Programme Area: Smart Systems and Heat

Project: Consumer Response and Behaviour

Title: Synthesis Report

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This report was prepared for the ETI by the consortium that delivered the project in 2013 and whose contents may be out of date and may not represent current thinking. In this report, the project team aim to draw together findings from different parts of the Energy Technology Institute's two year Consumer Response and Behaviour programme. This programme aimed to better understand the needs, behaviours and attitudes of consumers in order to design more effective and more attractive solutions. It deployed a wide range of methods to help those designing new and compelling energy solutions. The report highlights the importance of considering a wider range of needs and benefits offered by solutions.

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 Systems and Heat (SSH)
Technology Programme

Work Area 5:
Consumer Response and Behaviour

"Smart" Starts with the Consumer

Project Synthesis Report

Foreword

The way that the UK is thinking about heat is changing. The way that consumers will experience and understand heat at home in 2050 is likely to be radically different to the way they experience it now.

This report details the findings of the Energy Technologies Institute's Consumer Response and Behaviour programme, which aimed to better understand the needs, behaviours and attitudes of consumers in order to design more effective and more attractive heat solutions.

We aim, in this document to summarise the two years of work on this project, across a wide range of methods to help those who are tasked with the task of designing new and compelling solutions. We particularly highlight the importance of considering a wider range of needs and benefits offered by solutions.

First, however, a reminder that such wider impacts of heating on family life were being discussed 70 years ago and, indeed, how these attitudes may change in another 70 years' time.

"A small but noisy minority will want to do away with the old-fashioned coal fire.

These people - they are also the people who admire gaspipe chairs and glass-topped tables - will argue that the coal fire is wasteful, dirty and inefficient. They will urge that dragging buckets of coal upstairs is a nuisance and that raking out the cinders in the morning is a grisly job, and they will add that the fogs of our cities are made thicker by the smoking of thousands of chimneys.

All of which is perfectly true, and yet comparatively unimportant if one thinks in terms of *living* and not merely of saving trouble.

I am not arguing that coal fires should be the sole form of heating, merely that every house or flat should have at least one open fire round which the family can sit. In our climate, anything that keeps you warm is to be welcomed and under ideal conditions every form of heating apparatus would be installed in every house.

For any kind of workroom central heating is the best arrangement. It needs no attention, and since it warms all parts of the room evenly, one can group the furniture according to the needs of work.

For bedrooms, gas or electric fires are best. Even the humble oilstove throws out a lot of heat, and has the virtue of being portable. It is a great comfort to carry an oilstove with you into the bathroom on a winter morning. But for a room that is to be lived in, only a coal fire will do.

The first great virtue of a coal fire is that, just because it only warms one end of the room, it forces people to group themselves in a sociable way. This evening, while I write, the same pattern is being reproduced in hundreds of thousands of British homes.

To one side of the fireplace sits Dad, reading the evening paper. To the other side sits Mum, doing her knitting. On the hearthrug sit the children, playing snakes and ladders. Up against the fender, roasting himself, lies the dog. It is a comely pattern, a good background to one's memories, and the survival of the family as an institution may be more dependent on it than we realise."

- Extracts from, *The Case for the Open Fire* by George Orwell
8th December 1945

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1 Heat and Humans – What's the problem?

1.1 The UK Heat Landscape

The last 60 years have seen large changes to the way we heat our homes in the UK. Whereas homes previously typically had coal, wood, open-flame-gas or electric-bar fires, 87% of homes now have gas-fired central heating. These heating solutions required individual attention and – in the case of coal and wood – very labour-intensive support. Considerable space was needed for the heating system (chimney breasts, large coal bunkers, etc.), fuel storage and waste. Direct emissions from burning fuel required high levels of ventilation, resulting in highly uneven temperatures and a dependence on localised sources of radiant heat.

Central heating, with all waste gases emitted outside the home, has allowed us to safely seal up our homes, including installation of nearly air-tight double glazing and some form of insulation in the majority of homes. The consequence of this has been that our spaces are far more uniformly heated and heated to a higher temperature on average, transforming the standards of health and comfort that households expect their system to provide.

Hot water provision has similarly changed from back-boilers, gas-fired instantaneous heaters at point of use and immersion heaters through two waves of change: first, by moving to central heating and providing heat to hot water tanks and, more recently, the removal of hot water tanks to fit combination (combi) boilers. These changes have impacted consumers by freeing up the space previously occupied by the hot water tank, and by allowing a shift such that hot water is conceptualised as an unlimited, on-demand service.

Historic change has provided significant improvements in *convenience* (heat when you want it with less hassle), *comfort, safety, health* and *increased useable space* in a home, as the whole home is now heated and the heating system is significantly smaller. The move to central heating has allowed us to use our homes in more flexible ways than before; for example, bedrooms being used as living or working spaces. Converting unheated spaces such as lofts into heated living areas has also been made more achievable through central heating. Thus, a change in the way we heat has also changed how we use our spaces and increased the utility of our homes.

These "additional" benefits – greater convenience, comfort, safety, health and increased useable space – rather than savings in fuel costs appear to have been the driving force behind the consumer demand leading to mass-scale conversion to gas central heating. It is worth reflecting on these wider drivers when evaluating potential changes to the way we heat our homes over the next 50 years. The future drivers for change are potentially radically different. However we can confidently predict that change will not be driven purely by fuel cost savings. While we cannot say for certain what will drive future change, there are a number of factors that we can confidently suggest will force a change in the way we think about heat in the future.

1. **A need to mitigate climate change.** The UK Carbon Plan states that to meet our legal carbon emission targets most buildings will need to be "zero carbon" emitters by 2050. In order to stand a chance of meeting this ambitious and legally-binding target, UK Government's heating strategy (DECC, 2013) suggests that there will need to be significant increases in the prevalence of domestic energy efficiency, low carbon local heat networks and renewable heat, leading to a diversification of domestic heat (compared to the current situation of 87% gas central heating). These

changes are likely to remain unpalatable to a general public who generally are not motivated to act by climate change and where some of these steps have, to date, often been seen as a step sideways or backwards – leading to added expense, reduced convenience or increasing limitations or restrictions on usage.

Where homes are well-insulated, the average heat demand would be massively reduced, requiring heating systems of smaller capacity. An increasingly significant source of heating in many buildings may be the incidental gains from lights and appliances, etc.; if these are not efficient and we keep increasing the number of them, our buildings risk overheating, further increasing the likelihood of demand for cooling technologies (potentially increasing CO_2 emissions).

2. **A need to adapt to climate change.** The long lifetime of CO_2 in the upper atmosphere means that we will feel the impact of our historic burning of fossil fuels for decades to come, regardless of our future actions to mitigate climate change. Increased CO_2 levels are predicted to increase UK temperatures in both summer and winter. These increased temperatures may reduce the amount of heat we lose from our buildings in winter (although, this does not necessarily mean we will use less heating energy) and significantly increase the demand for summer cooling of buildings. Summer overheating is expected to become a serious health concern, potentially increasing summer mortality by 540% by 2050 from a 2012 baseline, with elderly people most at risk (HPA, 2012).

   Our research has shown that passive cooling, such as shading and night ventilation face significant challenges in uptake due to lack of consumer understanding of effective strategies. While passive cooling will play a role, it will need to be promoted and explained to householders and supported by means to combat concerns such as security, safety and external noise. Otherwise it is strongly expected that active cooling, through air conditioning or similar, will see rapid growth in uptake. While active cooling is currently present in very few homes (fewer than 2% of our surveyed sample), it is anticipated that an increase in cooling degree days will see consumers turning to cooling technologies, particularly air conditioning, familiar to them from other experiences such as commercial premises and cars. There should also be increasing demand for new buildings that are designed for a warmer climate, with effective shading, secure ventilation openings, controlled gains (e.g. from solar radiation or internal appliance use) and appropriate thermal mass, to minimise dependence on air conditioning.

3. **Concerns about fuel prices.** Our national energy system has faced significant under-investment over the last five decades and this will cost money to put right. In addition, if we are to decarbonise our supply this will, in the short term, be more capitally expensive. Therefore the likelihood is that fuel prices will rise in real terms. Projections estimate increases of up to 57% for electricity and 47% for gas by 2030 based on current prices (DECC, Updated energy and emissions projections, 2013). The relative fuel prices of different sources of energy may motivate some people to switch to different systems. Higher prices may cause some people to reduce their heating and some people to invest more in energy efficiency.

