modelling work suggests that it will often be a false assumption[5]. For instance, one large home in our longitudinal sample has found that rather than heating the upstairs of the property (exclusively bedrooms), only heating the ground floor with the primary system and using only portable heaters in the upstairs, has saved them noticeable amounts on their bills. It should be noted that this case is off-gas and, thus their primary system is electrically heated as well;

- **Waste** - related to cost, some participants felt that only heating the space that they were occupying was a more "efficient" way of heating and that centrally heating a whole home would be more wasteful;

- **Convenience and Flexibility** - related to the earlier points on control and responsiveness, many participants noted that secondary heating was better at helping them match unpredictable occupancy cases and different use cases of rooms. Again, with the large home case mentioned above, being a large household, it was difficult to keep track of who was going to be home and when. Portable heaters in each bedroom provided a convenient and flexible way of ensuring that rooms were only heated when people were using them;

- **Varying Household Members' Needs** - similarly to the above point, localised heat solutions provides a way for consumers to meet the heterogeneous needs of other members of the household. This particularly emerged in meeting the needs of children, where members of the

[5] Our modelling work also explored the question of whether secondary heating could be more cost-effective than heating the whole house. In general it found that, where gas central heating was present, secondary heating, even in limited locations and for limited time, would be unlikely to make significant savings on bills and, in some cases, result in higher energy costs - this is largely due to the higher unit cost of electricity compared to gas.

qualitative sample were able to use portable heaters in bedrooms or living spaces when children were sleeping or doing homework, while other members of the household were happy with the temperature provided by the primary system.

It is worth noting that most of these common themes align directly with the top needs identified in our qualitative and quantitative work, as described in Chapter 3. As such, it is not surprising that secondary heating is a popular component of consumers' heating strategies.

5.5.2 Portable Heaters

Portable heaters were used in 25% of the surveyed cases although featured in a higher proportion of the qualitative sample. Typically these tend to be oil-filled plug-in heaters or fan heaters. Beyond the reasons listed in 5.5.1, the benefits that portable heaters specifically provide, according to participants include:

- **Portability -** the nature of portable heaters is that they can be deployed wherever in the home they are needed and moved when household members move from room to room. While some participants chose to purchase multiple heaters, others noted that they would move their heaters between rooms during the course of the day;

- **Other comfort** - only emerging in one case, but still of note, is the case where one participant who works from home found that the noise made by his fan heater was a comforting and pleasant background sound. The same participant often used the heater on his legs while working - stating that this was not because he needed the warmth but because the feeling of warm air blowing on his feet and legs was pleasant while working at his desk.

5.5.3 Fixed Gas Burners or Electric "Fires"

While analogous to radiators or storage heaters, participants with fixed gas heaters or electric "fires" where there is an exposed, visible element, spoke of other benefits/concerns from this sort of heating:

- **Aesthetics** - as with wood fires, below, an open flame or a glowing emitter was seen by many participants as aesthetically pleasing, providing a visual and sensory experience that consumers said they valued. One participant also had an electric fire styled to look like a wood-burning stove that had the function of lighting up with a flame effect even without the heat being on. This feature was often used in evenings when the space was warm (e.g. in summer) for the aesthetically pleasing effect;

- **Safety** - one participant with electric "fires" in a home with young children stated that although they liked the effect and warmth produced by this technology, they were worried at the high temperatures produced and the danger posed to the children. As such they rarely used these technologies and, when they did, had purchased large wire guards that extended into the room to prevent the children getting too close.

5.5.4 Ovens[6]

Aside from the fact that ovens give off heat as a "by-product" of cooking, one participant in the longitudinal sample noted that they sometimes used their oven to heat the kitchen. In this case, he had no central heating, only gas fires, and felt that the oven provided a more efficient form of heating.

Another participant at one of the early qualitative workshops also spoke of using his oven to warm up, saying that he would sometimes come in with cold hands and warm them up over a gas hob. In this case he stated that it was because it was the "quickest way" to get them warm.

[6] Note: While there are also homes that are centrally heated by range cookers, we had no cases in our sample with this particular solution so have been unable to explore any other specific benefits to this type of system.

5.5.5 Wood Fires

As with gas and electric "fires" listed above, wood-burning fires and stoves provide similar benefits and a similar consumer experience. However, there were additional benefits noted by participants on this technology. Also, multiple participants mentioned their desire to have a wood-burning stove while none expressed a desire for electric or gas alternatives.

- **Aesthetics** - as above, an open flame was seen by many participants as aesthetically pleasing, providing a visual and sensory experience that consumers said they valued. In addition to that, people spoke more specifically of the creation of a focal point for the room and the "homeliness" created by a wood fire. Others mentioned the pleasing sound of wood crackling while burning;

- **Efficiency** - one participant spoke of a friend who had installed a wood burner that was 95% efficient. This appealed to him and he was actively looking at pursuing this measure. He noted that this efficiency appealed to him as he felt that traditional open fires were "about 35-40% efficient" with most of the heat "going out the chimney". He also noted that he would prefer this to a fan heater, partly because of aesthetic reasons but also because he felt that 95% efficient was much more efficient than electric plug-in heaters that were "a waste";

- **Environmental Concerns** - while not present in our sample, other research involving the installation of wood fires (such as the ETI's Optimising Thermal Efficiency of Existing Homes project) revealed that some people chose to install a wood fire for environmental reasons and to reduce the carbon footprint of the home. As noted in other reports in this project, environmental concerns are not as widespread as other needs, but for a small sample of the population, the carbon neutral nature of wood burners is an attractive characteristic;

- **Waste Disposal** - one participant with an open fire spoke of how the fire was a convenient way to dispose of combustible waste (generally paper - including wrapping paper at Christmas and confidential waste);

- **Safety** - one participant stated that they did not use their fireplace - not out of fear of burning the children in the household - but out of fear of fumes. They stated that a friend had told them that unless the chimney was cleaned regularly that they were at risk from carbon monoxide poisoning. As such, he felt the fire was unsafe and stopped using it.

5.5.6 Direct Heating of the Person

A number of solutions fall into this category, including electric blankets (both on beds and as heated blankets to wrap around the person), hot water bottles, having a bath or shower (although this will be discussed more in chapter 7) or having hot drinks or food.

Aside from the general themes listed in 5.5.1 participants often spoke of these methods as luxuries, treats or as otherwise pleasant things to do, even when the space may be warm enough. The other time that these solutions were discussed was during times of illness, to aid recovery or to cope with more chronic conditions.

5.6 Body heat retention

The most common methods for heat retention in the context of this chapter relate to preserving the body's own heat by insulating it from the surrounding space, either by adding clothes or using a blanket/duvet.

Most participants mentioned use of one of these methods at some point to keep warm in the home as a feature of their "control strategy". The quantitative sample, too, highlighted the high prevalence of these methods - 62% of people wore warmer clothes, 45% used warm bedding (e.g. a duvet) and 31% would use their bedding in other parts of the home.

Heat retention was seen by many as a positive way to keep warm, and "less wasteful" than heating the whole house/room. Otherwise, many of the described benefits align closely with those listed in section 5.5 for localised heat. In addition to the common themes listed in 5.5.1, some participants noted that adding or removing clothes or using blankets was an effective way of managing body temperature during varying levels of activity - e.g. taking off a jumper when doing housework or putting on a jumper or blanket when sat watching television.

However, heat retention behaviours seemed more prevalent in our qualitative sample in low income households and older households. Heat retention behaviours were actively avoided by multiple higher income members of our sample. One case in particular, who worked from home and thus spent much of his time there, noted that he preferred to wear fewer clothes at any time of year as this was more comfortable. He noted that he could afford to heat the space so would rather be comfortable in what he was wearing. Those that *did* add clothing when cold did not mention this being uncomfortable - this could indicate an issue of personal preference but where preferred comfort still is of core importance in making decisions in how to manage heat.

5.7 Needs-Focussed Summary

5.7.1 Hygiene

There are many health/hygiene related characteristics of solutions as discussed in this chapter. Firstly, radiators are notable for their use to dry clothes or warm towels, preventing mildew. Also, as an alternative to open fuel-burning heat emitters (e.g. fires), present a safe alternative by removing the risk of dangerous fumes. There were, however, downsides to radiators related to Hygiene. These include the risk of scalding, the impact on ability to place furniture where desired and a perception that they are "unsightly". There was also the perception that radiators would make the air "dry" (despite monitored evidence to the contrary).

Localised and secondary heating often provided a way for people to manage periods of illness by providing directional and immediate heat and also to look after the health of young children. Heaters with open flames (or even a flame effect) were also seen as aesthetically pleasing. Such localised heat sources, particularly "fires" were also perceived as being potentially dangerous - either from burning or from inhalation of dangerous fumes.

5.7.2 Comfort

As the technology components that transmit heat to the body, the comfort aspects of these technologies are key to the provision of comfort. A major theme throughout this chapter has been responsiveness - a theme that could potentially fit against any or all of these core needs - but the key message is that consumers want solutions that can provide them heat when they want it and stop emitting heat (or potentially even cool) when they don't. The long warm-up periods of radiators and other common primary systems was cited by many as a problem (with 23% of our surveyed consumers stating that they wanted more control over the speed at which their system heats rooms) and leading to periods when they were either too hot or too cold and where many would turn to secondary heat or body heat retention as a quicker way to be comfortable.

Underfloor heating was felt by many as a comfortable solution by warming feet, although those *with* this solution often complained that the lack of responsiveness of underfloor systems meant that there were many periods where this solution did not meet their comfort needs. Similarly, heat from secondary or localised heat was noted as a comfortable or pleasurable experience by many. Storage heaters were seen by some as poor at meeting comfort needs and, sometimes, leading to overheating in winter.

5.7.3 Resources

As above, responsiveness of systems at providing heat only when needed (and immediately) was seen as a common complaint at increasing costs without benefit and wasting energy. Others feel that central heating, in some instances, can be more expensive than using secondary heaters only in

rooms as and when needed (although modelling evidence suggests that this perception may be false).

Underfloor heating was particularly noted by participants at being expensive to run.

5.7.4 Control

Again, responsiveness of the system is a key concern for consumers. The slow response of underfloor heating and storage heaters is a common complaint with many, particularly those with storage heaters stating that they would prefer a radiator-based system. However, even those with radiators note that radiators take too long to respond to any control they might dictate.

The solutions that most commonly provided consumers with the most control in this chapter were secondary heating solutions (such as fan heaters and fires that provide near instant heat) and methods for retaining heat such as blankets or warm clothes.

5.7.5 Ease

Radiators, as the most ubiquitous emitter of heat in UK homes, provide consumers with a familiarity that makes it easy for consumers to integrate them into their heat control strategies. Other solutions seemed to be more inconvenient for consumers - underfloor heating due to lack of responsiveness, storage heaters by low flexibility to adapt to changing external temperatures and warm air due to hard-to-reach vents.

As with "Control", the solutions that consumers seemed to find most convenient, simple and flexible were secondary/localised heat and heat retention activities.

5.7.6 Other People

As previously mentioned, the ubiquity of radiators makes them a popular solution in terms of convenience but also in terms of social acceptance. The only types of solutions that seemed to relate to the way that people manage others needs in terms of harmony or hospitality are secondary and localised heating solutions and heat retention behaviours.

Wood fires (and, to a lesser extent, gas and electric fires) provide consumers with a focal point in their homes to bring families together and are seen as a way to create a welcoming environment for guests. Portable heaters and heat retention (e.g. adding or removing clothes) are seen as effective ways to manage varying needs within the household and ensure household harmony.

6 Centralised Heat Generation

- There is evidence that consumers are **less interested in the technology that produces their heat** than in how they receive, control and experience the end product (as detailed in Chapters 4 and 5);
- Individual-dwelling-level **boilers are the most common way of generating heat** and are seemingly considered by many consumers as a safe "default".
- Heat pumps are generally well enjoyed by those consumers that currently have them installed, with some noting that they presented a cheaper alternative to their previous boiler-based system. Concerns include **high upfront costs, disruptive installation, lack of good information and the requirement, often, for additional works** (e.g. to the building fabric or heat delivery/radiator system) to be carried out as well;
- Communal heating most strongly impacts consumers in **how they control** and **how they pay for their energy**. Other findings relate to concerns regarding the perceived sacrifice of authority to decide when the system is switched on or off as well as having no control over the maintenance and repair of the system.

In the previous section we considered the factors in terms of heat delivery that matter to consumers. A critical factor is that consumers want to have a system that is highly responsive, providing heat instantly, flexible and wherever it is needed. In this chapter we will consider the technologies that provide heat to a distributed delivery system, be that a heat pump, a combi boiler or communal combined heat and power (CHP) engine. As we have covered the characteristics of the heat that consumers want to receive and how they want to control it, this chapter will focus on other ways that the choice of central heat source impacts on consumers (although the way that it might impact on how they pay, such as with communal heating, will be considered in Chapter 12).

6.1 Individual Boilers

Individual (i.e. one per dwelling) boilers are the dominant heating source in UK homes and were reported or observed in over 95% of our surveyed sample (although there is some evidence that some people confuse a cylinder or water heater with a boiler). The majority of these are mains gas fuelled and supply central heating systems with radiators. As with central heating, the ubiquity of boilers make them a "default choice" both for consumers and installers. When discussed with participants in the qualitative sample, they would rarely talk about considering an alternative to a gas boiler, instead talking about replacing or potentially looking for a more efficient model. As with many of the other technologies discussed in this report, the norms of existing systems can arguably be perceived as "safe" by many consumers and an easier decision for consumers to make. As noted in Chapter 3, boiler replacement is typically done at the point when the technology fails, and our evidence suggests that consumers rarely have planned for this failure; the urgency of the decision-making process can be seen to encourage low risk, like-for-like replacements.

Consumers in our qualitative sample rarely interacted with their boilers. Some expressed nervousness at "messing around" with the controls that had been set by the installed and so did not take advantage of controls such as radiator flow temperature or hot water temperature.

Boilers are also seen to have a high capital cost - something that was mentioned by a number of the qualitative sample, who noted that they would rather endure a system they knew was inefficient than spend money on a new, more efficient system. While consumers seemed to value efficiency in their boilers, there also seemed to be a pervasive attitude that replacing a boiler before the end of its useful life would be wasteful, despite the acknowledged inefficiencies with old systems. Consumers seemed to have varying notions of what a boiler's lifespan should be, though. One participant from the longitudinal study expected that his new boiler would last 15 years whereas another had a boiler that

had been installed in the 1970s, which was still operating, leading to the belief that 40 years is a feasible lifespan for a boiler.

One longitudinal study participant noted that his older boiler used to have a flue that rose up out of the roof, with the flue pipe running through an upstairs airing cupboard. When replaced, the vertical flue was removed and the new boiler flue was installed directly out through the kitchen wall. This respondent noted that this had lost them the benefit of being able to dry clothes in the airing cupboard.

The appearance of boilers also seems to be of importance to consumers. One participant noted that their motivation for replacing their old boiler was due to their kitchen refurbishment and the old boiler looking out of place in the new surroundings. More still were observed to be installed and "boxed in" to a cupboard so that the boiler could not be seen. As previously noted, consumers seem to have a preference for not thinking about how their heat is generated - they just want to meet their core needs. As such, we can surmise that they would rather their boilers were "out of sight, out of mind".

Fuel type seemed to be a concern for some participants, with those with gas boilers noting the convenience of mains-gas whereas households with oil deliveries noting that this was inconvenient and expensive. The requirement for a store for the oil too was noted by one participant as taking up valuable space.

One final observed impact of boilers on consumers is in terms of the noise they make. One qualitative participant noted that the noise made by the boiler was enough to wake their baby and, therefore, they would often avoid having the boiler come on early in the morning to warm the house and use other control strategies for keeping warm during those times.

6.2 Heat Pumps

Heat pumps (both air source (ASHP) and ground source (GSHP)) are viewed by many as technologies that could be widely deployed in UK homes in the future as an alternative to boilers. However, they are not currently commonplace - fewer than 0.5% of the surveyed sample reported or observed the existence of a heat pump. As such, none of our longitudinal sample featured homes with heat pumps. However, a small set of additional interviews were commissioned to target this group - eight in total, comprising four ASHPs and four GSHPs).