4. **Security of supply.** If we, as a nation, do not invest correctly in our new energy system correctly and/or do not effectively plan the transitions in our supply and demand systems we increase the likelihood of power cuts or energy shortages. Although highly unlikely this would happen consistently over the long term, even a few periods of shortage of energy supply from the national system could radically change what people expect out of their

heating system. Our qualitative research shows that many people consider heat as a “right” and not having heat available is a crisis that people do all sorts of illogical things to avoid: the distress purchase of a new boiler when a poorly maintained one fails, rather than routinely servicing and replacing an old, inefficient boiler before it fails, is a classic and widespread example of this problem. The market for heating systems that are reliable and autonomous from the national system could feasibly expand significantly. Well insulated homes can be kept warm with heat from minimal sources and so are also more resilient to security of supply issues.

5. **Change in needs and demographics.** Major demographic changes are predicted over the coming decades, which will change the current balance of heat needs. The UK has an aging and growing population. We now live longer but our physiological systems will still deteriorate with age. The elderly are at an increased risk from both colder and warmer temperatures due to decreased effectiveness of the body's natural thermoregulatory systems (such as sweating) and reduced mobility.

   As a nation, we are also increasingly turning to living alone. Increased rates of divorce, improved global telecommunications and independence have led to higher numbers of single occupancy homes. The consequence of this is we now occupy a greater area per person than we did in the 1970s and consequently at a greater expense per person. Some of us are more sedentary, setting up a vicious cycle of obesity - leading to a sedentary lifestyle, and warm, comfortable temperatures facilitating sedentary living.

   Changes in social media also facilitate a completely different use of space and the Internet has facilitated some four million people working from home. We have moved to a 24/7 society and, based on our monitored homes, we already seem to be losing the difference in heating patterns between week days and weekends. Homes are no longer empty at set times but shift work and self-employment means a standard 9-to-5 routine is becoming far less common. We require greater flexibility to meet our diverse and unpredictable needs. Significant proportions of the working population have minimal time to engage in anything that is not directly related to their work or leisure. Many of us are therefore not interested in engaging with heating systems: we just need them to keep us warm while we get on with our lives.

UK Population over the age of 65 (ONS, 2013):

80%

more by 2050 (2012 baseline)

Single-occupant homes (CLG, 2008):

54%

more by 2033 (2008 baseline)

For more detail on the factors that may influence the way we use heat in the future see our report **"D5.3 External Factors Report"**

1.2 The Challenge

There is clearly a wide range of ways that our needs and behaviours in relation to heat may change – not necessarily the fundamental needs for comfort and health but the ways in which those needs express themselves. Policy and industry need to prepare for specific visions of the future, but where do they need to invest and which policies do they need to promote?

This report identifies the complexity of heating needs and behaviours and how they interact with both the building and its heating system in a complex socio-technical way. By mapping out the complexity of the existing systems we can support the design of new systems and policies to overcome the current low understanding of the consumer perspective. Our research does identify significant consumer barriers such as low demand for solutions to some of the problems with the existing provision of heat relative to needs as well as low consumer trust with many of the potential providers of solutions. However, we believe that these challenges can be overcome once they are better understood.

Findings from our research suggest a paradox between heating not being a major focus in people's lives and, at the same time, considered as a fundamental right. So the essential motive is present – heating is fundamental to lifestyle – but the challenge is either to re-engage householders with their heating or to develop systems that are sufficiently autonomous that lack of engagement is not an issue.

1.3 Meeting the Challenge

To better understand the consumer perspective of heat in the home, we undertook a complementary mixed-method approach to consumer research, integrating technical and social data to understand how and why people currently use heat in their homes and where the opportunities for improvements exist.

The Consumer Response and Behaviour project (part of the ETI's Smart Systems and Heat Programme) has mapped out the complexity of heat use from the occupant's perspective. We have undertaken this work by first getting people to look at how they use heat currently, then exploring their needs, initially in small group discussions with individual's representative of the likely variation in needs and behaviours.

A sub-sample of 30 homes has then had detailed monitoring of their heating behaviours and motivations, over summer and winter; this has included monitoring air and radiator temperature, light and relative humidity in most rooms in the home, hot water pipe temperature, and whether windows and external doors are open. This, combined with social interview data about what people think they are doing with heat, has enabled us to paint a very detailed picture of the complex interactions between people, behaviours, controls, building fabric and the provision of heat. Unlike many projects, we were able to iterate several times between analysing the physical data, integrating this with interviews and interpreting from the perspective of the household, creating very rich case studies. These activities were supplemented by one-off interviews with household/system types that were less well represented in the main sample (e.g. those with heat pumps and the fuel poor).

The resulting information was used to design a detailed, statistically representative survey of heating behaviours and needs in Britain (2,313 householders interviewed) to test if what we observed was in fact happening on a significant scale in the population as a whole. The survey also explored and quantified needs and behaviours in ways that had not been possible with the smaller samples in the qualitative research. The data collected has also provided valuable insights into the sorts of technologies currently deployed in different households and how these impact on needs and behaviours. This allows additional questions to be answered and the data to be used in future when developing and implementing smart energy solutions. We also used the case study data to explore what would happen if either the household or the home changed. This was explored with the use of building physics computer models of the case studies.

Finally we have explored a range of solution scenarios with home owners to see how they might react to them and actually tested two home energy management systems in 12 homes.

Unusually for this type of study, we have both been able to do in-depth qualitative and quantitative studies, building a strong understanding of both the physical conditions of the environment and fabric and heating systems.

Although the project method is complex, there are some clear messages that emerge from the research, for both policy makers and those developing

technologies, in terms of how any future system may be perceived and meet the needs of home occupants.

Our core findings into consumer needs and behaviours suggested a number of reasons behind barriers to uptake of smarter heat systems. These include the fact that marketing, policies, campaigns, etc. are failing to address heat in a way that speaks to the *right* consumer needs (as explored in Chapter 2) or how consumers currently manage heat. Our findings also suggest that promoted solutions fail to convince consumers that they will preserve or enhance the fundamentally core needs of health and comfort.

We have, so far, analysed the significant quantities of data in a way that makes the greatest initial sense to us as researchers. But part of the value of the project is in creating a data set that can be used to answer additional or more specific questions. We are sure that those who are deeply involved in developing policies and technologies will see value in radically different ways to analyse the data or run our models to address their own issues in future.

This report presents the core narrative that has emerged from this complex project, as perceived by the research team, and aims to help the reader understand the consumer perspective. Where relevant, we direct the reader to the other project deliverable reports where many of the emergent insights are discussed and evidenced in greater detail.

Chapter 2 explores the insights into consumer needs and behaviours emergent from the integration of our quantitative, qualitative and secondary research. Chapter 3 builds on these insights to present the implications for the design of future solutions and supporting policy.

2 What do consumers need from heat?

Key messages

- Consumers exhibit a wide and dynamic range of needs that can be broadly grouped using dimensions of *Comfort*, *Hygiene, Ease, Other People* and *Resources*
- Needs appear to exist along a hierarchical continuum, such that once more *core* needs are met, more *peripheral* needs become the focus
- Consumer needs are highly sensitive to their current circumstances and can fluctuate with changes in occupancy, environment, income, etc.
- A significant majority of consumers use multiple methods to typically keep warm in winter, beyond using their main heating system, that combine into complex control strategies
- Consumers use these strategies to be highly adaptable to their needs and environment, but are also highly resistant to change strategies that they have found to work for them
- Solutions that accommodate a broad set of needs and allow consumers to easily meet different needs at different times are likely to be well received

2.1 What needs drive consumer use of heat?

Our starting point in the Consumer Response and Behaviour project was to develop a better understanding of the needs that drive consumer behaviours in the context of heat usage. Through our qualitative and quantitative work, two similar categorisations of needs emerged. Understanding both of these categorisations is vital in order to understand how these drive consumer behaviour and how to design solutions that help consumers better serve these needs[1].

2.1.1 Categorising needs

We started with an extensive literature search, which yielded a long list of over 80 relevant needs, which was subsequently condensed to 21 needs.