In all cases, these homes were large properties off the gas grid with high earning households, factors that our evidence suggest significantly affected their decisions to procure heat pumps. As these participants are "early adopters" of these technologies, their opinions should also be taken as not necessarily representative of the general public.

Some of the motivators and benefits noted by those with heat pumps include:

- **Running costs** - the majority of participants felt that they had benefited financially from the installation of their heat pump both from reduced running costs and income from government schemes like the Renewable Heat Incentive. Lower running costs had been a key motivator for most of the sample as they found their old systems (typically oil central heating or electric storage heaters) overly expensive. One view expressed, though, was that the financial benefits of heat pumps would be less for homes on the gas grid;

- **Appearance** - perhaps surprisingly, two of the participants with ASHPs noted that the units were more aesthetically pleasing than the oil boilers they had replaced. Other research, in the past, has suggested that the appearance of ASHPs on the side of the property is a potential barrier either due to personal aesthetic taste or the perception that others (e.g. neighbours or prospective buyers) may dislike the look of them. One group in our sample, however, noted that heat pumps were less objectionable than technologies such as solar panels or wind turbines and that this had factored into their decisions;

- **Comfort and convenience** - some participants noted that the heat pump was a significant improvement over the old system with some saying that, having set it up to run automatically, it kept them warm at all times without having to think about it (although one noted that this may also be due to the significant building fabric upgrades (e.g. insulation) they had completed);

- **Future proofing** - one individual noted that he felt his previous system was unsustainable (particularly concerning rises in oil prices) and wanted to invest in a system that he and his wife could rely upon in their old age.

However, despite the generally positive opinions held by these participants on heat pumps, many detailed barriers that may impact uptake:

- **Information** - most of the sample noted that information was not easy to come by, concerning heat pumps. Many had turned to personal recommendations from friends due to a perceived lack of quality information available online. Some noted that information on other renewable technologies was easier to access and that persistence was needed to find the information they needed;

- **Installation -** some of the sample found that their systems had been poorly installed, and more expressed difficulty in finding a qualified and competent installer;

- **Compatibility** - those that had invested in insulation and a replacement of the heat delivery system (e.g. oversized radiators or underfloor heating) seemed to benefit the most, whereas those that had done little else but replace their boiler with a heat pump found that their systems often failed to meet their needs. A common view was that UK homes were generally not compatible with replacing boilers with heat pumps unless investing in the "whole package" and making wider changes to the system. Also particularly for GSHP, it was felt that those without available land or outside space wouldn't be able to take up the technology;

- **Disruption** - installation of GSHP was seen as particularly disruptive, with large areas of land needing to be dug up to lay pipes;

- **Upfront cost** - participants noted that their heat pumps had been expensive but not enough to prevent them from purchasing. However, our team also noted that as these were typically wealthy households with large properties, they were typically the sort of consumers that could raise the upfront costs required that many other households might not.

6.3 Communal Heating

The alternative to having a heat generating technology in every home is to have a system that generates heat and distributes to multiple dwellings. Communal heating takes many forms, from a gas boiler that provides heat to a handful of dwellings to combined heat and power engines that supply a wider local network of heat.

While wider spread than heat pumps, communal heating is still in the minority in the UK and typically only seen in dense, urban areas. As such, a further sub-sample of ten homes were interviewed to add to the four cases in our longitudinal sample.

Our findings suggested that people's experience of communal heating are strongly dictated by the level of control that they have, and whether they are metered or not. These two factors are covered in more detail in chapters 4 and 12 respectively.

One specific issue with communal heating in terms of control not detailed in Chapter 4 was the situation where a central operator was able to choose to turn the heating on or off at certain times of the year. In this instance, many consumers felt negatively towards the individuals making that decision and resented the fact that the choice was made by others.

One expected benefit of communal heating is that maintenance concerns are covered by someone else through a service charge. However, evidence from both the solutions workshop and the additional interviews suggested that many consumers do not see value in this. Those that have communal heating complain about the maintenance costs and seem more aware of times when the system may be down due to breakdowns or scheduled maintenance - again feeling a lack of control in this regard; they are not in control of when or how long this takes or who carries out the maintenance. Those without communal heating shared similar concerns that a communal heat source would feel out of their control and expressed concerns over reliability. The general perception seemed to be that consumers have less control or authority with communal heating.

6.4 Needs-Focussed Summary

6.4.1 Hygiene

The aesthetics of both boilers and heat pumps were mentioned by participants. The main responses seemed to be to hide equipment away or to opt for solutions that are in keeping with the aesthetic qualities of the home. Noise produced by these two types of technologies is also of concern to consumers although, in the case of the ASHP sample, none of them experienced noise-related issues. An ancillary benefit where temperature radiated from a vertical flue can be used to dry clothes was also valued by one consumer.

6.4.2 Comfort

When deployed effectively, consumers with heat pumps noted that the setup was more comfortable than their previous setup. However, in most of these cases, additional work to the delivery system (e.g. radiators) and thermal fabric of the property had been completed, making it difficult to assign this benefit to the source technology.

6.4.3 Resources

Consumers note that the high capital cost of boilers is a barrier to replacing their current system. There is also a common practice of waiting until a boiler breaks down beyond repair before replacing, even when the consumer is aware that the boiler is less efficient than a new alternative. In some cases, it was felt that replacing a boiler that was still working was somehow wasteful. Oil fuelled boilers were also seen as more expensive to run than mains gas boilers.

Heat pumps also are identified as an expensive capital investment and seem to be currently most widespread in wealthy homes where the barrier of upfront cost is less. Users of heat pumps typically find that their systems are cheaper to run then their old systems although, in most cases in our sample, these were off-gas homes previously using oil boilers.

The way that consumers pay for communal heating is a major factor in how they use their system, particularly in whether they are metered. This is discussed in greater detail in Chapter 12.

6.4.4 Control

Boiler-mounted controls were typically avoided by consumers in our qualitative sample. Many were not aware of the ability on many boilers to control the radiator flow temperature or the temperature of hot water. Some expressed fear of touching these controls as a risk of destabilising the system.

Level of control is the other main influencer on consumers' experience of communal heating (along with whether there is metered usage). In addition to the physical way that they experience control over the distribution of heat in their homes, consumers expressed concerns about a loss of control to a third party who could decide to turn off the heat at certain times of the year, even if it was warm. Similarly, a loss of control over the maintenance and downtime of the heat source was of concern to others.

6.4.5 Ease

Individual boilers, as the most common heat source in the UK, are an easy choice for installers and consumers when faced with an urgent need to replace (as is often the case, with consumers waiting until their current unit fails before replacing). However, boilers that are fuelled by oil rather than mains gas are seen as inconvenient.

Heat pumps currently present a greater number of concerns related to ease and convenience. As an unfamiliar technology, consumers found it difficult to find information about them or find a trusted, competent installer/service provider, compared to boilers where it is comparatively easy to find a capable contractor. The disruption required to install a heat pump (particularly ground source), particularly if additional works to the building fabric or wider heating system are needed too, is seen as another inconvenience that can be a barrier to this technology.

6.4.6 Other People

Noise created by boilers or heat pumps are of concern in some cases, particularly if this might impact on other members of the household (e.g. children) or neighbours. Similarly, consumers are keen to avoid disturbing neighbours by "spoiling their view" with unfamiliar technologies.

7 Hot Water

- Hot water is typically provided to UK homes either **"on-demand"** (usually via a combi boiler) or from a **stored reserve** (usually a cylinder);
- Hot water usage is typically related to **specific, discrete activities** (such as cleaning the self or washing dishes) rather than as a background requirement for completing other household tasks such as with space heating;
- Consumers typically are **less likely to engage with hot water controls** than heating controls and prefer hot water to be available as they need it;
- On-demand systems are generally popular with consumers and meet most needs. Areas for improvement for current systems include **speed of hot water delivery** (i.e. the time it takes for hot water to flow out from a pipe after turning on a tap) and **multiple load management** (i.e. maintaining flow temperature when different taps, showers, etc. are turned on);
- Those with stored hot water systems are typically happy with the system, although highlight areas for improvement including **speed of heating up extra water, reducing waste** (e.g. when stored hot water is not used), **aesthetics of cylinders** and **space taken up by hot water stores.**

In the UK, there are two dominant ways that hot water is provided - on demand via a combi-boiler (54%) or from a stored reserve of pre-heated water (e.g. a cylinder) heated by a standard boiler (34%) and/or immersion element (15%)[7].

7.1 What Do People Want From Hot Water?

In both the qualitative and quantitative work we identified a large number of ways that people use hot water in their home. The qualitative work identified that, compared to use of heating systems, consumers tend to have more specific utility from their hot water usage - i.e. they use hot water to accomplish specific, discrete activities. The quantitative work identified, through factor analysis, five dimensions of hot water usage as follows:

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

For all of these activities, consumers tend to operate their hot water systems in the background, rarely engaging with any hot water controls, generally wanting hot water to be available when they need it.

Of the above use dimensions, baths and showers potentially consume the greatest amount of hot water and tend to be the uses that most consumers spoke about during the qualitative interviews. Our quantitative survey highlighted that people shower more than they have baths and that they tend to have more showers/baths in summer than in winter. It also showed that households are more likely to shower in the morning and more likely to have baths in the evening.

[7] Note that the latter two statistics are not mutually exclusive as there are a number of hot water tanks that can be heated by a standard boiler *or* an integrated immersion heater.

The qualitative work highlighted a number of reasons that people shower or bathe. The primary reason is related to personal hygiene, cleaning the body. Many people have a daily routine involving showering first thing in the morning, during the evening after returning home or both to keep clean. Other reasons include to warm up or cool down the person during warm or cold periods respectively, as a way to relax (more commonly in a bath - where people spoke of it as a luxury), to treat aches and pains (also typically baths) and to wash young children (again, mainly baths in the evening before bed as part of a routine).

As mentioned above, consumers typically do not engage with any hot water controls they might have. This also seems to be the area where most consumers do not want any further control. Our survey showed that 62% of those asked did not want any additional control over their hot water (compared to 44% and 42% for heating and cooling respectively). The most common complaint across both types of main system was a desire for how quickly they were able to get hot water, either having to run a tap for a short while until hot water comes out or to heat up extra water in the store when they have used all of what they had available.

A minority of consumers did engage regularly with their controls, these were typically in homes with stored hot water and where consumers' needs typically aligned to resources (aiming to match supply with demand - e.g. turning off their programmed schedule when they were away from the house), comfort (e.g. potentially to heat more water to have a bath for comfort reasons) and other people (e.g. adjusting the amount of hot water depending on when other household members and guests are in). Users of combi-boiler systems seemed to very rarely interact with any controls (i.e. flow temperature on the boiler).

The following sections consider the different ways that consumers engage with on-demand hot water (typically from a combi boiler) and stored hot water systems.

7.2 On-demand Hot Water

On-demand hot water systems, typically supplied by a combi boiler are more prevalent in smaller homes with fewer household members as well as homes built before 1980. They also work best when consumer demand is unpredictable, with varying quantities of hot water needed each day and at different times.

Consumers in our qualitative sample with combi boilers generally had little to say about their hot water system apart from the fact that they generally were satisfied with the ability to have it whenever they wanted it. The consumer need most readily catered for by this type of hot water is "Ease", with consumers rarely having to consider how or when the hot water is generated - the convenience of having hot water as and when needed is of value. Some noted that they felt that this was also a "low waste" or "efficient" way of getting hot water and leads to not having to heat more water than is needed (also linking to the "Resources" need). It is worth noting that this style of heating water is similar to the way that some would like to receive their space heating - relatively instantly and only as much as needed.

Where consumers did express feelings on room for improvement was in terms of the speed at which hot water came out of their taps - often having to run the water for a short while to get the desired temperature, which some participants felt was inconvenient and wasteful. The other area for improvement was in the ability of a combi boiler to cope with multiple uses of hot water at the same time, with some consumers noting, for instance, that a shower would run cold if someone in another part of the house was using a hot water tap.

Perhaps unsurprisingly, consumers with on-demand hot water from combi boilers rarely interacted with their controls (typically only flow temperature on the boiler) in our qualitative sample although one participant did note that he varied the flow temperature to be warmer during winter months and cooler in summer months.

7.3 Stored Hot Water

Stored hot water systems typically feature a cylinder filled with hot water that has been heated (often overnight) by a boiler or electric immersion heater. Some systems fed by a boiler use an immersion as a secondary method for heating water at the top of the cylinder when they have run out of stored hot water that has been heated by the boiler as a quick alternative to heating another full tank from the boiler.

Stored hot water systems are more common in larger properties, with multiple household members, and in homes built after 1980. They are often controlled using a thermostat mounted to the side of the tank in conjunction with a programmer that controls the times at which the water is heated. This programmer is also often the same device used to control the heating timing.

As previously noted, consumers rarely interact with their hot water controls, but seem to be more likely to interact with controls related to the timing of hot water heating (including those that "boost" or give extra hot water when they have run out) than the temperature of the water via the thermostat. One longitudinal study participant noted that his immersion heater on his hot water tank sometimes heats the water to a higher temperature than desired. His solution for this was to use the programmer or manually reduce the hours that the immersion heater is on rather than adjusting the thermostat, which he expressed confusion over (again speaking to the point that many people are unaware what a thermostat does - see chapter 4).

Other participants expressed strategies for managing their hot water usage. Another low income participant living in a small flat with a small immersion-heated tank noted that she rarely runs out, but when she does she would rather wait until the following day to do things like wash up dishes or have a shower than heat extra water as she had used her daily allowance. In this case, the need to manage resources appears to be significant.

Most participants noted that their hot water tanks typically provided them with enough hot water on a day-to-day basis and, as with combi boilers, typically found that the hot water provision was convenient and something they didn't have to think about. However, compared to on-demand hot water, there seem to be more areas where consumers express preferences for something different:

- **Speed** - this is broken down into two areas. Firstly, as with combi boilers, participants in both the qualitative and quantitative research expressed a desire for hot water to reach the point of use faster without having to run the water for a short period. Secondly, when the stored hot water had run out, some consumers expressed a frustration with having to wait for a short while after "boosting" in order to get the hot water they needed. However, it should be noted that this was not widespread among the qualitative sample as many participants seemed to have normalised to the need to wait;

"We can have all the water we need heated up within twenty minutes, so it's near instantaneous."

- Longitudinal Study Participant Y8

- **Waste -** some participants felt that if they were not using their hot water in a given day then this was wasteful. This was felt most when many or all of the household were away and they had not adjusted the controls (either through forgetfulness or lack of confidence in how the controls work). Some identified a preference for a combi boiler in this regard as an alternative that would allow them to avoid this problem;

- **Convenience -** for the cases where they did find that they regularly ran out of hot water, participants noted that they were regularly having to actively think (and communicate between household members) about who had used the hot water, how much had been used and plan ahead what they could use for the rest of the day. Again, participants identified a preference for a combi boiler here;

- **Aesthetics** - at least one qualitative participant noted that she felt her cylinder was an "eyesore" and would rather it was not there, despite it being hidden away in a cupboard;

- **Space -** related to the above, one participant noted that the cylinder took up space that could otherwise be used for storage, which in her case, was in short supply.

A final point that did not arise spontaneously in any of our primary research but which has emerged in previous research is a final ancillary benefit of a stored water system. Those who have experienced a switch from a stored water system to a combi system have noted that despite the additional space they now have, they no longer have a warm cupboard (often called an "airing cupboard") where they can dry clothes using the heat that escapes from the cylinder.

7.4 Needs-Focussed Summary

7.4.1 Hygiene

Hot water is an important part of how consumers manage their Hygiene by using it to clean themselves, their families and their homes. As such, any system needs to provide hot water in quantities, at the desired temperature and when needed to allow consumers to achieve these needs. Showers are, in general, the preferred option for daily cleaning, although baths are preferred for younger children. Baths are also preferred for the purpose of relaxation and for the treatment of aches and pains. As noted above, the majority of people already seem to feel that their systems provide hot water to meet this need. Other related issues include the aesthetics of a hot water store, where one view was that this was an "eyesore" and the space that a cylinder takes up that could be used for other purposes.

7.4.2 Comfort

People with combi boilers noted some brief periods of discomfort when multiple people were using hot water at the same time - e.g. when in the shower and someone turns on the hot water tap in the kitchen - as the system briefly runs cold. This was less of an issue for those with a stored hot water system.

7.4.3 Resources

On-demand hot water was typically identified as the preferred option for efficiently managing resources by only heating the water that is required. People with stored hot water systems typically identified that their systems were occasionally wasteful in this regard - heating more water than was needed. One low income participant seemed to view her stored hot water as a daily "allowance" and was happy to delay using hot water to the following day when she had run out. Both groups of households noted that there was some wastage involved in having to run a hot water tap for a short while until hot water came out, but this typically was not a large concern.

7.4.4 Control

Most people in the qualitative and quantitative sample typically did not engage with hot water controls and expressed a preference for not having to think about their hot water. Where people have stored water, more people seem to engage with controls, but typically this is through boosting rather than through adjusting thermostat or programmer schedules.

7.4.5 Ease

Consumers typically want a hot water solution that they do not have to think about. They typically want a system that delivers hot water rapidly and on-demand without the need to think about how much has been used or to plan ahead to manage shortages.

7.4.6 Other People

Stored water systems typically seem to cater best for homes with large numbers of people, avoiding the problem faced by people with combi boilers of boilers struggling to supply multiple uses at once.

However, when participants experienced a shortage in supply of hot water from their storage vessel, they noted that they would need to coordinate with other household members to plan and manage the use of the limited supply.

8 Cooling and Ventilation

- Active cooling and ventilation systems are **currently not widespread** in UK homes and behaviours for both are typically aligned - most commonly by opening windows;
- Technologies for cooling and ventilation are **likely to become more important to consumers** over the coming decades due to a warming climate, an aging population and increasing airtightness and insulation of homes;
- Consumers are **familiar with active cooling** (e.g. air conditioning) through widespread deployment in cars and commercial premises. As such, many perceive benefits that could be enjoyed by having a cooling system in their home. However, the current barriers of **upfront costs** and **generally successful existing control strategies** seemingly outweigh the perceived benefits;
- Natural ventilation (primarily through opening windows) is the most common way that consumers ventilate and cool their homes and, in most cases, this meets consumers' needs. The most common barriers to this are **security** and **noise** concerns;
- Mechanical ventilation technologies are often not fully understood by consumers or otherwise are found to be less effective than natural ventilation. Areas of dissatisfaction include **disruptive noise** generated by the units and **perceived ineffectiveness** at drawing out smells, smoke, steam, etc. compared to the use of open windows;
- Portable ventilation (e.g. desk fans) seem to provide **multiple benefits** in a similar way to portable heaters (e.g. easy to control, able to support variation of needs across household members, etc.).

Compared to those in many other countries, UK homes typically do not feature systems designed for the provision of active ventilation or cooling. Of our survey sample, approximately 2% of homes currently feature technologies designed to provide a cooling function. Ventilation is most commonly provided by the use of passive vents (e.g. trickle vents, breeze blocks), windows and doors, chimneys and extractor fans (typically fitted in "wet" rooms - kitchens and bathrooms).

Due to this, the majority of homes in our research seem to manage their cooling and ventilation through similar practices, most typically the opening of windows to provide fresh air and air movement (and thus cooling). As such, it is useful to consider both areas in tandem when exploring solutions.

8.1 The Importance of Cooling and Ventilation

Historically, cooling and ventilation have not been as significant to UK consumers as the need to heat homes and hot water. There are a number of reasons for this. Firstly, our climate has meant that we rarely experience sustained periods of high temperatures, as experienced by many other countries that have widespread domestic cooling technologies. Secondly, our homes have been, historically, relatively well ventilated - mainly passively through low airtightness, vents and chimneys. Thirdly, our homes have been poorly insulated, allowing excess heat to escape (e.g. overnight during summer). Finally, the relative proportion of the population who are more at risk from higher temperatures (the elderly[8], the very young and those with health conditions) has been small, with the majority of people able to cope with warmer temperatures.

[8] Medical research has shown that the human body's ability to perspire (and thus regulate the body's temperature) decreases with age, making it more difficult for the elderly to get cool during hot weather.

Our external factors research has highlighted that all four of those cases are changing. The climate is warming and sustained periods of hotter weather are expected to become more common in the UK. Building regulations and common practices are leading to increased levels of airtightness and insulation in British homes. We also have an aging population, with the "baby boomer" generation (those born in the late 1940s and early 1950s) now at, or near, retirement age, and advances in medical treatment extending life expectancy so we now are able to live longer.

All of these factors mean that it is very likely that the importance of ventilation and cooling will grow significantly in the short, medium and long term in order to maintain personal health and home health. The latter of those is particularly evident in terms of ventilation. Airtight homes without effective ventilation can lead to the build-up of moisture in the air which increases the risk of condensation on cool surfaces and the development of mould. Mould spores are linked with various respiratory problems and, thus, can affect human health (with those vulnerable from overheating also more vulnerable to respiratory problems).

It should also be considered that, in previous chapters, we have explored the complex control strategies that consumers have for keeping warm that go beyond use of the primary heating system. Our research has shown that consumers similarly have complex control strategies for keeping cool (both in winter and summer). In the absence of a primary system for cooling, behaviours linked to cooling the self (e.g. through cold drinks, wearing less clothing, cool showers) and ventilating the home appear to be widespread. Low prevalence of cooling technologies combined with our awareness of these control strategies further supports the evidence that consumers are used to managing heat, both in terms of being too hot or too cold, using a range of different options and that, in general, they are able to meet their health and comfort needs through combinations of strategies. Our quantitative survey revealed that 73% of households are always cool enough (although 64% of the 73% utilise some sort of control strategy for this, highlighting that a majority do find that they need to take active steps to avoid overheating) but only 2% said they were rarely or never cool enough, taking into consideration their existing control strategies.

It can be further expected that due to the balance between days that are too hot and days that are too cool in the current UK climate (i.e. winter months see protracted periods of temperatures that are too cold to manage without some form of heating technology, whereas summer months see fewer periods of overly hot days, and those that are usually manageable without the need for cooling technology), technologies for heating will be of more importance to consumers than technologies for cooling.

8.2 Active Cooling

As noted above, only 2% of our surveyed sample have technologies in their home that feature active cooling (such as air conditioning or heat pumps that allow for cooling as well as heating). In our qualitative sample, none of our participants had active cooling systems. This includes those who we interviewed with heat pumps, either because these systems were heat-only or because the participants were not making use of any cooling features of their systems. Only four households in the quantitative sample of over 2,000 homes had heat pumps that they sometimes used to cool the home. As such there is little evidence to draw on about what consumers want from active cooling.

Of our quantitative sample, the 2% that have systems for air conditioning is dominated by portable units that vent outside (19 cases) or inside (13 cases). The latter point suggests that the net effect to the household may not be to cool the home as a whole and, potentially (considering heat gain from the use of the appliance) increase the heat energy supplied to the home. In general, there seem to be few homes in the UK that feature fixed, centralised systems for cooling.

However, this does not mean that UK consumers are lacking in experience of air conditioning. Most modern cars now feature air conditioning as a standard feature and an increasing number of commercial premises - shops, offices, etc. - include air conditioning systems, such that consumers are familiar with cooled environments when away from the home at work or during leisure time.

As such, there is evidence from our sample that there is a demand from consumers for active cooling to be introduced to the home environment. Some qualitative participants from the longitudinal sample

specifically identified that they were interested in purchasing a small, portable air conditioning unit. These cases tended to be in properties that our monitoring identified as warmer homes and that our technical team described as well insulated (including flats where the dwelling is surrounded by other heated spaces).

The key barriers to uptake of air conditioning technology appear to be based on a comparison of two key needs - "Resources" and "Comfort". In terms of Resources, consumers spoke of the barrier of upfront cost to purchase a cooling device and, to a lesser extent, the running costs of these systems. In terms of Comfort, consumers perceived the benefit to be more closely related to being comfortable during hot periods than any concerns about health (perhaps because they felt that overheating was rarely a concern for health, as they have control strategies for managing this - many of which are discussed in previous chapters, such as heat retention (changing clothing), cooling the body (e.g. with a cool drink or cool shower) or through passive cooling methods discussed later in the chapter.

The net effect of these needs is that many consumers seem to feel that the cost of purchasing a cooling solution outweigh the benefits that it may bring, particularly as they have existing strategies for keeping cool and particularly as the periods when they may want to make use of the equipment are comparatively brief to periods when they need heating. However, as noted above, if periods of hot weather increase and if prices of active cooling equipment drop, it can be expected that demand may rise.

8.3 Natural Ventilation

Natural ventilation is the most common way that consumers ventilate and cool their homes, (84% of the quantitative survey made use of natural ventilation behaviours to keep cool in the summer. The dominant behaviour in this is opening windows or doors. During the summer months, 79% of respondents open windows during the day and 53% at night. 40% open external doors.

It is interesting to note that, so far in this chapter we have discussed cooling in terms of summer, higher external temperatures. However, our research has shown that only 37% of people experience no overheating in winter. 50% of the population control winter overheating by reducing their heating but 28% open windows during these colder months.

As mentioned previously, consumers often have multiple reasons for opening windows - more than just wanting to cool the home. Participants in the qualitative study often talked about opening windows to let in fresh air or because rooms were "stuffy". Others open windows to purge odours or excess moisture caused by cooking or bathing.

Many spoke of their window-opening behaviour as habits or learned behaviours from childhood, but they typically identified that naturally ventilating through window opening was primarily about health (perceived need to remove stuffy or unhealthy air - identifying fresh external air as "more healthy"), comfort (e.g. to allow a pleasant breeze or to alleviate uncomfortable conditions) and other people (typically concerns about creating a healthy environment for the rest of the family).

Interestingly, window opening is sometimes a contentious issue between members of the same household, particularly in winter. Typically the contention surrounds the balance between needing "fresh air" and avoiding waste from letting heated air escape. As such, the need for harmony in the home is challenged by the behaviour of opening windows for two conflicting need groups - Resources and Health/Hygiene.

Consumers do experience other barriers to the use of windows and doors for ventilation and cooling. Participants in the quantitative survey were asked whether there were any situations where they would not open windows to keep cool. Only 32% of people responded saying they faced no such problems, implying that a majority sometimes find that there are barriers to opening windows to keep cool. The most common barriers were security (31%) and noise (24%). In both cases, it can be argued that these are both contributing factors to why a higher proportion of consumers open windows during the day than at night - fears of intruders being greater at night and noise disturbing sleep.

Natural ventilation appears to be a very simple thing for people to control. By simply opening or closing more or fewer windows, at different times and to a greater or lesser extent (i.e. ajar or fully open), consumers have an easy and intuitive way to control their ventilation rates.

Finally, it is worth noting that common practice in hotter climates is to use shutters, curtains, etc. to reduce solar gains in homes and, in many cases, to keep windows closed during the day while opening at night to "purge" heat - with internal doors open to allow cross ventilation. Our research suggests that these practices are not widely adopted in the UK, with fewer people opening windows at night than day and fewer still keeping internal doors open (35%) or closing blinds/shutters/curtains (29%). As such, the opportunities to apply enhanced levels of solar shading in the UK could be a more cost and energy efficient way of tackling overheating before resorting to active cooling methods.

It could be suggested that UK behaviours at achieving optimal cooling through natural ventilation are not widespread, potentially as current behaviours generally meet needs. However, in hotter weather and prolonged periods of heat, it could be argued that more people will find that their strategies for keeping cool are insufficient more often.

8.4 Mechanical Ventilation

Mechanical ventilation includes many technologies that involve fans or pumps to remove air from parts of the home to be replaced with fresh air from the outside. They range from single-room extract fans that draw air out of wet rooms, to whole-house ventilation systems that involve intake and output in multiple rooms and integrated air filters. Some technologies involve an element of heat recovery - where warm internal air heats incoming fresh air via a heat exchange.

In the UK, the most common mechanical ventilation technologies are single-room extract fans, typically found in kitchens and bathrooms for the purpose of drawing out excess water vapour, smoke and odours.

Across our qualitative sample, it was found that consumers would often avoid using these mechanical ventilation technologies in favour of opening windows and doors instead. Two main reasons were discussed for the reasons behind this:

- **Noise -** the dominant complaint across the sample was that extract fans were noisy to the point of disturbing members of the household. Complaints were more likely to be related to bathroom fans that would come on with the bathroom light, and be disruptive during night times due to the proximity of bathrooms to bedrooms. One case in the qualitative sample that suffered particularly high levels of internal relative humidity leading to condensation and mould in multiple rooms still found that the noise was a bigger concern than she was willing to endure so kept it switched off;

- **Ineffectiveness -** for a number of reasons, consumers often found mechanical ventilation ineffective compared to opening windows. Sometimes this was due to poor installation, where fans (usually kitchen - over cookers) were vented into the room providing only limited filtration of air. Often, also, this was due to the fact that fans were "extract-only" and not designed to draw fresh air into the same space - this was observed by the technical co-interviewer often, rather than the participant.

Our technical researchers also noted that sometime it seemed that lack of knowledge about the purpose of, or operation of, mechanical ventilation systems played a role in the underperformance of system and, hence, why consumers seemed to eschew them entirely at the preference of natural ventilation.

Only one participant in our longitudinal sample had a whole-house ventilation system - a force air heating system that could also be used without heating the air during warmer periods. This participant found that the system was good at helping cool the home during warmer weather (and said it was more effective in this regard than at heating the home in winter) but noted that they still would open windows regularly.

One final point of note is the response given by consumers during the solutions workshop, who were presented with an option for a solution that would provide whole home ventilation - to provide fresh air at all times - with the condition that windows should not be opened. In general, this response was negative, with consumers feeling that they would be unhappy with being unable to open their windows. Researchers observed a general mistrust of systems for mechanical ventilation, with consumers feeling that a mechanical system would not be as effective at "airing the home" as opening windows. This seems to be a product of habitual reliance and familiarity with natural ventilation methods added to negative experiences with the common applications of mechanical ventilation detailed above.

8.5 Portable Ventilation/Cooling

As portable air conditioning has been covered in section 8.2, this section examines the evidence for other forms of portable ventilation/cooling, typically portable fans that, while not cooling the air, can cool the person by creating air movement.

Our qualitative sample yielded a small number of people that used plug-in "desk fans" to keep cool. As such there is little evidence to draw on. In all cases, these were participants who lived in flats. Some key points that emerged include:

- Fans were often used in bedrooms to keep people cool while they slept during warmer weather - in our sample this was in conjunction with opening windows. One participant noted that this was "not about cooling the space, but cooling the body";
- Fans were sometimes used in the case of one participant who would use this in her grandchildren's room when they came to stay, particularly if they were "feeling poorly";
- One participant expressed a desire to consider a modern fan that operated using a vacuum rather than blades, and could provide cooling and heating. He also noted that it was attractive to look at and "not bulky", suggesting that the appearance of portable devices is of importance.

While not explicitly evident from the primary research, it can be argued that portable ventilation/cooling provides consumers with many of the same types of benefit as portable heating, helping meet multiple needs at once.

8.6 Needs-Focussed Summary

8.6.1 Hygiene

Ventilation appears to be a significant way that consumers maintain a healthy home and household. The desire for "fresh air" is important and can also help control condensation and mould. Secondary research suggests that cooling is also going to be increasingly important to manage the health risks of overheating, which our external factors work suggest will become more serious and widespread in future. However, current households rarely seem to experience internal temperatures that they feel impact negatively on their health.

Consumers were often reluctant to use mechanical ventilation due to being disturbed by the noise caused by such systems.

8.6.2 Comfort

While ventilation was often spoken of in terms of maintaining health, cooling was typically referred to in terms of comfort benefits. Overheating was typically seen as a temporary issue of discomfort that could be resolved through use of natural ventilation or other cooling strategies (similar to heating strategies).