Our qualitative work, starting with deliberative workshops and followed by a longitudinal in-home study (involving environmental monitoring and depth interviews) and additional interviews, subsequently explored consumer needs through deeper and richer engagement. With the longer list in mind, a shorter list of eight qualitative needs emerged, organised in pairs as illustrated in Figure 2.1.

[1] The latter point being covered in more detail in Chapter 3.

Figure 2.1 - Needs Emerging from our Qualitative Work

- **Comfort and Health (*Health and Wellbeing* pair):** These two needs emerged as the primary and fundamental needs most relevant to the way that people use heat in their homes. Given their fundamental nature, these needs are in some instances taken as a given, particularly *Health*. They may be so deeply embedded as a need in daily habits and routines that people are not always conscious of them, and may not articulate these as needs. This pair of needs may be distinguished from the others in that they are focussed on what people want to achieve through heating – the *aims* rather than the *means*;

- **Cost and Waste (*Resources* pair)**: While some needs tend to feature as needs that people actively *seek* (e.g. comfort, health, convenience), resource-related needs tend to feature in terms of *avoidance* (e.g. reducing cost and avoiding waste). These needs can be seen in relation to the *means* by which an aim is achieved (e.g. a behaviour that enables consumers to meet their comfort needs in a resource-efficient way) but still satisfying a desire to reduce costs or cut out waste;

- **Control and Convenience (*Agency* pair):** These needs relate to the extent to which people want to be actively in control of heat energy use within the home and the time and the effort people are willing to put in to meet personal or household requirements and preferences. They may feature in an active sense, where people want to be actively in control of choices relating to heat energy use. Alternatively, in some cases these needs are more passive, where people wanted to be removed from choices relating to heat energy use (for example, a person may not want the hassle of changing to a more efficient heating system; or may not want to be actively involved in the control of the heating system). Control and convenience may feature is flipsides of a coin in some instances – where convenience appears in the form of giving up 'active' control in the interest of ease;

- **Harmony and Hospitality (*Relational Dynamics* pair):** This pair of needs relates to social relationships, as these play out in the household context, addressing the issue of *whose need* is important. These needs relate to interactions with householders (harmony) and with guests (hospitality), and tie in closely with self-image and social acceptance.

As these needs emerged, in many cases, through deeper interactions with participants over the course of the year, they can be seen as **deeper-level needs,** often with consumers being **unaware of these needs on a day-to-day basis**.

For more detail on the qualitative needs see our report **"What people need and do that involves heat energy"**

Our quantitative work yielded a similar categorisation of needs[2], although condensed into five key *dimensions*:

For more detail on the quantitative needs see our report **"Quantifying heat energy needs and behaviours"**

- **Hygiene** (includes the qualitatively derived need **Health**) - extending to cover general cleanliness, neatness, security, safety and aesthetic appeal. As before, this dimension denotes basic needs that tend to be regarded as fundamental but often taken for granted if met;
- **Comfort** (includes **Comfort** and **Control**) - extending beyond thermal comfort to more generally being at ease, in control and free of concerns;
- **Resource** (includes **Cost** and **Waste**) - a clear financial focus although "waste" can also be seen from a non-financial perspective as something that is inherently wrong. It is particularly interesting that *concern for the environment* fits in this dimension, perhaps indicating that protecting the environment is seen as a consequence of the same actions that save money and avoid waste, rather than being a motivator in its own right;
- **Ease** (includes **Convenience**) - extending to include routine, habits and norms;
- **Other people** (includes **Harmony** and **Hospitality**) - extending to include *productivity*, suggesting that this need may be interpreted in relation to being able to get on with work or activities within the home, facilitated by cordial relationships and mutual support.

The needs and categorisations are shown in more detail in Appendix A. The categorisations derived from quantitative and qualitative research, as expected, do not exactly match. They are derived by different methods, the quantitative achieving immediate answers to closed questions, speaking to an unfamiliar interviewer, rather than emergent from a year-long period of interactions and open lines of inquiry with a researcher who has developed a positive rapport with the participant, as in the qualitative work. As such, the quantitative research reveals **surface-level, front-of-mind** needs whereas the qualitative work suggests that other, "**deeper**" needs can still be of significant importance.

The quantitative research also represents a **"snapshot"** of an individual consumer's needs at the time of the interview whereas the qualitative research was able to observe and explore how needs change over time, be this short term (e.g. during the day) or long term (e.g. over months). Averaged over a large number of respondents, this should not bias the overall picture but the responses of individual householders are not necessarily stable over time.

Understanding that there is a difference between *surface* and *deeper* needs is vital when considering how consumers will respond to solutions. For instance, it could be that *surface* needs may inform consumer purchase decisions, whereas *deeper* needs impact the consumer's longer term enjoyment of a solution. Therefore, awareness of *surface* needs could inform a marketing strategy or the way that solution benefits are communicated, while *deeper* needs could inform UX design and solution design parameters.

[2] Referred to, in our project reports, as the five "dimensions of need"

2.1.2 How needs change over time

While it is useful to isolate consumer needs, it is also important to illustrate how they are pursued and met differently within different households over time. Our longitudinal research enabled us to identify general patterns and consistencies in the way that people in our sample prioritised needs. Our evidence suggests that these needs exist along a **continuum of priority** such as that depicted in Figure 2.2. Some are *core* needs – physiologically fundamental, and essential for life, and closer to the principal purpose of heating – while others are more *peripheral* and perhaps better described as 'wants'.

Figure 2.2 Classification of and Prioritisation of needs

The needs that are more peripheral, in the outer circles, appear only to become **'front-of-mind'** once core needs (i.e. Health and Comfort) have been met sufficiently; only then do they begin to influence and drive behaviour. Simultaneously, as core needs are met, people may become less conscious of these: we found that people were less likely to articulate, and required far more prompting on needs that were met and, conversely, tended to be highly vocal about needs that were not being met adequately or that were, or that were perceived to be, out of their control.

Each of the eight qualitative needs should be seen as varying in their importance between individual consumers, between households and over time. The hierarchy is dynamic, with movement along a continuum, sometimes even during the same day (e.g. as a child goes to school and later returns) depending, sensitively, on the current situation. Furthermore, the ordering of needs along the continuum can vary from household to household and a need that is considered to be *core*, such as personal comfort, is sometimes partially sacrificed for domestic harmony or reducing costs. As such, the ordering of needs in Figure 2.2 is illustrative and not fixed.

This inherent dynamism of needs is crucial to the design of solutions as it suggests that designing a solution around one need may only work for a consumer temporarily or for part of the day or year. This suggests that a better approach would be to design solutions that are more accommodating of an ever shifting set of needs and can rapidly accommodate change.

2.1.3 Making use of our insights on needs

The previous sections outline some key features of consumer needs – that they are varied, hierarchical, conscious and subconscious (or *surface* and *deeper*), sensitive to circumstances and dynamic. Through this, we have suggested that solution design should avoid focusing on designing for one specific need and rather aim to facilitate multiple needs as they arise.

Our research highlighted a number of further, specific points of learning that emerge from our greater understanding of needs and how consumers view their existing solutions. These points can inform the design of smarter solutions:

- **Comfort is fundamental:** Heating is fundamentally for keeping warm, and comfort is how people can judge warmth itself and the likely impact of warmth on their own health and the health of others. So comfort is a fundamental need in this sense. Other needs will be typically less critical than this core aim;

- **Aims vs means:** Some needs may be seen as the aims of a behaviour (e.g. the need for comfort is addressed by heating the home). Others can be seen in relation to the means by which an aim is achieved (e.g. the need to heat the home in as simple and convenient a manner as possible). The *aim* can be seen as having higher priority in this sense, but the *means* might be closer to consumers' consciousness;

- **Awareness of needs:** As noted above, needs that are not "front-of-mind" can still be important. This often depends on whether it is currently being met; for example, a person who is already comfortable may not think of comfort as a need but this does not mean that comfort is unimportant;

- **Concept of home life:** While heating may be seen as fundamental from one perspective, it can also be seen as subservient to broader concepts and purposes of the home. Heating may, for example, help to meet a more fundamental need of caring for a family;