Participants also noted the pleasant feeling of air movement from open windows or fans.

8.6.3 Resources

Ventilation can sometimes be seen, during periods of heating system use, as creating conflict between managing waste and maintaining fresh air in the home. Another conflict was seen in the consumer decision-making process when weighing up the capital and running cost of cooling technology compared to the limited times that they feel it will be necessary to keep cool.

8.6.4 Control

The dominant way that UK homes control their ventilation and cooling is by opening windows. This method is often habitual, trusted and simple for consumers to engage with. Similarly, portable cooling is simple to control (in much the same way as portable heating). Consumers tended to feel that natural ventilation through window opening offered them greater control over ventilation than mechanical ventilation and, consequently, often preferred such methods to mechanical systems.

8.6.5 Ease

Ease appears to be an important factor in consumer decisions for ventilation and cooling. Consumers seem to rely on habitual and learned behaviour rather than exploring more efficient control strategies (e.g. cross-ventilation and limiting solar gain) or investing in technologies. Opening windows is typically seen as more convenient and more effective than using mechanical systems and is thus, usually preferred.

8.6.6 Other People

Conflict between household members over opening windows was evidenced in our qualitative sample, with the need to maintain a healthy environment sometimes at odds with the need to limit wasting heat. Use of cooling technology, particularly portable cooling was noted by participants as a way of looking after other household members, such as visiting grandchildren.

9 Insulation and Building Fabric Improvements

- **Loft** and **cavity wall** insulation are the two dominant types of insulation technologies experienced by UK households. There is limited consumer experience, to date, of solid wall or underfloor insulation;
- For solid wall and floor insulation, some anticipated consumer concerns include **disruption of installation, aesthetics of finishes, loss of space** (particularly internal wall insulation) and **additional works required** (e.g. decorations, roof extension, etc.);
- There is some evidence that, as insulation has been subsidised for a number of years, this has "devalued" the concept in the eyes of the consumer - with many consumers expecting that this is something that **should be provided free** or otherwise **heavily subsidised**;
- Double glazing is a popular solution and provides consumers with additional benefits including **noise reduction, added security** and **enhancing property value.**
- Improvements that can preserve the appearance of the property (particularly period properties) were generally viewed positively by consumers although some felt that they would not just want something that looked like an original feature, they would rather use classic materials and approaches to preserve heritage features.

While the previous sections have typically looked at technologies to provide heating, hot water or cooling to the home, this section explores ways that people can impact the demand of these systems through changes to the building fabric - through improvements to insulation and airtightness.

9.1 Insulation Solutions

In the UK, the most prominent types of insulation found pre -installed in homes, or subsequently retrofitted by occupants are loft insulation and cavity wall insulation.

Thanks to government-backed schemes such as the Carbon Emissions Reductions Target (CERT) and Energy Companies Obligation (ECO) loft and cavity wall insulation installations have been heavily subsidised and seen widespread uptake in the last 10 years.

Indeed, of the interviewed sample, 31% of cases said they had installed loft insulation during the last five years. Of the remaining 69% it can be assumed that a proportion of these are flats with no loft to insulate and others had lofts that were already insulated - rather than 69% of lofts remaining uninsulated.

Cavity wall insulation rates were lower than loft but higher than cases of installation of solid wall insulation.

Our qualitative samples typically only had experience of installing loft or cavity wall insulation. All three groups within the solutions workshop had participants that mentioned installing loft or cavity wall insulation and a few participants within the longitudinal sample had similar experiences. No participants had experience of solid wall insulation or floor insulation. As such we cannot provide direct primary evidence for consumer response to these types of technology but will discuss what can be inferred later in this section.

Solutions workshop participants note that the benefits of insulation were primarily to "keep heat in". Consumers at this workshop perceived this as a way of saving money on bills as well as being warmer and more comfortable. Participants in the longitudinal sample had more mixed views on insulation, though. Two participants noted that they were unsure whether their insulation had made a major difference as they didn't "feel warmer" and hadn't noticed any change to their bills (although, as discussed in Chapter 12, consumers typically were disengaged with their bills and levels of

consumption, potentially explaining why no impact was noticed). These findings are not particularly surprising as insulation is a relatively "invisible" solution that consumers are unable to see working and, in many cases, the impacts may be difficult for consumers to detect. As noted in the section on "Feedback" in Chapter 4, a system that helps show consumers the impact achieved by installing new measures or changing behaviours may help address this problem.

A further problem with insulation, as noted in literature evidence[9] is that subsidised schemes, that have provided insulation at a low price, or free, may have resulted in the consumer expectation that insulation is something that should be, and will continue to be, provided at a low cost. Further, this may lead for consumers to perceive the product as low-worth, rather than generating future demand. Lack of value in insulation, in this way, was observed in our longitudinal sample.

"I don't think I would have got the insulation if it wasn't free. I don't think there was any great need for it but I did it anyway because it was free"

- Longitudinal Study Participant N38

Our sample of additional qualitative interviews included some people living in well-insulated new-build homes. Of these, some people noted that while they were rarely too cool in winter, that overheating in the summer was more likely to be an issue for them now than in previous properties. As noted in our chapter on cooling, this is likely to result in reduced comfort and, increasingly in future, potential health impacts. As such, it can be suggested that greater levels of insulation may increase the need for cooling.

While our primary research has no direct evidence for responses to internal/external wall insulation or underfloor insulation, some inferred ideas about consumer response, based on consumer attitudes towards other solutions include:

- **Concerns about disruption -** Whereas loft and cavity wall insulation installations are typically quick with minimal disruption, solid wall and floor insulation are more disruptive and time consuming, with floor insulation requiring whole rooms to be cleared of furnishings and . It is likely that consumers would be concerned about this, particularly given previously noted lack of value in the effectiveness of insulation;

- **Aesthetics -** External wall insulation can result in a change to the outward appearance of the home, particularly marking it out as different from surrounding properties (particularly for terraced or semi-detached homes. This point is discussed in more detail in section 9.3;

- **Space -** For internal wall insulation, the sacrifice of internal space for a layer of insulation may be a concern for some consumers, particularly in smaller properties with smaller rooms. Some may feel that a loss of internal space may lead to a negative impact on the value of the property;

- **Additional works** - In both solid wall cases, additional works are often required in order to allow for the full benefits of the insulation to be enjoyed. For internal wall insulation, this may involve replacement of built-in units, rerunning of pipework, refitting radiators and redecoration. External insulation may require repositioning of window frames, rerunning downpipes, relocation of external drainage, extension of roof eaves and removal/replacement of existing external fixtures. These added works will add hassle and, in all likelihood, cost. As such, consumers may find this a barrier to uptake.

9.2 Glazing Solutions

Double glazing (and to a lesser extent, triple glazing) were typically much more positively viewed by consumers in our qualitative sample than insulation.

One participant in the qualitative sample summarised the four drivers for his installation of double glazing, that cover a range of the common reasons consumers raised for installing double glazing:

[9] Consumer Focus (2012), *What's In It For Me?* (pp72)

- To **save money** by retaining heat;
- To stop condensation and mould for **health** reasons[10];
- To stop water getting in the home, for property **maintenance** reasons;
- **Aesthetic** reasons - as the old windows were wooden and rotting.

Another three common motivators that emerged from our workshop sample included:

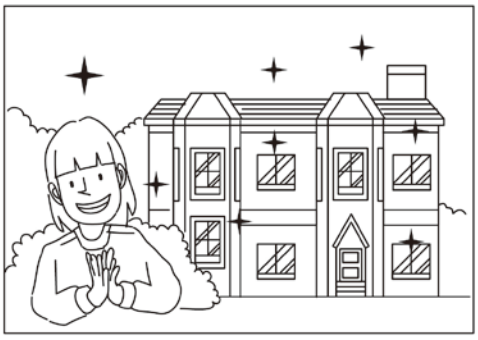
- Added **security** through better locks as found on many modern units;
- **Noise reduction** - sealed double glazing units are more effective at acoustic insulation than single glazed units;
- **Increase in property value** - perhaps a product of the other widely perceived benefits of double glazing, is that replacing windows for double glazing is perceived to increase property value.[11]

The only time that consumers raised objections to double glazing in our primary sample was typically those with older homes, where double glazing would not fit with the period aesthetic or, otherwise, the home was in a conservation area. For those consumers, the way the property looked - to them and to others - was more important than any of the benefits listed above. One participant also noted that double glazing was expensive to install and that the upfront cost may be a challenge for him to overcome.

Two cases in the longitudinal study had secondary glazing (i.e. a second window fitted internally) as a way of managing the period or conservation concerns of double glazing. In general, they felt that secondary glazing was a good alternative to double glazing and helped give them some of the benefits listed above. One was planning to fit secondary glazing in the downstairs of his home after being happy with the units fitted upstairs.

It is interesting to note that participants without secondary glazing were often unaware of this as a potential measure - particularly when the technical interviewer asked respondents whether they had ever considered it.

9.3 Preserving Appearance



As part of the solutions workshop and in-home interviews, we explored a number of basic concepts related to services to improve the home in terms of energy performance.

One concept was a series of measures that could be applied to a property (typically older, with period features) to replace or cover existing features with insulation or glazing products that would retain the original look of the property.

Response to this was generally very positive. Some felt that this would add value to the property as well as make it more comfortable. Respondents in the solutions workshop noted that it may cost more

[10] although it should be noted that double glazing that makes the property more airtight, without effective ventilation, may increase the risk of condensation and mould

[11] Participants at the solutions workshop generated a quick list of the sorts of things that would be "good investments" if looking to sell a property and increase property value - "central heating, double glazing, nice kitchen, nice bathroom, decent garden, neutral décor". It is interesting to note that, while central heating and double glazing feature in this list, insulation does not.

for such a solution, but that it would be "worth it". There was also an idea that arose in more than one group session that older properties need more money invested in them to maintain them.

The main objection to this concept was that some people did not want a replica, they wanted the original features (or otherwise replacements made like-for-like). This suggests that for some consumers, their period features are not just about appearance, but a deeper feeling of preserving the heritage of their homes.

One final idea that emerged from discussion of this concept with one longitudinal study participant was that this may appeal to people as a way to improve their homes without upsetting neighbours. Beyond concerns that neighbours may not dislike the look of the changes, one group discussion raised the point that works done that disrupted the "symmetry" or collective character of the group of properties may devalue his neighbours' properties.

9.4 Needs-Focussed Summary

9.4.1 Hygiene

Across insulation and glazing technologies, it seems that concerns on aesthetics are important, particularly if insulation or glazing might disrupt the external appearance of the property (particularly for older homes with period features).

One participant felt that double glazing would help manage condensation and mould problems. Secondary research suggests that consumers also find that double glazing improves noise reduction and home security.

9.4.2 Comfort

Some consumers noted that both improvements to insulation and glazing could help improve comfort in their home, although some who had installed loft or cavity wall insulation stated that they didn't notice feeling more comfortable. Those with high levels of insulation, however, did notice that their homes were typically less likely to be uncomfortably cool in winter, but did sometimes suffer from summer overheating.

9.4.3 Resources

Consumers noted that both double glazing and insulation could help reduce energy costs. Consumers only seemed to feel that glazing would have a positive impact on property value. Insulation typically seems to be poorly valued by consumers. This may be due to the fact that it is now something that they expect to get for free and that subsidies have inadvertently led to a devaluing of insulation measures. Measures that preserved period features while increasing thermal performance were typically viewed positively, although some noted that energy efficient replicas of period features may not be preferred to original features or like-for-like replacements.

9.4.4 Control

There was no evidence emerging from the research related to Control as a need and insulation and glazing.

9.4.5 Ease

Many of the barriers to insulation seem to be related to ease and convenience. Solid wall insulation and floor insulation could be seen as particularly disruptive installations compared to cavity wall or loft insulation. Furthermore, should these installations require additional works (e.g. decoration, rerunning of pipes), the added hassle (and cost) may be a barrier to consumers.

9.4.6 Other People

Consumers noted, for both insulation and glazing solutions, that the impact of these measures on their neighbours was a concern. This was expressed as not wanting to have their property stand out from the local character, but also in terms of a fear that unsympathetic solutions may impact negatively on neighbouring property prices.

10 Installation Process

- A significant majority of consumers have recent experience of carrying out improvement works to their homes, most commonly **decorative works, extensions, conversions** and **work to heating or hot water system**;
- Motivations to home improvements seem to most closely align to needs related to **Health/Hygiene** (including aesthetics), **Comfort** and **Resources** (e.g. to improve property value or reduce running costs);
- The dominant influencer on how consumers seem to make decisions on installation processes or contractors seems to be **trust**, with many consumer seemingly to prefer DIY or use of a qualified friend/family member before turning to tradesmen who come recommended by others that they trust;
- Two types of home improvement work were noted - those works completed "bit-by-bit" and those completed as part of a major refurbishment comprising multiple pieces of work with consumers typically deciding between the two based on **resource** and **convenience/ease** considerations;
- Consumers were generally positive about the concept of building energy-related works into existing improvement plans although were sometimes concerned about **"upselling"** or the **added costs** of these works;
- Similarly, consumers were positive about a "whole house" approach although raised concerns about the **high upfront costs** and **prolonged disruption**. Consumers were also, typically, reluctant to get into debt by taking out a loan to pay for works;
- Ideas for ways to reduce hassle (e.g. by providing a project management service or providing a holiday for consumers while works were taking place) were typically met with mixed opinions. In many cases, consumers wanted to **be present to manage the process** throughout and **feel "in control"**. Being away from the home also presented barriers related to trusting contractors to be alone in the home.

The previous chapters have focused on a range of solution components that could be installed in consumer homes as part of an upgrade to a Smart Energy System. This chapter considers the evidence for how consumers respond to different types of installation components.

10.1 Current Approaches to Home Improvements

A useful starting point in this chapter is to consider the types of installation (or otherwise) work that consumers carry out in their homes.

The quantitative survey revealed that the most common types of work that consumers had carried out in their homes over the last five years included:

- **Adding or refitting rooms (94%) -** this is dominated by painting/redecorating (75%) but also includes refurbishment of kitchens/bathrooms, re-carpeting, extensions and conversions;
- **Work on the heating/hot water system (75%)** - most commonly servicing of the boiler/heater (37%) or replacing a boiler (28%);
- **Changing heating/hot water controls (61%)** - most commonly installing TRVs (22%), a thermostat (19%) or programmer (18%);

- **Insulation or draught proofing (58%)** - most commonly installation of loft insulation (31%) but also including cavity wall, solid wall and floor insulation. This category also included changes to the glazing (e.g. installing double glazing).

The survey also explored the motivations behind these works:

- **Adding or refitting rooms** - motivated by a desire to **improve the look of the home** (78%) or to **make the home more comfortable or healthy** (54%);

- **Work on the heating/hot water system** - motivated by a desire to **improve energy efficiency and save money on energy bills** (62%) or to **make the home more comfortable or healthy** (31%). This was also motivated by **system breakdown/need for repair** (31%);

- **Changing the heating/hot water controls** - motivated by a desire to **improve energy efficiency and save money on energy bills** (69%) or to **make the home more comfortable or healthy** (42%). This was also motivated by **system breakdown/need for repair** (39%);

- **Insulation or draught proofing -** motivated by a desire to **improve energy efficiency and save money on energy bills** (82%) or to **make the home more comfortable or healthy** (52%);

These motivations can be clearly aligned against the two core need groups (**Hygiene** and **Comfort**) as well as the third group of **Resources**. These patterns (both of types of works and motivations) were also seen in our qualitative work, with participants at the solutions workshop listing motivations that could be categorised typically into these three needs categories:

- **Hygiene -** motivations related to aesthetics seemed to be top here, with people noting that they want their home to "look and feel nice". Others noted that it was important what other people thought of your home (as such, the need group of **Other People** is relevant) or that it was important to "keep up-to-date" with "modern fashions". Participants noted that this was often "cosmetic rather than functional";

- **Comfort** - participants spoke of a desire to be "warm", "comfy" or "cosy" with participants in more than one group noting that they had replaced wooden floors with carpet as this is "cosier". Others noted that works would "reduce discomfort" such as the participant who has replaced his old shower because it was dripping;

- **Resources** - two key factors emerged here - firstly was the general need to reduce running costs, but the second common theme was to improve the value of the home. Participants noted that even when they had no plans to sell in the foreseeable future, resale value was often on their minds. Others noted that even if works may not add value to the home it may facilitate a quicker sale as a buyer would recognise that they had "less work to do".

Now we have a better understanding of what people do and why they do it, we can consider the providers that they typically use. Participants in our longitudinal qualitative sample discussed a range of options, commonly arranged in the following hierarchy:

- **DIY** - particularly for smaller jobs and decorative works, consumers often carry out works to their home themselves;

- **A friend, acquaintance or family member** - many consumers spoke of knowing a friend (or friend-of-a-friend) who could carry out works to their home, often related to works requiring accreditation (such as electrical or gas works);

- **A "recommended" contractor** - where a friend or relative was not available, consumers often turned to recommendations from friends and relatives as to who to use;

- **A branded contractor** - where no recommendations were available, consumers turned to brands that they felt they could trust. Many highlighted "British Gas" as an example of a provider who they had turned to in response to television advertising campaigns.

The fundamental theme that emerges from the above hierarchy is that of **trust**. Consumers throughout the qualitative sample had experiences, directly or indirectly (e.g. through a friend/family member), of problems with installation works with many speaking of a fear of "cowboy builders". It was felt that such "untrustworthy" installers would be responsible for a range of problems including poor workmanship, overcharging and insisting on additional work requirements that aren't needed. As such, the importance of building decisions based on existing trusted relationships seemed key.

Finally, consumers seem to have experience of carrying out works to their home in different ways. These typically can be classified as either:

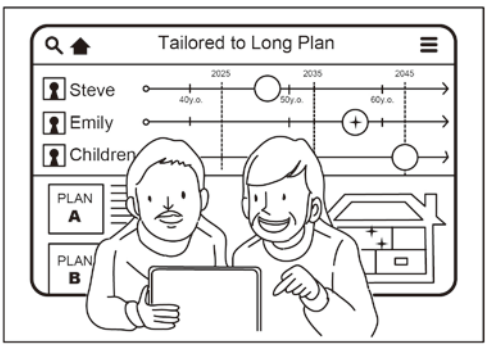
- **Piecemeal or bit-by-bit** - typically related to smaller jobs, consumers sometimes had a list of works that they planned to complete in future and, in many cases, were part way through that list. Typically, consumers were motivated to carry works out like this for two main reasons: **Resources** - to save up to complete each stage of work; **Ease** - some consumers preferred to complete work room-by-room and in short bursts to avoid inconvenient periods of upheaval to the home;

- **Major refurbishment** - in contrast to the above, consumers often had experiences of carrying out large-scale upgrades to the home - often involving extensions or conversions or multiple rooms and works at the same time. Often, these involved consumers borrowing money through re-mortgaging or following a "windfall", where they had additional funds available to them. The primary motivator behind doing more at the same time relate to **Ease** - for instance, only having building materials on site once rather than over an extended period of time, to minimise repeated periods of disruption and to be able to plan extended periods off work (either to be involved in the works or to oversee them);

A final point to note is that some consumers noted that doing works at all to the property depended on how "attached" you were to it and how long you intended to stay. One solutions workshop participant noted "If it's not your forever home, you won't spend as much on improving it". As such, it can be considered that moving to a different house (perhaps where the desired works have already been completed) could be considered as a third alternative to the above main methods of improving the home.

10.2 Building Improvements Into Existing Plans

To explore consumer response to different ways of carrying out installations, two concepts were developed to be tested with participants at the solutions workshop and in the longitudinal study. The first concept was "Room in a Roof" - a concept that focused on building energy efficient upgrades into existing plans such as conversions.



The basic premise was that if consumers have wider refurbishment plans (such as extensions or kitchen upgrades), for other motivations (such as adding space or improving aesthetics) additional energy efficiency upgrades could be integrated to these plans. Doing so would be more cost effective and allow them to gain wider benefits from their main plans,, for instance, by adding a room but not increasing overall home space heating costs.

Consumers were typically interested in the concept and felt that it "made sense". Some identified that doing it when they had other works planned would be "cheaper" and "less disruptive". However, there were a number of concerns raised by participants:

- **Mistrust of "upselling"** - while some participants noted that they trusted their builder to recommend additional works like this, others were negative - feeling that this was a "scam" or otherwise that they wouldn't want a builder to "upsell" due to a perceived conflict of interest;

- **Additional costs** - others noted that they would be concerned about how much extra the works might cost - as they would have a budget in mind for the works and a specific reasons for carrying these works out (e.g. adding extra space). As energy efficiency may not have been a key motivating factor in these works they were unsure how much more they would be willing to spend;

- **Achieved savings** - others discussed the requirement to see savings immediately, or within a short space of time. For some, this was about how quickly the additional measures would "pay for themselves" and thus leave them in a "better position". For others, this was about the "visibility" of savings. With participants noting that a number of factors such as increased demand from increasing the size of the house and fluctuating energy prices may make it impossible to see whether genuine savings on bills had been made or not.

A key finding here is that consumers seemed to conceive this concept primarily in terms of **Resources** - being concerned about additional costs and wary about payback. Consumers didn't seem to perceive, without prompting, that there would be any additional benefits from incorporating energy efficiency/energy system works into planned improvements.

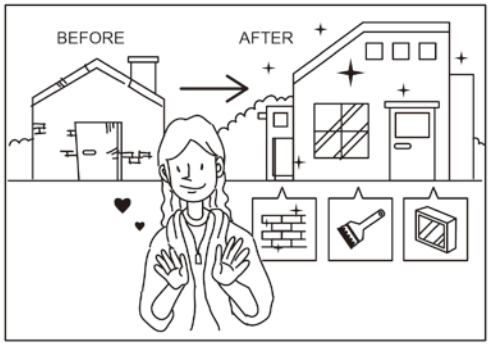
10.3 Whole-House Approach

The second concept tested with qualitative participants was an approach that focused on a "whole-house" refurbishment, dominated by upgrades to the energy system and building fabric, and potentially offered by a single service provider.

Many consumers reacted positively to this idea with the most common type of response being "this is a great idea if you can afford it". Consumers identified a number of benefits to the concept:

- **Less hassle** - consumers were divided between preference of a single period of prolonged disruption or preferring a bit-by-bit approach in terms of the hassle to consumers. One consumer compared this to removal of a plaster - do you rip it off fast or slowly? **-** but those that felt "one hit" would be better were broadly supportive of this idea;

- **Overall cost savings -** there was greater agreement that a whole-house approach would be more affordable overall than a bit-by-bit approach for a number of stated reasons: buying in bulk, getting multiple uses out of hired services (e.g. scaffolding, or a skip) and buying now before prices rise;



- **Adding value to the home** - while we have observed that usually consumers do not feel that insulation works would add value to a property, in the case of a whole-house approach, some consumers felt that the scale of works would serve such a purpose.

Key barriers to the approach included:

- **Upfront cost** - almost all consumers who were presented with this idea noted that the cost to carry out works like this would be high, and that this would be the primary barrier to them and other consumers. One consumer in the longitudinal study noted, interestingly, that she'd be concerned if the price was too low, feeling that if it were too low this would indicate poor quality;

- **Requirement for finance** - related to the above, others suggested that the only way that such works would be viable would be through taking out a loan or extending the mortgage. While some

participants mentioned that they had done so for home refurbishments before (e.g. extensions), the dominant feeling among members of the qualitative sample seemed to be that they were unhappy with the idea of taking out a loan and would rather save;

- **Time taken and disruption** - many raised concerns that a whole-house approach, while potentially better than spreading out over years, could take a significant amount of time - "perhaps months" - and that this might mean "living on a building site" for a prolonged period. There was an additional concern that a whole-house approach may increase the risk of builders "finding something" that needed additional works and this impacting on both time and cost.

Ultimately, the combination of barriers often seemed to outweigh the perceived benefits, with consumers commonly feeling that the energy benefits alone were not enough to outweigh perceived costs and disruption from the works. Typically, those that spoke more favourably of the concept anticipated improvements to the aesthetics and value of the home being a part of the proposition.

10.4 Reducing Hassle

Many of the above installation processes present consumers with hassle - through organising works or through having to live in the property while works were carried out. As such, two ideas for reducing hassle were built into the two vignette concepts detailed in the previous two sections:

10.4.1 Managing and Coordinating

One idea presented to consumers was for a role that would plan many of the works on the consumer's behalf - for instance, making recommendations, coordinating and selecting contractors and managing any arising issues.

While some consumers seemed to see the potential benefit of this approach, others raised two key objections. Firstly that they typically wanted to be in full control of many of the decisions and, secondly, that they may not trust the provider to make the right decisions. For instance, one participant in the longitudinal study noted that he would "usually rather ask friends, family and neighbours about what is best rather than relying on a service". Another said that he preferred having the onus on him to find out information, although did note that he would be interested in a service that helped rate and review installers "like Trip Advisor".

This finding resonates with other research, such as ETI's Thermal Efficiency project, which interviewed several people who had carried out significant refurbishments to their home and, for the majority of cases, had managed almost every step of the process.

10.4.2 Holiday During Works

Another idea suggested was to take a holiday during the works, potentially paid for as part of a package payment for the installation works. Some consumers seemed to like it, but a majority seemed very against the idea.

Typically, those opposing the idea argued from one of two areas:

"I need to be there to agree to any changes and see that they're doing what they're paid to do, not having three-hour tea breaks"

- Solutions Workshop Participant

- **Trust** - as previously noted, consumer trust in installers is often low and, as such, many consumers noted that they would not feel comfortable leaving a contractor in their home, unsupervised, "unless it was a friend". Common concerns were either that they might steal from the home, carry out poor work or, otherwise, make decisions that the consumer was unhappy with. Some said they would want to see things happening e.g. that "insulation had definitely been put in";
- **Control** - many others felt that they would need to be on site to "feel in control" and also to have input into ongoing work and that being away from the home would prevent them from doing that.

When presented with options for video cameras in the home or daily contact with the installer, this rarely made a difference to opinions. In general, consumers felt there would be no substitute for being on site themselves during the works.

The response to these two smaller ideas suggest that, while consumers identify the hassle involved in the installation process (and in some cases "too much hassle"), in many cases they are opposed to ideas that might help mitigate that hassle. However, the reasons stated show that the ideas presented create new issues in terms of some of their core needs - in particular a perceived reduction in **Control.**

10.5 Needs-Focussed Summary

10.5.1 Hygiene

Consumers currently make a significant number of improvements to their home for aesthetic benefits. Similarly they will often upgrade their heating system for the purpose of improving health in the home. Some raised concerns about extensive, prolonged works in terms of the safety to the family of "living on a building site".

10.5.2 Comfort

Home upgrades for the sake of comfort seem to be another key driver with consumers carrying out works to be "warmer", "comfier" or "cosier". Otherwise, works are often done to "reduce discomfort".

10.5.3 Resources

Resources are a key consideration for consumers in planning installations. In many cases it is the dominant front-of-mind consideration when thinking about energy upgrades. Consumers seem to see the value of energy efficiency in terms of reducing running costs but often want to express this in terms of payback and have better ways for accounting for the achieved savings. In many cases, works to improve the resale value of the home are prioritised, even if the consumer is not planning on selling in the near future.

Finally, there were mixed views about how best to pay for works with many noting that while it may be cheaper to do "lots at once", the high cost would require them to take out a loan or remortgage - something that many people felt unhappy with. This was cited as a key reason for taking a slower "bit-by-bit" approach.

10.5.4 Control

Control over the installation process typically manifests itself as a desire to control decisions and installers. Many consumers felt that it was important to take responsibility for finding out information, selecting contractors, overseeing their work and giving ongoing input during works. While they identified that this was a hassle, they generally indicated that the requirement for control superceded the problems of hassle. This seems to be reinforced by the aforementioned issues of trust.

10.5.5 Ease

Ease and convenience are major considerations for consumers in a lot of their plans for works. However, there appeared to be tension between which was more inconvenient - combined works or staggered installation works. Combined works were seen to be easier and less hassle in the long term - something that can be endured only once - whereas staggered approaches were sometimes seen as easier to manage. As previously noted, the hassle of carrying out works is often at odds with the need for control.

10.5.6 Other People

Other people appear to play a major role in consumer decisions related to home upgrades. Firstly, the need to be seen as fashionable or up-to-date was a stated motivator for carrying out works, while others noted that they valued works that other people approved of.

Other people, particularly friends and family, appear to take an important role in the decision-making process by helping consumers overcome trust-related barriers. Using people who they already trust to carry out works or seeking advice on technologies or contractors from friends and family seems critical to consumers' current processes for carrying out works.

11 Advice

- Consumers value advice on their energy systems but, typically, expect that this is **related to the Resources Need group** (e.g. how to save money, how to be less wasteful, etc.). However, evidence suggests that consumers also value advice related to other needs such as Control and Health/Hygiene;
- The two main requirements consumers seem to desire for a provider of advice are **a trusted source** and **impartiality**;
- A "Building MOT" service was met by mixed consumer responses. Those who valued it suggested that it would help gain a better understanding of the home in a low hassle way and help diagnose specific faults with the current setup. Those who disliked it found it difficult to conceive the potential benefits and stated that they may not trust the service to be completely independent;
- Consumers suggested that they would be more trusting of advice that was **"government endorsed",** able to be **delivered by a local tradesman, able to guarantee performance of recommended measures** and would find it more convenient if any information could be gathered using sensor technologies.

Whereas previous chapters have focused on consumer response to specific types of measures and how they would like these installed, this section considers evidence for how consumers might gain advice on how to use their systems and how to make decisions on what measures to install.

11.1 Advice on current system

As noted in Chapter 3, a key finding from the Solutions Workshop was that consumers commonly noted that they would value the opportunity to gain better advice on how to make the best use of their current system. This resonated with findings in the longitudinal qualitative interviews where consumers felt that there were various elements of their system that they felt they were not using as effectively as they could be (as previously noted, with regards to lack of knowledge of how to use controls, for instance).

Technical interviewers noted that sometimes consumers seemed aware that they lacked knowledge but did not have the motivation to address this, and other times they were not specifically aware of this knowledge deficit. Interestingly, even when they weren't aware of the specific area that they were not optimising, they often felt that there were probably ways that they could be saving energy or money. This crucially seemed to present a barrier to consumers in terms of exploring technical options to improve their home. A sense of failing to use current technology to its full potential meant that they felt they could potentially make some of the savings or improvements that they perceived new technologies to provide for "free".

When asked what sort of advice they would like to receive, consumers typically responded:

- **How to save money** - typically this was expressed as ways to use their current system to achieve the same levels of thermal comfort but to use less energy, through specific energy saving behaviours;
- **Which control strategies are "most efficient"** - a common concept that arose was with consumers stating that they "had heard" (although they were often not able to identify the source) that maintaining a "background" temperature at all times was more efficient than turning the

heating completely off during periods when heat was unneeded. Our modelling work explored this concept and found that this was not the case, and that this will invariably use money[12]. This highlights that there may be potential for computer modelling to be used (in an accessible way) to help consumers gain clarity on this and other similar heating "myths";

- **How to use their controls** - This was typically characterised by people who didn't fully understand either how to operate their controls or what their function was.

In general, the advice that consumers seemed to want was primarily related to resources - gaining greater efficiency (i.e. less waste) and saving money. However, our technical interviewers noted that there were other areas of need (for instance, related to ways to improve convenience or to improve health and comfort by methods to control draughts, mould or condensation) that could currently be addressed following provision of simple advice.

During the final interview of the longitudinal sample, it was agreed that the technical interviewer would provide some "Energy Tips" to the participants (a sample of which are included as supporting information to this report). This was typically following the interviewer gaining a rich understanding of the social, technical and physical characteristics of the home through combining monitoring data, social insights and awareness of the current capabilities and components of the home system. Advice was typically split into simple behavioural changes to some low cost suggestions for measures (and, in some cases, some thoughts on some bigger investments, when specifically asked by the participant).