- **Causes and consequences:** Embedded in the previous four points is a notion of causes and consequences, whereby one need is met by first meeting another. For example, health may be addressed by achieving comfort, and caring for others might be achieved by meeting the need for control (of warmth). Related to this, the ways in which consumers talk about needs ranges from broad terms such as "comfort" to specific elements that might contribute, such as "achieving personal thermal comfort". An important case is "control", which can be interpreted as a general need to feel in control or as a specific need to be in control of achieving one of the other needs (e.g. being in control of the heating in order to achieve thermal comfort);

- **Whose need?:** Any need might be important to a consumer either for his/her own benefit or in relation to someone else (e.g. a dependent, a guest or simply someone else in the household). There are also needs that are, in effect, imposed by another party – whether by relational dynamics in the household or by regulation through standards, labels or legislation. The need to comply with regulation can be seen as a burden but also supports the need to be confident in technology - i.e. our qualitative work suggests that regulated and endorsed technologies may increase consumer confidence;

- **Frequency of behaviour:** The literature review distinguished between behaviours that are frequent (more-or less daily), occasional

(investments such as a new boiler) or in between (e.g. servicing a boiler). Priorities of needs may vary depending on the frequency of behaviour that is being considered. The qualitative research focused on frequent behaviours but did conclude, for example, that **aesthetics** are important for investment decisions but much less so for frequent behaviours;

- **First thought or deep purpose:** In terms of research process, needs may be prioritised according to what consumers are most immediately able to report and explain, or according to a more in-depth exploration of their needs. Solution design should take account of both levels but grabbing people's interest may depend more on what needs they are immediately aware of. The full range of evidence should be used to design solutions that will have immediate appeal but also prove satisfactory once consumers have acquired and used them;

- **Needs implied by behaviour:** In theory, priority needs might be deduced from what people actually do. In practice, it is difficult to make sufficient independent observation to make this kind of deduction. However, the qualitative research has sought to explore needs partly from a starting point of what people say they do, challenged through monitoring data on what they actually appear to do.

For some examples of how needs play out in different households, see our **Consolidated Case Studies**

To summarise, consumer needs are complex, fluid and often unpredictable. Consumers are often unaware of some of the needs that are important to them or otherwise unable to describe or identify their priority needs. However, consumer needs are a vital factor in the way that consumers perceive solutions, both in terms of uptake and use, so solutions necessarily must support consumers to meet their changing and often subconscious needs. Fortunately, some emerging themes suggest that, generally, health/hygiene and comfort are of fundamental importance to most households. This suggests that solutions that keep these needs as a mandatory baseline requirement, while seeking ways to help consumers meet other needs in a better way than their current system allows, are likely to be more successful than those that target a single need.

The impact of our research on consumer attitudes towards solutions is discussed in more detail in Chapter 3 of this report.

2.2 What do consumers do to heat their homes, heat water and keep warm?

In the previous section, we explored how consumer needs vary within the population and how they are dynamic, often unpredictable and complex. Our work has also explored the actions or behaviours that consumers carry out in order to meet these needs, which we discuss in this section.

For more examples and detail on consumer behaviours see our qualitative report **"What people need and do that involves heat energy"**

Our work has highlighted that people display or describe a vast variety of individual behaviours and combinations of behaviours by which they heat their home. The qualitative workshops and time spent in people's homes during the qualitative studies revealed a range of general approaches and highly specific behaviours to their use of heat energy. As a summary of behaviours, Table 2.3 provides some insight to the kinds of things people do to try to meet their needs.

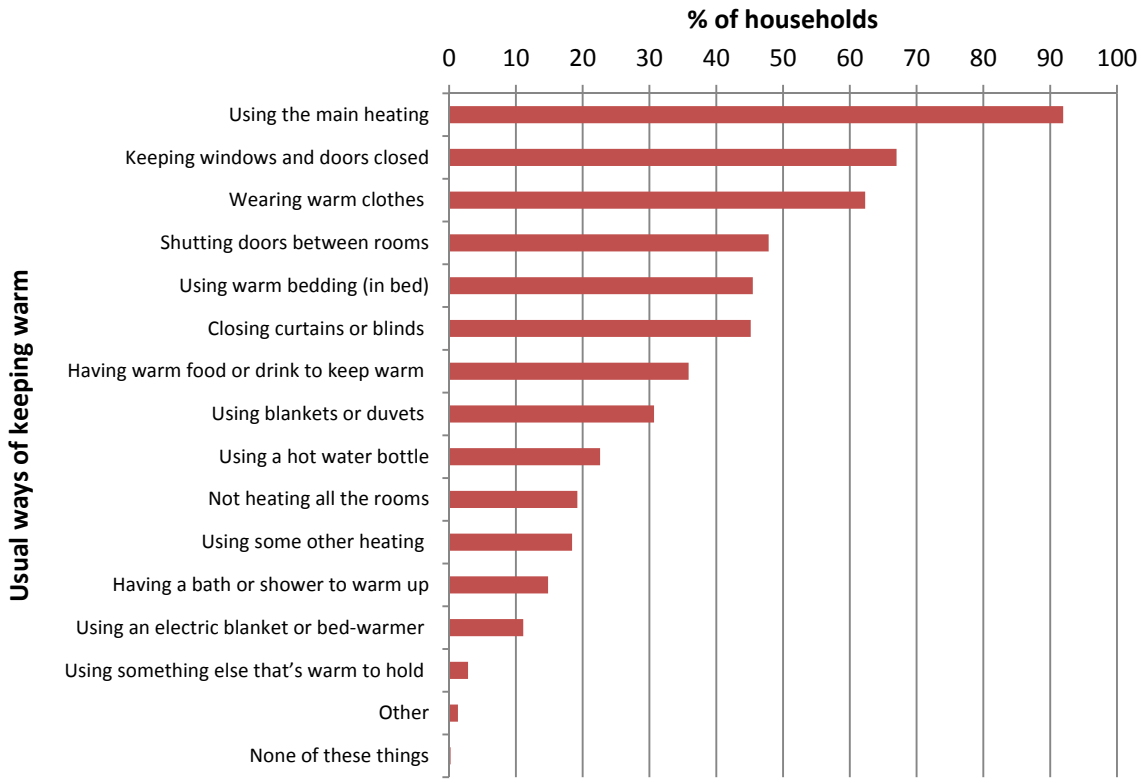
Table 2.3 Examples of behaviours mapped against needs

	Heat Space	Heat Water	Heat Person	Ventilation & Insulation
Health	Keeping the heating on to avoid damp and mould growth	Using hot water to clean the house	Using a hot water bottle to treat aches and pains	Keeping windows open to ensure fresh air
Comfort	Setting heating to come on early in order to be comfortable when returning home	Having a bath to rest and relax	Using a thicker blanket in bed to be warmer and more comfortable	Keeping windows closed to prevent draughts
Cost	Heating only one room to save money, rather than the whole house	Having a shower rather than a bath to save money	Putting on a jumper rather than turning up the heating to save costs	Adding loft insulation to save money on energy bills
Waste	Turning off central heating in kitchen when cooking to avoid wasting heat	Putting off washing up until tomorrow rather than reheating the whole hot water tank in the evening	Using an electric blanket rather than heating the whole bedroom as this is less wasteful	Keeping windows shut when heating is on to avoid wasting heat
Control	Using a portable heater because it is simpler, easier and quicker to turn on/off as needed	Switching on the immersion heater for 20 minutes to have just enough hot water for a shower	Walking around in shorts and t-shirt with the heating on because this creates a sense of choice and control	Using windows rather than extract fans as these are easier to understand and control than fans
Convenience	Having the heating on a timer so no need to think about it	Having a shower rather than a bath as it is quicker	Putting on a jumper because it's quicker and more convenient than waiting for the house to heat up	Opening the window if it's too hot in winter as this is quicker and more convenient than turning the heating off
Harmony	Using a secondary heater in the grandmother's room, in addition to the main heating as she feels the cold more	Coordinating hot water use to avoid running out of hot water in the morning	Wearing more or less clothes because other people in the family like it warmer/cooler	Turning off the fan in the bathroom as it disturbs the baby
Hospitality	Turning the heating on before guests arrive in order to avoid looking "tight"	Overriding the hot water timer to ensure guests have enough hot water	Giving a guest an extra blanket in case they get cold during the night	Opening the window to air the guest room before they arrive so it's a fresher environment

Each household is different, as is every property and every heating system. Typically, therefore, people adopt **a wide range of strategies** to meet their

specific heat energy needs. Our quantitative work highlighted that 87% of people employ multiple activities to keep warm in winter with the most common response (35%) being a **combination** of all of: use of heating systems, controlling where heat goes, retaining own warmth and heating the person directly.

Figure 2.4 What people do to usually keep warm - quantitative survey



Some consumer control strategies are highly sophisticated and consciously considered, while others may be rudimentary, habitual or reflexive. What appears to remain constant across the population, however, is that strategies generally enable people to meet the *aims* (or fundamental needs) of comfort and health, while being prepared or required to make trade-offs in relation to the *means* (more peripheral needs, such as cost and convenience) by which they get there. In other words, fundamental needs of comfort and health are typically met at the expense of other needs such as convenience, cost or control.

The nature of these behaviours illustrates that people are **extraordinarily adaptable** in how they meet their needs. At the same time, however, they remain **highly resistant to change** once they have developed a strategy that allows them to meet their basic health and comfort needs. This commonly is seen in cases where consumers are not making optimal use of their existing controls, for instance where their programmer is not set to match their occupancy profile and they are compensating by using the "boost" function. In our longitudinal study, such consumers typically noted that they didn't know how the programmer worked but, with some effort (either by looking online or by finding the instruction manual), could probably work it out. However, they also admitted that they felt no real need to do so, as their current strategy worked for them and boosting each time was quicker than learning how to change the programme. The view seems to be - if the strategy works, why change it?

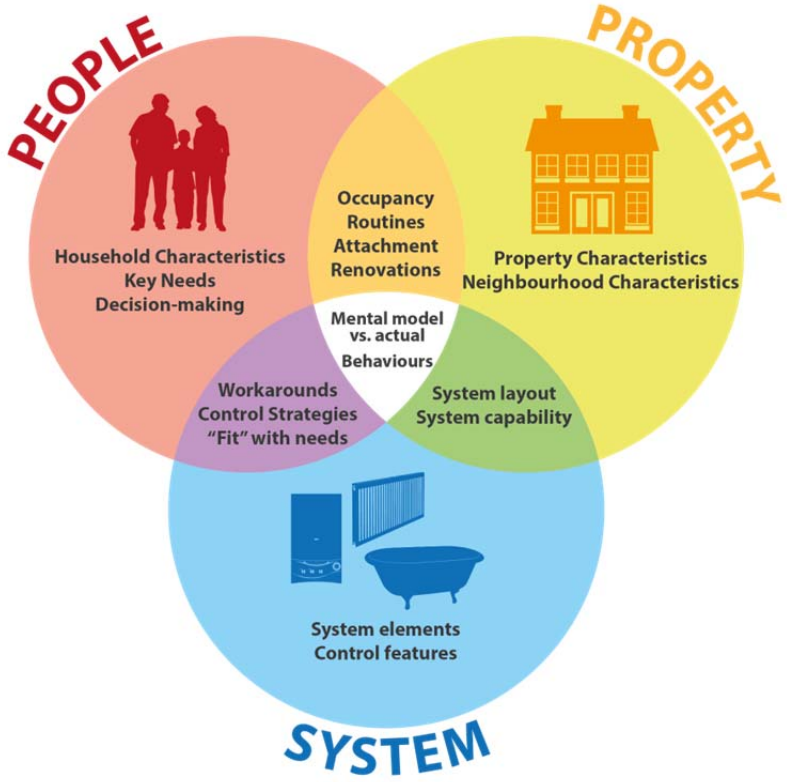
Similarly, consumers rarely seem to feel a need to make a change to their energy systems to make their control strategy easier to manage. Changes seem to be either built in to other works (e.g. replacing a boiler when refitting a kitchen, or insulating when adding an extension) or triggered when there is a disruption to their normal flow of life that 'pushes' them to change -– for instance the birth of a child or retirement. This suggests that, most of the time, they find behavioural alterations to their control strategies preferable to physical alterations to the home.

2.3 How do needs drive behaviours?

While there is a logical sequence whereby needs drive behaviours, this does not mean that behaviours can easily be predicted from knowledge of consumer needs. The same set of needs can result in quite different patterns of behaviour, and the same patterns of behaviour can arise from different needs. For example, one consumer may use a portable fan heater for comfort reasons, while another may do so because they believe it is less wasteful to heat a smaller space.

It can even be said that behaviours help bring needs front-of-mind, in the sense that a person may become aware of a need that is not satisfied by current behaviour. Furthermore, it is **not only needs that affect what people actually do**. A dynamic and interacting set of household-level factors, encompassing *people, property and system* (Figure 2.5) affect how and to what extent people are able to meet these needs, and which needs come into focus and influence behaviour.

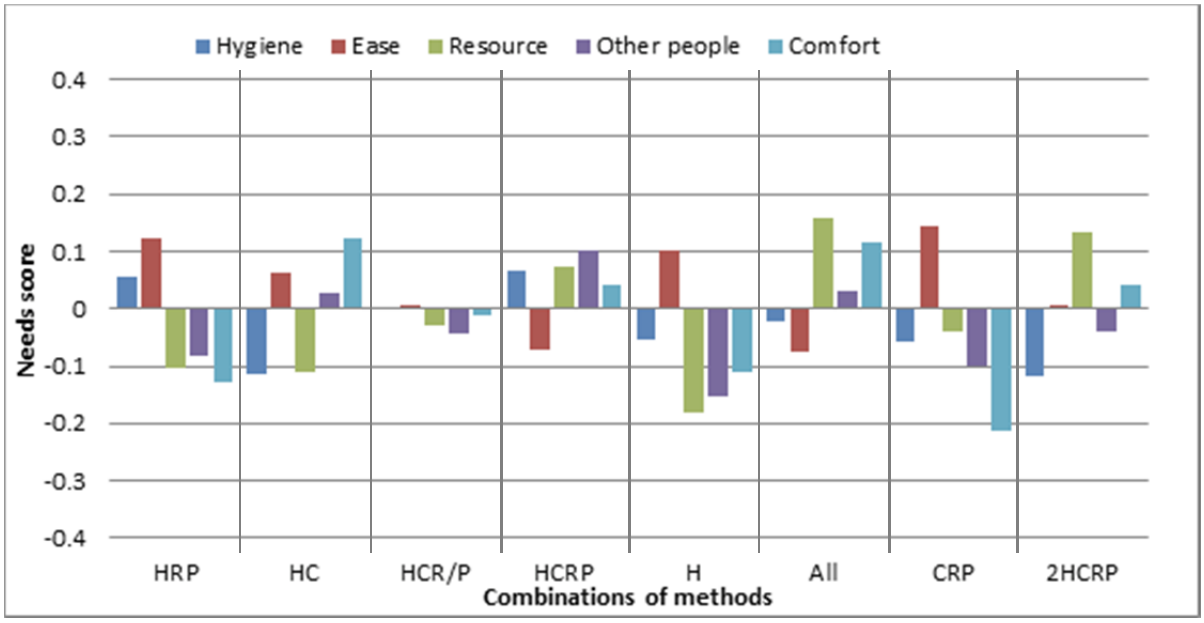
Figure 2.5 How People, Property and System factors impact Heat Energy Use



While it is generally not advised to predict consumer needs from behaviours or vice versa, our quantitative work highlighted a pattern in how the five

dimensions of need vary according to the sorts of things that consumers do to keep warm; this is shown in Figure 2.6.

Figure 2.6 Dimensions of heating need against behaviours to keep warm



Key:

Coloured bars represent the five dimensions of need discussed in section 2.1 and their respective factor scores for each combination of methods for keeping warm.

Method category codes: H – Primary or secondary heat system; C – Control where heat goes; R – Retain own heat; P – Heat the person

One example of an insight that this data reveals is that those who currently use the greatest range of behaviours to keep warm (All, HCRP and 2HCRP) are also the consumers who more consciously prioritise *Resource*-related needs, possibly because they are more actively engaged with the process of keeping warm. Conversely, those who only use their heating system (H) are less likely to focus on *Resource*-related needs, and of all the need dimensions are more likely to emphasise *Ease*, possibly because their system functions well, they can afford their bills and/or they don't want to have to think about the process of heating.