In almost every case, consumers responded very positively to this advice and, in some cases, mentioned to the team afterwards that they had taken up some of the recommended changes. It is, however, difficult (from these interactions alone) to determine which aspects of the advice consumers found most useful as, by this point, they had typically developed a positive rapport with the research team and may be biased towards a positive response. Purely from the experience of the research team, it seemed that the advice that people were more interested in the lower cost measures and behavioural changes rather than any measures that would require significant cost or time investment.

In terms of the characteristics of the provider of advice, two key characteristics emerged from discussions with participants at both the Solutions Workshop and the longitudinal study:

- **A trusted source** - participants spoke of the need for a source that they could trust. As noted in the previous chapter, this was not always someone who they viewed as an expert on the topic, with many participants noting that they would often turn to friends or family for advice on how to use their systems;

- **Impartiality** - a key aspect of mistrust in professional providers of advice is that they may have a conflict of interest in the provision of advice, where they may stand to gain from the advice they provide (for instance, by recommending that there is no way that they can use a system better and that they should purchase something from the advice provider's company).

As such, it can be noted that this may be a factor in why participants responded well to the advice provided by the research team - over the course of the year-long study, we had built strong relationships with participants, demonstrated credibility and professionalism and were well-known enough that participants knew that the advice was impartial, with nothing for the research team to gain from the recommendations made.

11.2 Advice on potential upgrades

Advice on potential home upgrades is typically viewed in a similar way to advice on operation of energy systems - with trusted sources and impartiality being of core importance and type of advice typically related to resources (most commonly cost of installation and payback).

[12] For more detail, see the Consumer Response and Behaviour Modelling Insights report

One slight difference is that the source of advice, from our qualitative interviews, seemed to be more likely to be friends, particularly those who had some technical professional background (e.g. a builder). One participant note that her model of trust was as follows: if she is not sure about a technology/home improvement she would talk to her trusted builder who is also a family friend. If it is technology she is familiar with, she would ask her male work colleagues (the participant stated that as they were men, she assumes "they know what they're talking about".

Participants also seemed more concerned about conflicts of interest in relation to potential upgrades with some consumers clearly stating that advice on the choice of technology should come from an independent source, "not the company that supplies the system".

Some also noted that they would be happy to seek for advice online and look at customer reviews for specific technologies.

11.3 Building MOT

As part of the Solutions Workshop and final longitudinal interviews, one concept tested with consumers was of a home energy assessment styled as a thorough, independent, performance test of the home and occupant interactions with the system as well as providing recommendations for appropriate solutions. This was presented as analogous to a car MOT - a service check for the home.

This generally was met with mixed opinions from consumers in the qualitative sample. Those who were positive about the idea spoke of the following benefits:

- **Less hassle** - some consumers liked the idea of being able to have another party carry out the effort of gathering the information on their behalf. Some also liked the idea that this would be a "one-stop-shop" for advice - with one person providing advice on use, solutions and installers;
- **Diagnostics** - the element of this concept that seemed to be most valuable was in terms of diagnosing the current system's faults and providing targeted specific advice about how solutions or behaviour changes could improve the situation. One participant noted that if they were able to identify significant savings with a solution, this "Building MOT" would give him added confidence in pushing ahead with it.

Concerns included:

- **Unsure of benefits** - some participants noted that this idea "wasn't for them" as they weren't sure it would be of benefit to them. Another view was that this would only really be useful if you had already decided that you wanted to go ahead with some works. Another view was that this would be "paying someone to do work that you could do yourself";
- **Mistrust** - many participants still felt as though they may not trust such a service. Some felt that they wouldn't be able to trust the independence of the provider. Some felt that they would want this service for free, but if that was the case they would have to be getting paid from somewhere. Others suggested they may be happy to pay for the service but only £20-30. Finally, some expressed concerns that the advice would be coming from one person - they felt that they may want a second opinion and others questioned what would happen if the advice they gave was "bad" - would they accept liability?;

Finally, some suggestions for ways that this idea could be made more attractive, based on consumer feedback include:

- Provide guarantees for the future work, to give confidence and peace of mind;

- Be a government endorsed scheme, to further give confidence to consumers. This was a common suggestion. Consumers often said that government-backed schemes were more trusted as they would be "regulated";
- Make sure that it could be provided by a local tradesman. Many people noted that they wouldn't trust energy companies or other large organisations to provide this service and that smaller local companies would have a "reputation they would need to maintain in the local area";
- Finally, consumers were interested in whether some of this service could be carried out by self-assessment or through the use of in-home technology and sensors. They typically felt that this would be more convenient and may save on the cost of the service.

11.4 Needs-Focussed Summary

11.4.1 Hygiene

While consumers typically do not seem to consider advice related to energy systems to cover needs related to Hygiene, there is evidence that when provided advice that speaks to these needs (for instance, on how to reduce humidity and better ventilate the property to avoid mould and condensation) that they value this information greatly.

11.4.2 Comfort

Similarly, consumers don't seem to seek out advice on how to be more comfortable. This may be due to the fact, as previously noted, that consumers generally are able to meet their comfort needs through their existing control strategies. Advice may still be valued in terms of how to achieve high levels of comfort but help focus on how to achieve similar levels of comfort with fewer other needs "sacrificed".

11.4.3 Resources

In general, consumers conceive advice on energy systems most consciously in terms of resource-related benefits - how to reduce energy bill or how to be more efficient (or less wasteful). Consumers also seem to be concerned about the financial motivations of providers of advice, being mistrustful if they feel that advice may be influenced by the need for advice providers to make a profit (e.g. by recommending their own products or an affiliate's). A relatively universal opinion seemed to be that advice providers should be independent. Other comments related to the provision of advice by a government-backed scheme, delivered by trusted local trades and providing a guarantee on the expected performance If the advice was taken up.

11.4.4 Control

As with the first two need groups, consumers typically didn't seek out advice on how to control their systems, but responded positively when such advice was offered in the context of the qualitative interviews.

11.4.5 Ease

Advice should be provided to consumers at a convenient time and in a convenient format. One way to make the provision of advice more convenient, as suggested by one group in our qualitative sample, was to find a way to use technology (e.g. sensors) and self-assessment to help gather information by which to make an assessment.

11.4.6 Other People

Other people form the backbone of much of consumers' current advice channels - they typically value advice from their peers (friends and family) very highly. When their existing relationships are not able

to meet their needs here, many also seem to value advice that comes from other consumers (e.g. through review sites on the Internet). This relates to the previous point about the value placed in independent advice.

12 Paying for Energy

- Upfront cost is a major barrier for consumers in terms of paying for energy upgrades. However, consumers seem reluctant to take out finance to pay for works. There is a widespread feeling that such works should be heavily subsidised;
- Consumers are, typically, **detached from their energy consumption** and their energy bills, particularly those on a direct debit, rarely keeping track of their spend;
- Those off-gas-grid and requiring deliveries of fuel seem more closely aware of their energy spend and the inconvenience of arranging for fuel deliveries;
- Many consumers note that they are not likely to switch suppliers due to a number of reasons including, **hassle, lack of perceived savings, existing debt on accounts** and **confidence in the process**
- When presented with the concept of "Paying for Comfort", consumer response was mixed with common concerns including a **reluctance to sacrifice control** to a third party and perception that this would lead to **increased costs**;
- The concept of "Community Energy" was also met with mixed opinion and concerns including **current lack of "community"**, perceived **lower quality** (due to being a community-based service rather than a large, national provider) and a **sacrifice of control** over maintenance and operation of the system.

This final chapter in the main section of this report considers all of the previously discussed aspects of a smart energy system and reviews the evidence for the ways that consumers might pay for these, as well as the fuel that powers their systems.

12.1 Current payment models

12.1.1 Paying for solution components

As noted previously, consumers typically have very limited experience in the purchase and installation of many of the elements of smart systems and, in general, do not see significant value in them when compared to other categories of works (such as kitchen upgrades). As such, the sorts of work that consumers are willing to pay for are works to the home that are often cosmetic (e.g. to redecorate a room) or for a specific function (e.g. to create more space). Those involved with our longitudinal qualitative study would generally opt to use savings for these works rather than get into debt, although some had spoken of experiences in taking out loans or re-mortgaging. However, one view repeated by different participants was that this was only when they felt that works would add value to the house greater or equal to the value of the loan.

As also noted in Chapter 10, consumer perception is typically that works to the energy system and building performance (e.g. insulation) currently don't add significant amounts to the property value. As such, it is an unsurprising finding that consumers in our sample universally expressed an aversion to taking out loans or increasing debt for the purpose of energy upgrades. Similarly, if they had savings available, typically they had other plans for the home that took priority over improvements to the energy system (such as those in the previous paragraph).

Most respondents to our qualitative work noted that upfront cost was a major barrier to the uptake of new energy solutions. A common view was that they noted that they were aware that there were solutions available to them that would reduce running costs, but that the capital costs and "payback period" were too great to

"If there is an option for things to be cheaper, that don't involve inconvenience, or, you know, some kind of terrible risk, I'll definitely take it."

- Longitudinal Study Participant L12

convince them to spend their money. Furthermore, as previously noted in this report, consumers are generally able to make their systems work to meet their health and comfort needs and felt reluctant to "get into debt" when what they have "does the job".

Another view expressed in the longitudinal study was that the inconvenience of the installation or the risk of changing to a new technology would outweigh the predicted savings gained from the change.

Some consumers did express an interest in government-funded schemes, particularly the Feed-In Tariff for solar photovoltaic panels, where the perceived benefit of making money from the installation of technology was an attractive proposition to some of our longitudinal sample. Awareness of schemes like the Renewable Heat Incentive, however, was typically low.

Others expressed interest in subsidies available for installation of things like insulation or efficient boilers. However, as previously noted, this was often accompanied by a general sense that, as energy efficiency works had been subsidised in the past, they should continue to be subsidised in the future.

Finally, consumers often demonstrated a lack of awareness about existing finance schemes for energy works, particularly Green Deal, the Renewable Heat Incentive and the Energy Companies Obligation. A common belief that emerged from both the solutions workshop and the longitudinal study was that "I don't qualify" for subsidies, as subsidies are reserved for "people on benefits" or the elderly.

12.1.2 Paying for energy

"So you don't have beef on a Sunday, you just have mince, or you stop smoking cigarettes and smoke roll-ups instead because you can't afford cigarettes… you only go out with your friends once in a blue moon."

- Longitudinal Study Participant Y8

Most consumers in our qualitative sample noted that they felt that their energy costs were high - a significant proportion of their income, often only second to monthly mortgage or rent payments. Interestingly, the most common view of energy in the sample seemed to be that energy was a fixed outgoing and not something paid for out of disposable income - with many saying versions of "it costs what it costs". Many spoke of being aware of prices increasing and, when that happens, they opt to make cutbacks in other areas of life. Some expressed annoyance over the perceived high prices but admitted that they were not too high that they felt they needed to do anything different. One view was that there would need to be a significant price increase before they felt that the price of energy might motivate them to make changes to their home or behaviour. Others, however, did note that they would make changes to their heating practices - but typically this was by making a choice between different heating strategies (e.g. using a secondary heater room-by-room as opposed to running "expensive" underfloor heating) rather than accepting a reduced level of comfort. We also found that energy conservation behaviours (e.g. boiling only what you need in the kettle, switching off unused lights, appliances, etc.) were relatively widespread, but typically these seemed to be more related to electricity usage than heat usage.

Many consumers take a typically removed position regarding their bills. Many noted that they may submit meter readings, but otherwise don't pay much attention. Many also noted that they did not read their bills, they just paid what was due. In many cases they also stated that they didn't understand their bills. This finding was exemplified by the consumer response, in our longitudinal study, to a request to find an energy bill to have ready for one of the interviews. In many cases, consumers didn't do this and stated that they hadn't kept their bills. Others still noted that they were now "paperless" and that this meant that they were even less familiar with their bills as they would often not open these emails.

Detachment from energy costs seemed to be more pronounced with customers on direct debit tariffs. The predictability of fixed monthly bills means for many consumers that they do not see the consequence of how much energy they are using day-to-day until the monthly payment is changed (and even when changes were made to this tariff many consumers in the longitudinal sample admitted that they often didn't question this). Consumers seemed to value the convenience and

predictability of a direct debit but this may have a "knock-on" effect to facilitating a detachment to how much energy is being consumed day-to-day. Some participants noted that they were paying the same rate every month throughout the year, despite being aware that they were using less energy during the summer. Most seemed content with this, however, as they often felt that this balanced out the higher consumption during winter. One participant actually noted that his energy company had offered to reduce the monthly payments during the summer one year and he had contacted them to ask to stay on the same rate. In this case he preferred to continue building up a credit to ensure that his bill did not go up again too much in the winter.

However, those with credit meters seemed to be somewhat more connected to the cost of their energy and how much their day-to-day energy cost. Often, these households were also on low incomes and, as such, their energy usage was constrained by their finances, rather than it being a choice in meeting needs. Quite often, those on credit meters valued the fact that this method of payment kept them engaged with their energy consumption as they found it easier to budget their weekly or monthly spend, and one particular case in our longitudinal sample told us that she had specifically asked to be put onto a key meter to make managing costs easier.

Those who were off the gas grid, and on some form of delivered fuel (e.g. oil) also seemed to be more aware of the cost of their energy. Those in the longitudinal sample that were on oil-based heating typically found that this was more expensive than if they were on mains gas. Arranging deliveries was also seen to be inconvenient. These consumers often spoke of the fact that they were frustrated with the added cost and hassle of their oil systems, but were sceptical of the alternatives available to them. One view was that the hassle and upheaval involved in replacing the system was too big a barrier and that they would rather just "put up with" what they currently have. Another view was they felt that they had limited control over their situation - not just in terms of technology but in terms of supplier as "all of them charge the same". Finally, there was evidence from one case of the household conserving the oil supply in the later winter months to try and "make it last" until the heating could be turned off. This particular case noted that they used fan heaters to help conserve that fuel.

Some longitudinal participants spoke about switching suppliers, although the majority of these noted that they would likely not be switching any time soon. A number of barriers to switching included:

- **Lack of potential savings** - a thought that they all charge the same;
- **Hassle** - perceived effort required to research suppliers or perception of a difficult transition;
- **Confidence** - lack of confidence in one's own ability to be able to navigate the process (e.g. through using a switching website);
- **Existing debt** - the thought that they may be in debt to their current supplier - either through direct debit or paying off a debt through a key meter - and that this would require the debt to be paid off before switching;
- **Motivation** - a general feeling of "I can't be bothered". This may be a product of some of the above perceived barriers and limited benefits.

12.1.3 Paying for maintenance

While not specifically explored during the longitudinal sample, one particular case discussed his experience of paying for a maintenance package for his heating system. In general the motivations behind paying for such a service, in his case, were convenience - having a maintenance package is perceived as less hassle - and cost - that there wouldn't be any large payments to be made that would come as a shock.

"I say it's convenience and peace of mind, but it's also about paying a little bit now to save yourself from having to pay a fortune in the future."

- Longitudinal Study Participant L12

As this is just one isolated case, it would be valuable to explore this area further with a wider sample before drawing too many conclusions. However, these insights suggest the sorts of need groups that might be addressed by a maintenance package - i.e. Resources and Ease.

The quantitative survey briefly explored consumer preferences for maintenance packages where they 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, with this typically being higher for households with young children or for social tenants. In terms of the dominant heating technology, homes with central heating showed 61-63% in favour of a fixed annual fee, 74% for those with district heating but significantly lower for those relying on individual heaters (39% for portable heaters and 44% for fixed heaters). This suggests that preferences around maintenance regimes are significantly affected by the type of solution system in place.

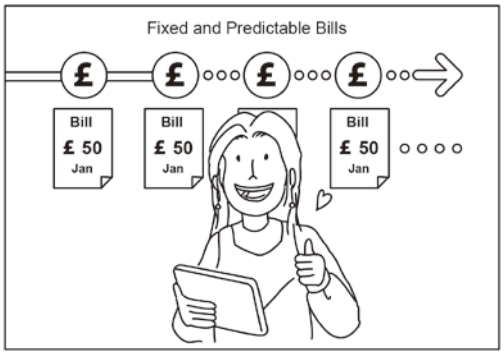
12.2 "Paying for Comfort"

At the Solutions Workshop, one concept that was tested with consumers was that of a new model for paying for energy - paying, instead, for comfort - with a service provider offering a fixed, predictable price to guarantee a level of comfort in the home. The provider would be incentivised, then, to find ways to reduce the demand in the home to increase their margins. [13]

Response to the idea was mixed. Some noted that it would be of benefit if they could guarantee their comfort and a fixed price would be very convenient, such that they would not need to worry or think about their energy costs.

However, concerns for the model were typically dominant. These concerns include:

- **Sacrifice of control** - there was a perceived sacrifice of control to the provider - in order for them to be able to guarantee this comfort, consumers felt that the provider would need to be in control. Many participants were reluctant to accept this;
- **How can they guarantee comfort?** - others noted that their comfort needs vary according to a range of different factors day-to-day, including who is in the home, different preferences between family members and how active they are. As such they were sceptical as to how a system could guarantee their own comfort, others questioned what happened when circumstance change (e.g. someone moves in or out of the household);
- **Lead to waste** - one view was that this model could lead to waste, as consumers would not be encouraged to use less energy themselves. Others felt that it may be open to abuse if consumers felt that the more energy they used the "better value" they were getting from the fixed charge;
- **Payment -** a general view was that they would be reluctant to pay more for such a service than they currently paid for their energy bills;



- **General doubts of possibility** - the view that this couldn't work due to combinations of the barriers above.

[13] As a potentially complex model, a simplified version was presented briefly to participants at the workshop for a short discussion. As such, it would be advisable for the ETI, if interested further in consumer response to this concept, to carry out a dedicated workshop or study into consumer response on this.

One interesting response from one group was that they felt that the only way this would be acceptable would be if they had control over the system, but that this would "defeat the object". A follow-up response to this was that if they were able to control their energy usage but were paying a flat rate, that this was no different to their current situation of paying a direct debit for their energy of a fixed price every month.

12.3 Communal and Community Energy

This section will look at two different aspects of shared, local area heat - communal heating for a small group of dwellings (typically operated by a stock owner) and a concept for a community-owned heat network, with profits reinvested into the local area.

12.3.1 Communal Heating

As noted in Chapter 6, our additional interviews with consumers in communally heated homes typically showed that the specificities around how people pay for their energy and how they control it make the biggest impact on their attitudes and usage of the system.

We found from the interviews that there were two main types of payment models in common usage - unmetered payment (typically through a service charge) and metered systems. In the sample of interviews conducted, the majority of participants were on unmetered systems. There were mixed opinions on the benefits and disadvantages of this system. Benefits included:

- **Ease of budgeting** - as the energy was built into monthly rent payments, this made it easy to plan outgoing costs in a secure and reliable way;
- **Support for others** - a less common view was that this type of system helped those who may be less fortunate as there was a perception that there was less likelihood of being "cut off" by the energy company.

"There's no benefit in turning it off… I pay a fixed rate through my service charge on the flat so there is no incentive to turn the heating off."

- Additional Interviews Participant

Perceived disadvantages include:

- **Abuse** - a common feeling was that other people on the same system may be taking advantage of the system by using more energy than the average;
- **Subsidising others** - related to the above was the concern that some users would inevitably be subsidising others. Some spoke of the fact that this incentivised them to use more energy, to "get the best value" for their payment;
- **Low users** - concern that one was paying for more energy than they were using was also a common complaint; particularly for people who were regularly away from the dwelling.

Metered systems had a mixed view. While some on unmetered systems expected that they may be able to make savings using a meter, others felt that this may lead to added costs. This was also the view of those who *were* on metered systems - typically due to a perception that they were paying more for being on communal heating than on an individual dwelling system. A view that there could also be "hidden costs" (such as standing charges or other opaque service charges from the metering agency) with such a system was also presented.

A view from the literature[14] is that a major factor in consumer acceptance of metered communal heating is *fairness*. This is not just restricted to whether they are able to control it (see Chapter 6) but also as to whether they feel that they have control over how much heat is required to heat their home (i.e. the energy performance of the dwelling - are they in control of making improvements?) and their

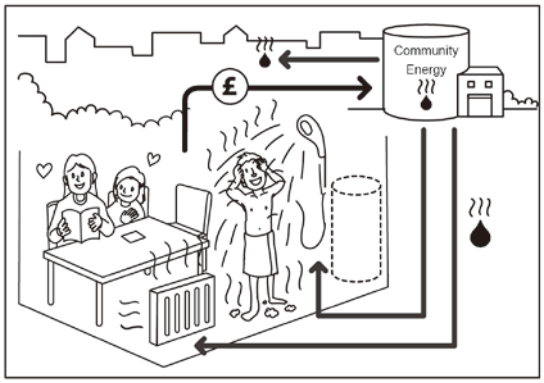
[14] Morgenstern P (2012) Identifying challenges to the introduction of heat meters in poorly-performing district-heated apartment blocks. MRes dissertation, The Energy Institute, University College London.

confidence with any control regime in place. This also suggests that metering requires consumers to have to think carefully about control, something that could be considered an inconvenience or, where consumers feel that the controls are too complicated to use, unfair.

12.3.2 Community Energy

The Community Energy vignette considered a community-owned and -operated system that reinvested profits into local training schemes and installation of energy efficiency systems. Responses to this concept were mixed. Identified benefits include:

- **Not having to buy or maintain your own boiler** - some viewed this as a more convenient option with less risk in unexpected costs due to system failure;
- **Local benefits** - some found it appealing that money for energy was being reinvested locally and benefiting their community, potentially helping to bring community members together;
- **Using profits to improve homes** - this was an attractive alternative to having to rely on own savings or government subsidies;



Concerns with the idea, however, included:

- **Pricing** - how would the individual costs be assigned and how would the community ownership work? There was a general view that they would expect this to be more expensive than what they are currently paying for their energy**;**
- **Lack of community** - a view in two of the groups in the Solutions Workshop was that modern urban and suburban communities are detached from their neighbours and others in the local community, as such, the desire to invest in the community was lower. Some felt that this would work better in rural locations where there is a perceived greater level of community interaction;
- **Challenges of uptake** - it was perceived that for this to work there would need to be large numbers of people in the community taking up the idea;
- **Quality** - one view was that a system owned and operated by a community-based organisation would be less reliable and of a lesser quality than a national-level system and that outages would be more common than, for instance, power cuts;
- **Lack of control** - some felt that this would mean sacrificing autonomy or independence to the local community.

12.4 Needs-Focussed Summary

12.4.1 Hygiene

Consumers typically don't consider Hygiene in terms of paying for energy, other than to typically perceive that their Hygiene needs will always be more important than the cost of their energy.

12.4.2 Comfort

Similarly for Comfort, consumers are typically reluctant to sacrifice personal comfort for the sake of saving on energy bills. Consumers have mixed opinions about a system of paying for comfort; partly due to perceived variations, day-to-day and between household members in what they feel is "comfortable".

12.4.3 Resources

Consumers are keen on ways of paying for energy that make it easy for them to budget - either through fixed charges, such as direct debits, or through using a key-meter to control their weekly demand. Those currently on oil-based systems find that this is an expensive system to operate. Consumers are also, typically, reluctant to get into debt in order to pay for the installation of any solution components and are focused on the "payback" of how long it will take for savings to match the upfront cost. Communal systems where consumers pay a fixed charge for unmetered usage is viewed with mixed opinions, but a common view is that this results in low users subsidising higher users.

Some models for payment are perceived by consumers as encouraging waste - such as unmetered communal heating.

12.4.4 Control

A key finding related to control is that a major objection to a "Paying for Comfort" payment model is that this is perceived to be sacrificing control over their system. Similarly, one view was that a community-based model could result in sacrificing control to the local community.

12.4.5 Ease

Consumers typically value the convenience afforded by a direct-debit tariff as this allows them to pay a predictable amount without otherwise thinking about their energy consumption or engaging with it. Convenience is a common theme across all elements of paying for energy - including maintenance and installation. Aversion to hassle and inconvenience is seen as a barrier to a number of things discussed in this chapter, including investigating any improvements to the energy system or even switching energy suppliers. There is also evidence to suggest that unmetered heating tariffs (such as with some communal heating) are considered as convenient for consumers, in the sense that this payment method means that they don't feel as great a need to think about being effective at controlling their usage.

12.4.6 Other People

Other people appear to be important in relation to systems that are seen to supply a community. Feelings of abuse in unmetered systems were raised, along with the concern that some users would be subsidising others. A general feeling of a lack of community in relation to community-owned schemes was seen as a barrier to uptake of such schemes.

Finally, competing needs within the family were identified as a barrier to payment models such as "Paying for Comfort".

13 Consumer-led Solution Evaluation and Design

The previous chapters have detailed what consumers want from solutions, generally and in terms of specific elements. Wherever possible, we have aimed to link these insights back to a set of core needs from the qualitative and quantitative work due to the broader insight that **tailoring systems to consumer needs is a strong approach to designing appealing solutions**.

This chapter aims to build on these insights to present a useful way of assessing new solutions against consumer needs through comparing how needs might be impacted by changing an existing system.

As previously noted, **there is a difference between the needs that might inspire consumers to acquire a solution from the benefits (expressed as met or better-addressed needs) that consumers experience following installation**. The quantitative work also suggested that it was often difficult to predict which needs are going to be important to consumers based on observable features such as demographics or house-type. As such, despite the importance of needs, it's difficult to identify which need to focus on for any given household or consumer.

Crucially, however, solutions **should not be designed to focus exclusively on one or two needs, a holistic spread of needs should be addressed**. If, for instance, you focus on a need that appeals to consumers before acquiring the solution, at the expense of other needs, you run the risk of developing solutions that people will buy but not enjoy using. Consequently, these consumers will fail to endorse them to their friends and family (or even advise against a purchase) and thus reduce crucial market growth through word-of-mouth and peer-to-peer advice, which our research has shown to be vital in energy-related improvements. Otherwise if you were to focus on a need that is more tangibly realised following installation, at the expense of other needs, there is the risk that you develop a great product that people might really like using, but that nobody is motivated enough to buy. Furthermore, our research has showed that consumers' priority needs vary significantly, over both long and short term periods. As such, the most important needs to a household today may be different to their most important needs tomorrow. Only by designing solutions that cater to a full spectrum of needs can we allow these solutions to have wide, immediate and lasting appeal.

The following table presents the various elements of a solution, as set out by the previous chapters, set against the core needs. The intersects of each need and solution element contain prompt questions, based on the insights from the consumer research, that help determine whether there is a positive or negative impact on a need for any given solution to be assessed. The prompt questions are not exhaustive but should aid thought processes in each case.

The following pages show a worked example of how a potential solution may be evaluated using this method.

[NB: A3 copies of the two tables will be provided in Appendix A to aid reading small fonts]

Solution Element	Health & Hygiene	Comfort	Resources	Control	Ease	Other People
Control & Feedback	Does this enhance the health of the internal environment? Does it have the potential to degrade the internal environment e.g. through mould risk? Is the solution aesthetically pleasing?	Does this help improve one or more household member's thermal comfort? Does this solution impact on any other way that consumers enjoy using their home? Does it allow flexibility of settings to meet varying comfort needs?	Does it enhance awareness of energy consumption? Does it enable the consumer to limit heating unused spaces? Does it enable variation of comfort in different spaces? Does it provide useful feedback on usage?	Does it enhance the ability of the user to achieve the desired environment? Is the feedback in a form that allows consumers to make informed changes to their behaviour? Is the feedback at a level to avoid information overload?	Is the system intuitive enough to be used without a manual? Is the solution convenient to access? Is the feedback flexible enough to allow varied use cases? Is it portable and convenient to use?	Does the solution allow for different household members' comfort needs to be met? Does the solution require everyone in the household to use it?
Heat Delivery & Localised Heat	Does it provide or remove added value through e.g. clothes drying? Does it reduce risk to health? Is it aesthetically pleasing?	Is it responsive to meet changes in required comfort? Are there added comfort benefits e.g. warm feet from underfloor heating? Is there a risk of under or overheating?	Does responsiveness of the system change how they may consume heat (e.g. waste less)? Is it likely to cost more or less to run? Is the capital cost a barrier?	Is the system responsive enough to be controlled to meet changing need?	Is the solution familiar enough to consumers to be used intuitively? Does it allow usage to easily and flexibly be adjusted with needs?	Is the solution "socially acceptable" or seen as socially desirable (e.g. wood fires)? Does it enable needs of others in the home to be catered for?
Centralised Heat Generation	Is the solution aesthetically pleasing? Does the solution produce unwanted noise? Does it provide or remove added value through e.g. clothes drying?	Does the solution lead to a more comfortable internal environment?	Is there a high capital cost? Is the existing system currently performing well - will replacement be deemed wasteful? Is the system more or less expensive to run?	Does it require controls to be mounted to the unit itself? Does it change the level of control that consumers will have over the delivered heat? Does it change control over maintenance?	Is it a familiar, trusted technology to install? Is it quick to install? Could this be a disruptive technology to live with?	Will the technology impact other people (household members, neighbours, etc.) differently? Will it spoil neighbours' views?
Hot Water	Does it change the way that hot water can be used for cleaning? Is the solution aesthetically pleasing? Does it provide other benefits (e.g. hot water tank drying clothes)?	Does it change how comfortable hot water may be during use?	Does it change any limitations on quantities of hot water used? Does it change how much hot water might be "wasted"?	Does it change how users control hot water? Does it enable intuitive controls?	Does the solution require consumers to think about and manage their hot water usage differently?	Does the solution require coordination between household members to manage the quantities of, or usage of hot water?
Ventilation & Cooling	Does it impact the way the household maintains fresh air? Does it reduce the risk of condensation/mould? Does it help avoid health risks of overheating? Does it generate unwanted noise?	Does it help (cool) to achieve greater levels of comfort? Does it create other pleasant sensations (e.g. movement of cool air over the skin)?	Does it conflict with heat usage in terms of waste? Are the capital costs too high to justify the benefits? Are the running costs too high to justify the benefits?	Is there a greater level of control than e.g. opening windows? Are there intuitive controls on the unit itself? Does it allow different rooms to be ventilated or cooled differently?	Is the system more or less convenient than the current situation to live with?	Does it change home harmony by, for instance, reducing conflict over ventilating and retaining heat? Does it enable different members of the household to be cooled/ventilated differently?
Insulation & Building Fabric Improvements	Does it change how the home looks (particularly considering period features)? Does it impact on other health-related problems (e.g. mould growth)? Does it reduce transmission of external noise?	Is the system likely to improve comfort to the home? Does it change risk of overheating?	Does it help reduce energy costs? Does it impact property value? Is the capital cost acceptable?	N/A	Is the installation of this technology likely to be disruptive? Will the installation require additional works (e.g. redecoration)?	Does the installation impact on neighbours or how others may view the property?
Installation Process	Does the installation process require prolonged periods where the home could be at greater risk in terms of health and safety?	Is the installation process likely to cause any discomfort to the household (e.g. through loss of heating for a day?)	Is the installation affordable?	Does the installation allow the consumer to make decisions about the installer? Are consumers able to control when and where works take place? Are consumers able to have input into the process?	Can the installation be carried out in a way that is convenient for the consumer?	Can consumers make use of their peers to help make decisions related to the installation process?
Advice	Does the advice help consumers to improve the internal environment to reduce risk of health issues?	Does the advice focus on helping consumers maintain or enhance their existing levels of comfort?	Are the financial motivations of the advice provider transparent enough to ensure consumer trust? Does advice help consumers reduce waste or energy usage?	Does it help consumers control their systems more effectively?	Is advice required at all? Can it be provided on demand? Can it be provided in multiple formats? Can information be gathered discreetly (e.g. through sensors)?	Does advice need to be provided to multiple people? Can consumers provide advice to each other to enhance trust?
Payment	Does the payment method impact the health of the consumer or the way that they are able to maintain a healthy home environment?	Does the payment method impact on consumer ability to manage their household's comfort?	Does the payment method make it easy for consumers to budget? Does the payment method impact the running costs? Is the payback on the measure considered acceptable?	Does it change the level of control that consumers have over their heating system? Does it change who has control over the system?	Is the payment method convenient for consumers? Does it enable consumers to manage their energy consumption without thinking? Is it potentially a hassle for consumers?	Does it involve charges that are impacted by how much people outside the household use? Does it impact the ability of varying household needs to be managed?