This kind of insight suggests that, in some cases, varying patterns of behaviour can highlight needs that are either unmet or of importance to consumers for other reasons. This, in turn, can help identify areas where smart solutions could help consumers or appeal to consumer values.

For this particular example, one potential solution could be to target a solution that focuses on saving energy costs or reducing wasted heat (or otherwise marketing a solution in those terms) to consumers that are more likely to have a range of strategies to currently keep warm. Such consumers could be identified by further analysis of the survey data (and identifying, for instance, whether there is a correlation between complexity of heating strategies with property or heating system type) or by directly asking questions to potential customers about their current control strategies.

While the research has shown that household demographics are a poor predictor of needs and behaviours, flexible use of the quantitative database can help answer specific questions about whether there is a link between

types of needs or behaviours and other characteristics such as property or system types in order to identify opportunity areas for smart energy solutions as well as the most effective way to communicate these benefits to stimulate uptake.

The implications for solutions are discussed further in chapter 3.

2.4 How do consumer behaviours impact energy consumption?

To support our understanding of how consumer behaviours impact energy consumption and the internal environment, we utilised energy modelling techniques, augmented with real monitored data and real case studies from our longitudinal sample as test cases. We demonstrated that modelling can be used, in this way, to explore different scenarios and questions to quantify the impact of consumer behaviour on energy consumption and internal environment.

2.4.1 Maintaining a background temperature

One question put to the modelling team (which had previously emerged from our qualitative work as a common area of confusion for consumers) was whether turning the heating off completely at night or when at work was more or less efficient than maintaining a low "background temperature" during those times.

The modelling work concluded that turning the heating off is the more efficient approach, varying in magnitude of difference across the case studies. However, it also showed that there are three other potential benefits to maintaining a low "background temperature":

- **Control of moisture and mould** – colder temperatures can lead to higher relative humidity, which can lead to condensation and mould. Maintaining a background temperature reduces this risk;
- **Increasing comfort** – if people need to get up during the night or otherwise have unpredictable occupancy patterns, background heating can be more convenient and mitigate feeling too cold;
- **Compensating for an undersized boiler** – if the boiler is undersized (or no longer performing at designed efficiency) it may struggle to bring the home to a set point. Maintaining a background temperature will mean that the boiler has to work less hard to affect a large increase in temperature.

These insights show how modelling can be used to address consumer confusion but also highlight the wider impacts of behaviours on things like health and comfort, in the provision of advice or feedback in a control system.

2.4.2 Not heating unoccupied rooms

Another scenario that our modelling team explored was related to the most extreme form of zoning – not providing any heat to part of the home (e.g. a spare room). This relates to the concept that heating unused rooms is "wasteful".

All modelled cases showed that turning off the heating in one room led to a reduction in total household energy consumption. However, as before, there was more information to put this into context.

Firstly, the unheated room will naturally draw heat from surrounding rooms, by conducting through the walls and by air flow under and around the door (or indeed through the open doorway if the door is open). This places an additional load on the heat sources in these rooms, meaning that total energy savings are less than might be expected. Building Regulations (Approved Documents, Part F) recommends a gap under internal doors to allow for effective ventilation and so air flow is to be expected even with doors closed.

Secondly, perhaps obviously, if the door to the room is left open, any energy savings will be negligible. Our qualitative work, however, highlighted that many consumers *do* however like to keep internal doors open (for a range of reasons including communication between rooms, light levels and aesthetics), meaning that an associated behaviour (keeping internal doors open) can significantly impact the efficacy of another behaviour (turning off the heat in one room).

Finally, the modelling highlighted that, if air changes were kept to a minimum, relative humidity levels in the unoccupied room were likely to increase and, with this, risk of condensation and mould.

In conclusion, choosing to not heat unoccupied rooms will save some energy, but less than the energy typically consumed by that room when it is heated. Any savings are lost if doors are kept open, however there is an increased risk of condensation and mould in the unheated room.

2.4.3 Further modelling to explore behaviours

This section has demonstrated how modelling, combined with case study data can be used to answer specific questions or scenarios but also highlighted how it can be used to identify wider impacts on internal environments than simply an impact in energy consumption. Future modelling work using the project's model framework can further help identify the impacts of different behaviours in different cases and better help understand where solutions could help address issues or, in some cases, avoid causing problems (e.g. by facilitating under-heating that may lead to mould growth).

For further detail on some of the project's modelling insights, see the final project report **"Modelling Insights"**

3 How do we design better solutions?

Key messages

- Consumers often view heating as a low priority activity in their day-to-day lives, yet simultaneously view having a warm home as a “right”
- As most consumers can meet their core health and comfort needs through their existing control strategies, solutions must offer more in terms of other needs that are currently unmet or sacrificed
- Some key barriers to uptake of solutions include lack of awareness, unachieved optimisation of existing system, lack of trust and lack of money. Overcoming these barriers is as important as designing more attractive solutions
- Advanced controls don’t necessarily guarantee energy savings, particularly in homes that are currently under-heated
- Key ways that the market can stimulate uptake of smart energy solutions include improving awareness of consumer needs; empowering and advising consumers; building trust in technologies, the energy sector and installation sector; and design for simple, intuitive usage

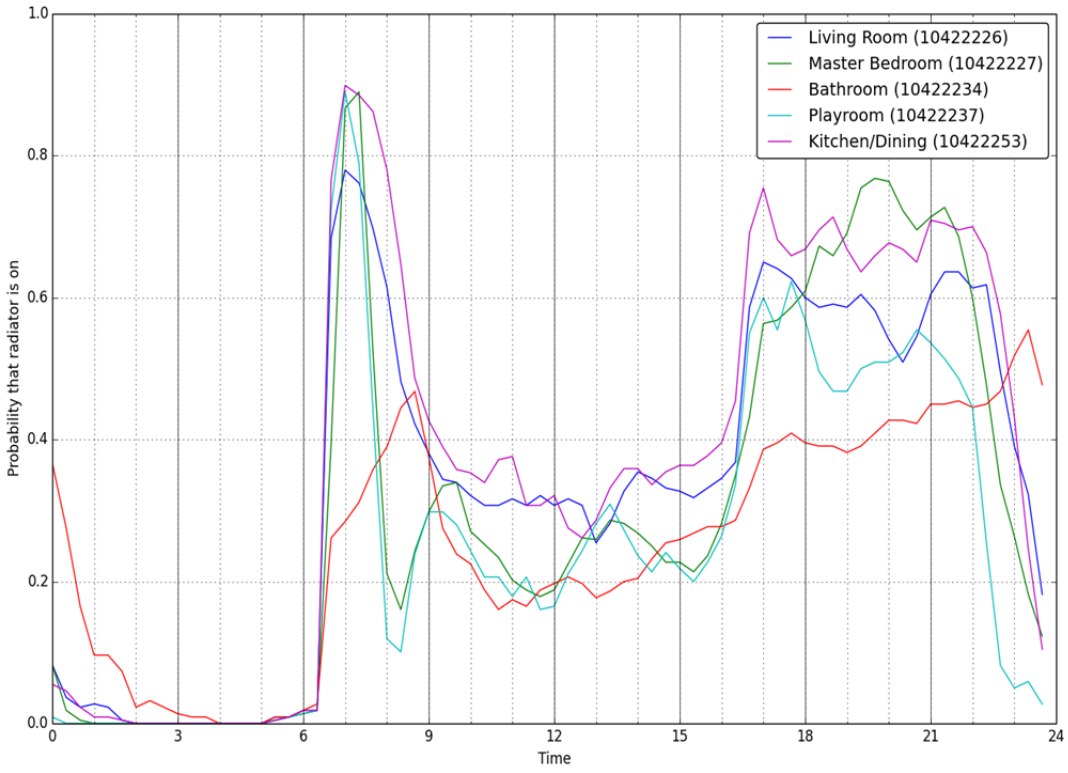
3.1 What are the challenges?

In the previous chapter we explored the various needs and behaviours that consumers have that impact the way they use heat and the way they might consider making changes to that. In this chapter we explore how that greater understanding impacts the way we might think about designing solutions for consumers.