NB: The above prompts are based on findings from the research but are only as a guide - a wider range of things in each case are likely to be needed to be considered.

13.1 Worked example (Ground Source Heat Pump):

In this example, we consider using the table to review the various ways that a solution may impact on a household, considering as many elements as possible:

- **Current situation** - rural, detached, pre-1900s home with a family with two school-aged children. Currently on oil-based heating with old radiators and no TRVs, controlled by a thermostat and programmer. Hot water provided via an insulated cylinder.
- **Solution** - replace oil boiler with a ground source heat pump, upgrade insulation and replace heating delivery with underfloor heating controlled by a smart-phone app.

Solution Element	Health & Hygiene	Comfort	Resources	Control	Ease	Other People
Control & Feedback		Controls provide feedback that assists in making decisions about how to create greater comfort	Controls allow for effective programming to manage resources.	New controls increase and enhance the amount of control that household has over system.	New control is convenient to use. May require some consumer acclimatisation and education.	Controls allow for different rooms to be "zoned" to meet varying household needs
Heat Delivery & Localised Heat	Removal of radiators increases and enhances usable space	Underfloor heating provides warm feet and a stable household temperature. Heating may be less responsive. Added insulation may increase risk of overheating	High capital cost of underfloor heating may be a barrier			
Centralised Heat Generation	Removal of oil storage tank makes external areas more aesthetically pleasing	Scale of upgrade may increase property value.	Running costs of system are projected to be significantly lower than the oil system High capital cost of unit may be a barrier		System designed to run in the background without need for too much consumer involvement.	
Hot Water					System able to be connected to existing hot water system to be convenient	
Ventilation & Cooling		System can be run in reverse during summer to provide cooling				
Insulation & Building Fabric Improvements	Improved insulation may reduce risk of condensation or mould Changes the aesthetic look of the property	Improves ability of home to retain heat May result in summer overheating	Reduces heat losses through walls, saving money and reducing waste Perception that change in look of property may reduce property value High capital cost of added works may be a barrier	Requires less need for control of heating system due to passive effects		
Installation Process	Some additional risk to household members during installation				Solution is applied and external fixtures are replaced as part of the process. Requires occupant to be decanted while underfloor system installed. Disruptive installation.	Installation may be disruptive for the whole family and potentially neighbours.
Advice			Advice on efficient usage provided.		Advice provided at installation, by installer, to demonstrate the controls and explain how to optimise system. Free advice line provided for one year after installation.	
Payment			May require consumers to take out a loan or re-mortgage		No more need to arrange fuel deliveries. One electricity bill on direct debit is convenient to manage.	

This illustrative example shows how a potential solution could be evaluated in accordance with its potential impact on needs - green being a positive impact, red a negative. More complex solutions with multiple components can be combined on the same assessment sheet.

13.2 Additional Considerations

This method of testing a solution against needs is useful to help broaden the considerations for the ways that consumers may perceive a potential solution and help identify areas where there may be resistance. However, it is not a holistic picture of how consumers may respond.

Our research has demonstrated that there are wider considerations that impact consumer decisions. Consumers don't always make decisions purely and rationally based on how a solution will meet their needs.

A major barrier remains of trust - in technologies, service providers and in processes involved in delivering solutions. As such, solutions should also be considered in terms of how different these are to what consumers have been used to in the past. They should also consider whether there are ways to help build consumer trust in things that are unfamiliar to them.

Finally, it is worth noting that the assessment can be used flexibly, adding columns or rows as is most useful. Furthermore, it is of little consequence as to which cell the user records their thoughts - its utility is in helping explore a fuller range of impacts that a solution may have on consumers and review that against specific needs.

14 Reflections and Recommendations

This section will review the project's success against the 5.8 objectives detailed in the Introduction.

14.1 Successes of the Research

In general, the research has been successful in identifying how consumer needs broadly impact the way that solutions may be perceived by consumers. In particular:

- It has identified some of the ways that consumers currently use their systems and how consumers are adaptable at using their systems to meet their core needs of comfort and health;
- It has identified key groups of needs that consumers aim to meet through use of their systems that can inform the way that we design solutions for future use;
- It has highlighted how a needs-based approach could be of benefit to designing better solutions and identifying where innovation is needed, particularly in terms of how solutions might be presented to consumers;
- It has shown that the common model is that comfort and health needs are typically met at the expense of other needs - where solutions could focus on helping consumers meet their core needs while reducing those "sacrifices";
- It has highlighted that a strong starting point in engaging consumers could be to help them identify how best to use their current systems and identify where there will be definite areas that require a change to the installed systems;
- It has led to a way of assessing solutions against needs to better focus solution design and communication of the benefits to consumers;
- It has highlighted the value of solutions that provide greater levels of flexibility and responsiveness to allow consumers to make their systems match a varying set of needs and accept changes in circumstances, such as changes in household composition or even a complete change of occupants - e.g. when moving home.

14.2 Limitations and Gaps

There are remaining some limitations in our approach that could be addressed in future research:

- The core aims of the wider project have been to focus on needs and behaviours rather than to test specific concepts and technologies with consumers. As such, many of the conclusions about how consumers may respond to a "needs-based" design approach are, at this stage, hypothesised;
- Resources dedicated to assessing consumer response to solutions have been limited to a single workshop and testing concepts as a small part of a larger longitudinal study. Other findings have been inferred, often from those who have already adopted solutions - either through being housed in homes with smart solution elements or because they are early adopters. As such, there is limited confidence in how applicable these findings are to a wider general population, particularly in terms of how consumers may or may not decide to take up new solutions;
- As has been found in previous research, there is a difference between what consumers say in terms of whether they would be interested in taking up a solution and their actual actions (i.e. they may say they would be interested in buying a solution but, when it comes to actually buying they may not go ahead with it);

- Consumer response to some of the solution elements being considered for a smart solution up to 2050 (e.g. smarter controls) has been limited to a small-scale field trial of controls. That study has highlighted that there are many arising insights that can come from an in-home trial as opposed to social research and prospective concept testing;

- The quantitative and qualitative study has not specifically generated enough evidence to be able to identify specific, easily-identifiable consumer segments that might respond differently to different types of solutions. This is not, necessarily, a failing of the project, as much of the evidence we have seen has suggested that system design may not be best designed around meeting the needs of specific segments (partly due to the fact that consumers seem to be aware that they want to ensure that their homes retain or improve the value to other, prospective consumers who may have different needs to themselves).

14.3 Recommendations for Future Research

Based on these assessments, some areas where future research could enhance our understanding of consumer response to solutions could include:

- **In-home, co-designing of solutions for specific home use cases** - the complexity of the interactions between people, property and solution elements suggest that there would be value in detailed co-creation of bespoke solutions, testing the needs-based approach in the context of a real potential solution;

- **Further social research** - there would be value in carrying out further workshops, similar to the successful approach used in the solutions workshop and interviews, to gain deeper, broader and richer insights into the responses of consumers detailed in this report. Further depth in aiming to better understand variation in response across the population to a wider range of solution elements would also be of value;

- **In-home trials** - the small-scale HEMS trial, though very specific and lacking representativeness, highlighted the value in real tests of technologies in consumer homes. The expected use cases seemed to vary from the actual use cases, and better understanding what consumers value of solutions before experiencing them as well as what they value when they are in place will be vital in designing solutions that are widely taken up and widely enjoyed;

15 Appendix A - Large Size Assessment Tables

Solution Element	Health & Hygiene	Comfort	Resources	Control	Ease	Other People
Control & Feedback	Does this enhance the health of the internal environment? Does it have the potential to degrade the internal environment e.g. through mould risk? Is the solution aesthetically pleasing?	Does this help improve one or more household member's thermal comfort? Does this solution impact on any other way that consumers enjoy using their home? Does it allow flexibility of settings to meet varying comfort needs?	Does it enhance awareness of energy consumption? Does it enable the consumer to limit heating unused spaces? Does it enable variation of comfort in different spaces? Does it provide useful feedback on usage?	Does it enhance the ability of the user to achieve the desired environment? Is the feedback in a form that allows consumers to make informed changes to their behaviour? Is the feedback at a level to avoid information overload?	Is the system intuitive enough to be used without a manual? Is the solution convenient to access? Is the feedback flexible enough to allow varied use cases? Is it portable and convenient to use?	Does the solution allow for different household members' comfort needs to be met? Does the solution require everyone in the household to use it?
Heat Delivery & Localised Heat	Does it provide or remove added value through e.g. clothes drying? Does it reduce risk to health? Is it aesthetically pleasing?	Is it responsive to meet changes in required comfort? Are there added comfort benefits e.g. warm feet from underfloor heating? Is there a risk of under or overheating?	Does responsiveness of the system change how they may consume heat (e.g. waste less)? Is it likely to cost more or less to run? Is the capital cost a barrier?	Is the system responsive enough to be controlled to meet changing need?	Is the solution familiar enough to consumers to be used intuitively? Does it allow usage to easily and flexibly be adjusted with needs?	Is the solution "socially acceptable" or seen as socially desirable (e.g. wood fires)? Does it enable needs of others in the home to be catered for?
Centralised Heat Generation	Is the solution aesthetically pleasing? Does the solution produce unwanted noise? Does it provide or remove added value through e.g. clothes drying?	Does the solution lead to a more comfortable internal environment?	Is there a high capital cost? Is the existing system currently performing well - will replacement be deemed wasteful? Is the system more or less expensive to run?	Does it require controls to be mounted to the unit itself? Does it change the level of control that consumers will have over the delivered heat? Does it change control over maintenance?	Is it a familiar, trusted technology to install? Is it quick to install? Could this be a disruptive technology to live with?	Will the technology impact other people (household members, neighbours, etc.) differently? Will it spoil neighbours' views?
Hot Water	Does it change the way that hot water can be used for cleaning? Is the solution aesthetically pleasing? Does it provide other benefits (e.g. hot water tank drying clothes)?	Does it change how comfortable hot water may be during use?	Does it change any limitations on quantities of hot water used? Does it change how much hot water might be "wasted"?	Does it change how users control hot water? Does it enable intuitive controls?	Does the solution require consumers to think about and manage their hot water usage differently?	Does the solution require coordination between household members to manage the quantities of, or usage of hot water?
Ventilation & Cooling	Does it impact the way the household maintains fresh air? Does it reduce the risk of condensation/mould? Does it help avoid health risks of overheating? Does it generate unwanted noise?	Does it help (cool) to achieve greater levels of comfort? Does it create other pleasant sensations (e.g. movement of cool air over the skin)?	Does it conflict with heat usage in terms of waste? Are the capital costs too high to justify the benefits? Are the running costs too high to justify the benefits?	Is there a greater level of control than e.g. opening windows? Are there intuitive controls on the unit itself? Does it allow different rooms to be ventilated or cooled differently?	Is the system more or less convenient than the current situation to live with?	Does it change home harmony by, for instance, reducing conflict over ventilating and retaining heat? Does it enable different members of the household to be cooled/ventilated differently?
Insulation & Building Fabric Improvements	Does it change how the home looks (particularly considering period features)? Does it impact on other health-related problems (e.g. mould growth)? Does it reduce transmission of external noise?	Is the system likely to improve comfort to the home? Does it change risk of overheating?	Does it help reduce energy costs? Does it impact property value? Is the capital cost acceptable?	N/A	Is the installation of this technology likely to be disruptive? Will the installation require additional works (e.g. redecoration)?	Does the installation impact on neighbours or how others may view the property?
Installation Process	Does the installation process require prolonged periods where the home could be at greater risk in terms of health and safety?	Is the installation process likely to cause any discomfort to the household (e.g. through loss of heating for a day?)	Is the installation affordable?	Does the installation allow the consumer to make decisions about the installer? Are consumers able to control when and where works take place? Are consumers able to have input into the process?	Can the installation be carried out in a way that is convenient for the consumer?	Can consumers make use of their peers to help make decisions related to the installation process?
Advice	Does the advice help consumers to improve the internal environment to reduce risk of health issues?	Does the advice focus on helping consumers maintain or enhance their existing levels of comfort?	Are the financial motivations of the advice provider transparent enough to ensure consumer trust? Does advice help consumers reduce waste or energy usage?	Does it help consumers control their systems more effectively?	Is advice required at all? Can it be provided on demand? Can it be provided in multiple formats? Can information be gathered discreetly (e.g. through sensors)?	Does advice need to be provided to multiple people? Can consumers provide advice to each other to enhance trust?
Payment	Does the payment method impact the health of the consumer or the way that they are able to maintain a healthy home environment?	Does the payment method impact on consumer ability to manage their household's comfort?	Does the payment method make it easy for consumers to budget? Does the payment method impact the running costs? Is the payback on the measure considered acceptable?	Does it change the level of control that consumers have over their heating system? Does it change who has control over the system?	Is the payment method convenient for consumers? Does it enable consumers to manage their energy consumption without thinking? Is it potentially a hassle for consumers?	Does it involve charges that are impacted by how much people outside the household use? Does it impact the ability of varying household needs to be managed?

In this example, we consider using the table to review the various ways that a solution may impact on a household, considering as many elements as possible:

- **Current situation** - rural, detached, pre-1900s home with a family with two school-aged children. Currently on oil-based heating with old radiators and no TRVs, controlled by a thermostat and programmer. Hot water provided via an insulated cylinder.
- **Solution** - replace oil boiler with a ground source heat pump, upgrade insulation and replace heating delivery with underfloor heating controlled by a smart-phone app.

Solution Element	Health & Hygiene	Comfort	Resources	Control	Ease	Other People
Control & Feedback		Controls provide feedback that assists in making decisions about how to create greater comfort	Controls allow for effective programming to manage resources.	New controls increase and enhance the amount of control that household has over system.	New control is convenient to use. May require some consumer acclimatisation and education.	Controls allow for different rooms to be "zoned" to meet varying household needs
Heat Delivery & Localised Heat	Removal of radiators increases and enhances usable space	Underfloor heating provides warm feet and a stable household temperature. Heating may be less responsive. Added insulation may increase risk of overheating	High capital cost of underfloor heating may be a barrier			
Centralised Heat Generation	Removal of oil storage tank makes external areas more aesthetically pleasing	Scale of upgrade may increase property value.	Running costs of system are projected to be significantly lower than the oil system High capital cost of unit may be a barrier		System designed to run in the background without need for too much consumer involvement.	
Hot Water					System able to be connected to existing hot water system to be convenient	
Ventilation & Cooling		System can be run in reverse during summer to provide cooling				
Insulation & Building Fabric Improvements	Improved insulation may reduce risk of condensation or mould Changes the aesthetic look of the property	Improves ability of home to retain heat May result in summer overheating	Reduces heat losses through walls, saving money and reducing waste Perception that change in look of property may reduce property value High capital cost of added works may be a barrier	Requires less need for control of heating system due to passive effects		
Installation Process	Some additional risk to household members during installation				Solution is applied and external fixtures are replaced as part of the process. Requires occupant to be decanted while underfloor system installed. Disruptive installation.	Installation may be disruptive for the whole family and potentially neighbours.
Advice			Advice on efficient usage provided.		Advice provided at installation, by installer, to demonstrate the controls and explain how to optimise system. Free advice line provided for one year after installation.	
Payment			May require consumers to take out a loan or re-mortgage		No more need to arrange fuel deliveries. One electricity bill on direct debit is convenient to manage.	

This illustrative example shows how a potential solution could be evaluated in accordance with its potential impact on needs - green being a positive impact, red a negative. More complex solutions with multiple components can be combined on the same assessment sheet.