A key challenge in designing solutions that appeal to consumers is in avoiding the assumption that consumers have a specific, definable problem and that a technical solution can be designed to address that problem. Our research has demonstrated that consumers have wide and varied needs, that are often unpredictable, fluid and that they, themselves, are not consciously aware of.

One insight that highlights the unpredictable needs of consumers is in the monitoring work that was carried out in the longitudinal homes. A common finding was that radiators on a timed system, in many cases, were not performing as an external researcher might expect – i.e. it may be expected that radiators would always be on for a period in the morning and, again, always in the afternoon/evening. Instead, our data, highlighting the probability that any given radiator was on at a particular time of the day, often showed an unpredictable picture, as illustrated in Figure 3.1. This highlights that our expected consumer patterns of use may vary significantly from the actual use case, with householders overriding the programme and varying TRVs as they see fit.

Figure 3.1 – Probability that monitored radiators are on at a given time (example from longitudinal study)



Some insights from our work that challenge solution design include:

- Many consumers consider heating the home as a *low priority* activity in their day-to-day lives. While a warm home is viewed as a right or a fundamental requirement, the way that this end is achieved is often actively put out of mind;
- Many consumers are not aware of areas for an improved experience or have become normalised to the current operation of their systems;
- Many also will live with inefficiencies and suboptimal performance (e.g. timer set to the wrong times) that they are aware of, for a wide range of reasons, but typically because they have developed a control strategy to make it work for them;
- Improvements to the thermal fabric or heating system are typically not made for the purpose of increasing efficiency or improving performance. Usually they are in response to system failure, included with other home upgrade works or for other perceived benefits (e.g. property value improvements, noise reduction, etc.);
- Property, person and system factors combine in complex ways, and are dynamic (e.g. because of household composition and needs varying throughout the day, week or over years) and/or unpredictable (e.g. because of property and system characteristics, where small, unrecorded peculiarities related to system installation or configuration can result in major impacts to the installation of new solutions). This makes it difficult to segment the market for the purpose of targeting solutions on particular consumers. However, designs can be informed by what we now know about common patterns of needs and behaviours and, as noted in Chapter 2, our quantitative database *can* be used to answer specific questions about what sorts of needs or behaviours may

For some examples of how existing system issues can impact installation of new controls see our report **"HEMS Small-Scale Field Trial"**

be exhibited by certain cases. Here, “cases” could be individual dwellings, streets or larger clusters that have known property, household or system characteristics.

We also discussed in the previous chapter that the majority of consumers are currently able to meet their end needs of comfort and health, often through the use of multiple methods in a complex control strategy. This being the case, solutions targeted *purely* at enhancing these met needs are unlikely to be sufficient in their own right to inspire consumers to make a purchase.

Our research has also suggested that it is not sufficient to simply enhance the end product by making it more attractive to consumers by designing it to meet a wider range of needs. There remain a number of barriers to uptake that need to be considered.

Figure 3.2 – Customers, obstacles and solutions

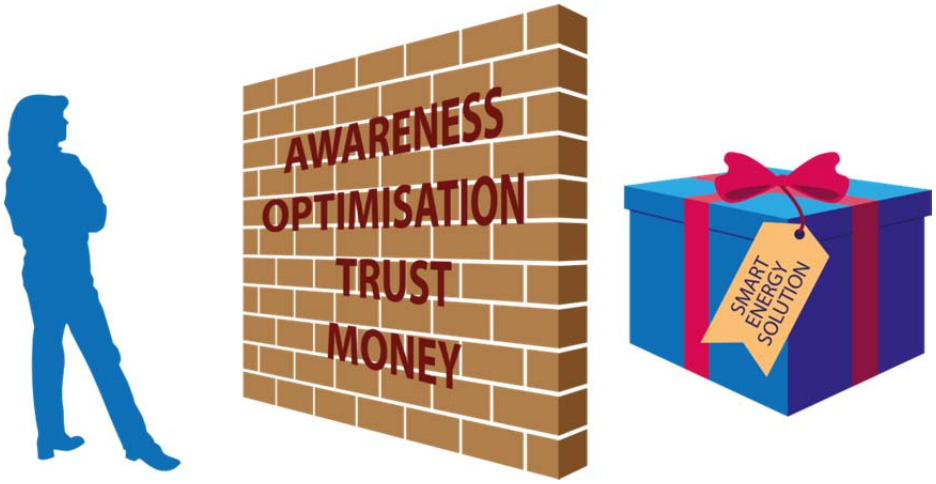


Figure 3.2 highlights the difference between solutions and the existence of barriers to uptake of solutions. A common approach is to enhance the value of the solution, but often this does not address the existence of the obstacle – if the "wall" is large enough, the consumer will not be able to see the solution simply making solutions better will often not be enough unless solutions are able to help overcome the obstacles, by reducing them, eliminating them or (in some cases) demonstrating to the consumer that the obstacle does not exist.

Some common barriers that have emerged from our research include:

- Lack of awareness – referenced previously in this chapter, consumers demonstrated a lack of awareness in the existence of problems or the existence of solutions to recognised problems;

- Unachieved optimisation – a commonly repeated theme across our qualitative work highlighted that consumers were vaguely aware that they were not getting the most out of their current system. Their logic model dictated that until they were achieving the optimum of their current setup, there was little reason to make changes (note, this ties into a key need of wanting to avoid waste). Related to this was the reluctance to replace an old boiler while it is still working;

- Lack of trust – consumers presented concerns about trust in terms of unfamiliar technologies, providers of services and advice, payment methods and delivery processes throughout our research;

- Lack of money – lack of upfront capital (or prioritising something other than heat energy for use of existing capital) to invest in solutions was a frequently stated reason for not pursuing solutions. And as consumers are used to making an existing or “low cost” system meet their core comfort and health needs, there is little perceived value in investing in anything above and beyond what they currently have, particularly if it comes at a higher investment cost (as long as they perceive it only in terms of comfort and health needs).

Unfortunately, the first three points seem to frequently combine – perceived unachieved optimisation, lack of awareness in how to achieve that optimisation and lack of trust in many people who may provide advice presents a perfect storm of a barrier.

3.2 How to improve uptake/generate demand?

The previous section paints a particularly bleak picture for the uptake of solutions; with consumers frequently disinterested in current solutions, unaware or unconvinced of a need to change and facing significant barriers to want to take up new solutions.

However, it is the belief of the research team that there are a number of ways that well-designed solutions, including a strategy for marketing and presenting solutions, could address many of the problems with the mismatch between the consumer and designer view as well as mitigate many of the barriers.

3.2.1 Addressing barriers

Dealing with the common barriers first, it appears that an important first step in engaging consumers with solutions is to engage them with their existing systems and help demystify the “optimisation gap” that they perceive. There are two key ways to do this – by enabling consumers to better utilise their controls and by giving clear guidance on efficient usage and behaviours.

Our work highlighted widespread misunderstanding in what thermostats (and, by extension, thermostatic radiator valves – and the concept of zoning) do, despite being aware how to physically adjust them. Conversely, we found that most consumers know what a programmer does, but don’t know how to operate it, finding the controls unintuitive and confusing. Finally, we found that boiler- or cylinder-mounted controls (controlling such things as hot water temperature and radiator flow temperature) were rarely used or even known about. Finding ways to give consumers skills and confidence with the full range of their existing controls is key to getting them engaged with the full capabilities and, crucially, the limitations of their heat energy systems.

Similarly, consumers expressed confusion over perceived contradictory advice on how they should operate their systems and which conservation behaviours to adopt. A key example is in the widespread confusion over whether it uses more energy to maintain a background temperature rather than turning heating off completely when the home does not need to be warm (e.g. when asleep or at work). This particular question has been answered by our modelling work and confirmed that maintaining a background heat will always use more energy, although may provide ancillary benefits such as greater comfort (or fewer periods of discomfort) and avoidance of damage to the property/person due to condensation and mould. Modelling is one way that we could provide consumers with answers to the questions about how they should operate their systems. Solutions that help people understand how best to use heat to meet their needs or give them confidence in the right advice for them and their system (e.g. using modelled data) could be very successful.

Lack of awareness is the next challenge to overcome. If consumers are not aware that they are misusing a control or are not aware of the controls that are available to them it may be difficult to gain their attention or engage them. It may be that the third challenge of trust is something to tackle at the same time here. Our work has shown, in discussions with consumers at the solutions workshop and in the longitudinal study, that the most trusted providers of advice are friends, family members and peers, ahead of experts in the field. Tapping into existing networks of trust could be a key way to improve access to advice that is acted upon. Otherwise, advice could be provided by professionals with existing, relevant, trusted relationships – such as installers or maintainers of boilers.

Our experience on the longitudinal study in this area came from the final round of interviews, when the social researcher was accompanied by a technical interviewer who gave bespoke advice to the participant about how to get the most out of their current system. In almost all cases, this advice was received enthusiastically and in some cases, participants later told us that they had taken up some of the suggestions. By building on a trusted relationship, these consumers were open to advice.

For more information on the sorts of advice and feedback that consumers valued, see the report **"Smart Energy Solutions – The Consumer Perspective"**

Addressing the cost barrier may be a bigger and different challenge to meet. As noted, consumers may be willing to spend large quantities (in some cases taking out loans or remortgaging) to make cosmetic or functional changes to the home where they see value, in a way that they do not for energy improvements. One practical suggestion that arose from our work is to identify a non-energy investment that consumers *are* willing to make and align the energy improvement to that, effectively circumventing the existence of the cost barrier. For example, consumers responded well to the idea of energy improvements built into planned renovations such as an extension, seeing the value of doing such work at the same time. One word of warning, though, is that, with consumers already investing significant quantities in this work, it is vital that they can be convinced of the added value that an added cost for energy solutions might bring. In that case, we must consider the wider needs that the solution might address.

3.2.2 Addressing needs

It is the belief of the research team that the key to designing solutions that consumers will want to buy is to convince them that their comfort and health needs can be met (or better met) while addressing one or more needs that are currently sacrificed to achieve these needs (e.g. make it cheaper to use, more convenient, or easier to maintain harmony in the home). After prioritising helping them to get the most out of what they currently have, solutions can be designed that help them address any remaining shortfall.

In order to do this, the designer needs to have a good understanding of the impact of the current system on needs, particularly where other needs are sacrificed, and be able to identify solutions that speak to the sacrificed needs.

The project report **Smart Energy Solutions – The Consumer Perspective** provides an example of how solutions can be assessed in this way; for more detail please refer to this report directly.

As part of this process, it is important to look at solutions through the experience of the consumer. For example, consumers rarely interact with their boilers. There is a machine in their home (or in the case of community heating, in the near vicinity) that provides heat and hot water. The way they experience heat is through radiators, underfloor heating, etc. and that heat can then be characterised in terms of response time, control interface, output temperature and ultimate cost of fuel (which is often, to the consumer, very disconnected from the specific act of using that heat). The way that a boiler or

cylinder itself can specifically impact on the consumer experience is often more down to the way it looks, how much space it takes up and how much noise it makes.

Another useful example to consider is secondary heating and the role that this plays in consumer usage. To an end-user, some of the benefits that a secondary heater provides over a central heating system are that it is very responsive (instant heat), directional (it can be pointed right at the self or the thing that they want to receive heat, and is often portable), flexible (can be used easily as and when needs dictate) and it is easy and intuitive to control. There is also a common perception that use of a secondary heater is more economical than central heating, when used to heat specific rooms at specific times (our modelling work suggests that this is a false economy but the same may not apply to directly heating the person, as distinct from the room).

It is interesting to note, also, that one of the perceived benefits of a remote-controlled heating system (or, indeed a programmed, automated control system) is that the warm-up time can be compensated for by setting the heating to come on ahead of the time that a warm environment is required. It is possible to envisage a system that could deliver extra heat “instantly” and/or to selected spaces, as with secondary heating. It is not known whether this would reduce the perceived potential benefit of remote control but this might be tested by exploring whether consumers value remote control over secondary heating.

Flexibility of use seems to be a key feature for desirable solutions. As consumer needs are likely to vary, it is logical that their systems should be able to help them meet their needs without them needing to resort to the wide range of strategies discussed in Chapter 2. Improved controls with customisable interfaces (e.g. one mode of use that provides high levels of control, another that focuses on automating heating) may be a strong way of allowing users with different needs (or the same user with varying needs) to get the best out of the same system.

Finally, it is worth considering our understanding of needs and the way that *Health* seems to be a key need for most consumers, albeit a need that many feel that they have already met. However, as noted in this section, many consumers are unaware of the existence of problems or how to optimise control systems to ensure the healthiest conditions. Solutions that help consumers understand and then achieve the healthiest indoor conditions are likely to be well-received, particularly with an aging population (as noted in Chapter 1).

3.3 What are the potential impacts of better solutions?

As with Chapter 2, we have been able to use modelling techniques applied to real cases to assess the impacts of solutions on energy consumption and the internal environment.

3.3.1 The impact of changing controls

For six case studies, we modelled the impact of upgrading controls in a home from a timer only up to a thermostat, timer and programmable thermostatic radiator valves – allowing for improved levels of zoning compared with a standard TRV system.

The findings suggest that for each additional control feature, consumers are likely to be able to enjoy a more **comfortable** environment that was more **consistent** with expectations (or *actual environment* more often matches

desired environment). It also suggested that savings on energy consumption were also possible with enhanced controls.

This depends, of course, on how the original and new controls are used. For example, additional controls may, potentially, lead to an *increase* in energy consumption if the property was previously under-heated or if the consumer was manually turning on the heating when getting up or getting home from work and now sets a timer to preheat the home so the home will be warm at those times.

Therefore, improved heating controls do not *guarantee* lower energy consumption. Indeed, based crudely on meter readings over a short period, the small-scale trial of heating controls showed inconsistent and, at times, trivial reductions in energy consumption.

3.3.2 The impact of upgrading the fabric and heating system

The modelling also explored the impact of upgrading insulation and heating system components. In one case example, the modelling explored upgrading an old inefficient boiler and installing cavity wall insulation.

The modelling concluded that, for this case, savings from cavity wall insulation were negligible and savings from replacing the boiler for a more efficient one were more significant.

In this case, replacing the boiler was the most appropriate solution. However, for other cases, these figures can be significantly different. This highlights the importance of considering each case for its own specificities, rather than applying generic expected savings.

Furthermore, this work identified that combining solution elements further complicates the expected energy savings. Should the boiler be replaced first and cavity wall insulation fitted later, the savings achieved from the cavity wall insulation would be reduced due to the efficiency savings gained for each unit of heat now produced by the boiler.

As such, solutions that focus on multiple measures should ensure that the combined effects of measures are calculated rather than simply summing the savings of individual measures.

3.4 Implications for the market

This chapter has explored a number of the implications of our research for the development of smart energy solutions. This final section considers some key areas in which the market could respond to some of the challenges and opportunities we have highlighted.

- **Needs matter:** First and foremost is an imperative to focus on the needs that matter to consumers. Consumers typically start by wanting to achieve their health and comfort needs. Solutions should therefore seek to ensure consumers can maintain their current levels of health and comfort while tackling other needs that might currently not be met. This is also important in the way that solutions are communicated to consumers – marketing could be as important as physical design features of the solution.

- **Empower and advise:** Consumers typically demonstrated a lack of education or confidence with common control systems such as thermostats, programmers, or boiler-mounted temperature controls. They also commonly felt that, until they were confident that they had optimised their current system, they were reluctant to invest in new solutions. Therefore, a strong way to improve consumer demand could be to support

consumers, through advice or otherwise, to gain a better understanding of how to optimise their existing systems, where and why there may be problems and to make tangible the potential benefits that solutions could bring, within the context of their existing systems.

- **Build trust:** Overcoming consumer mistrust in the energy sector, installation sector and in unknown technologies is going to be vital to increase uptake. Tapping into existing networks of consumer trust (such as friends and family) by developing supply chains that are encouraging of and receptive to word-of-mouth recommendations could be key. Similarly, developing solutions that can be applied to a wide range of homes could further encourage consumers to recommend them.

- **Design for simple usage:** Consumers typically do not need to read an instruction manual to set up or operate modern technologies such as televisions, computers or smart phones. Control systems that are intuitive, easy to set up and operate can help overcome some of the common problems of consumers not interacting with their controls and choosing, instead, to resort to a different control strategy or “workaround”.

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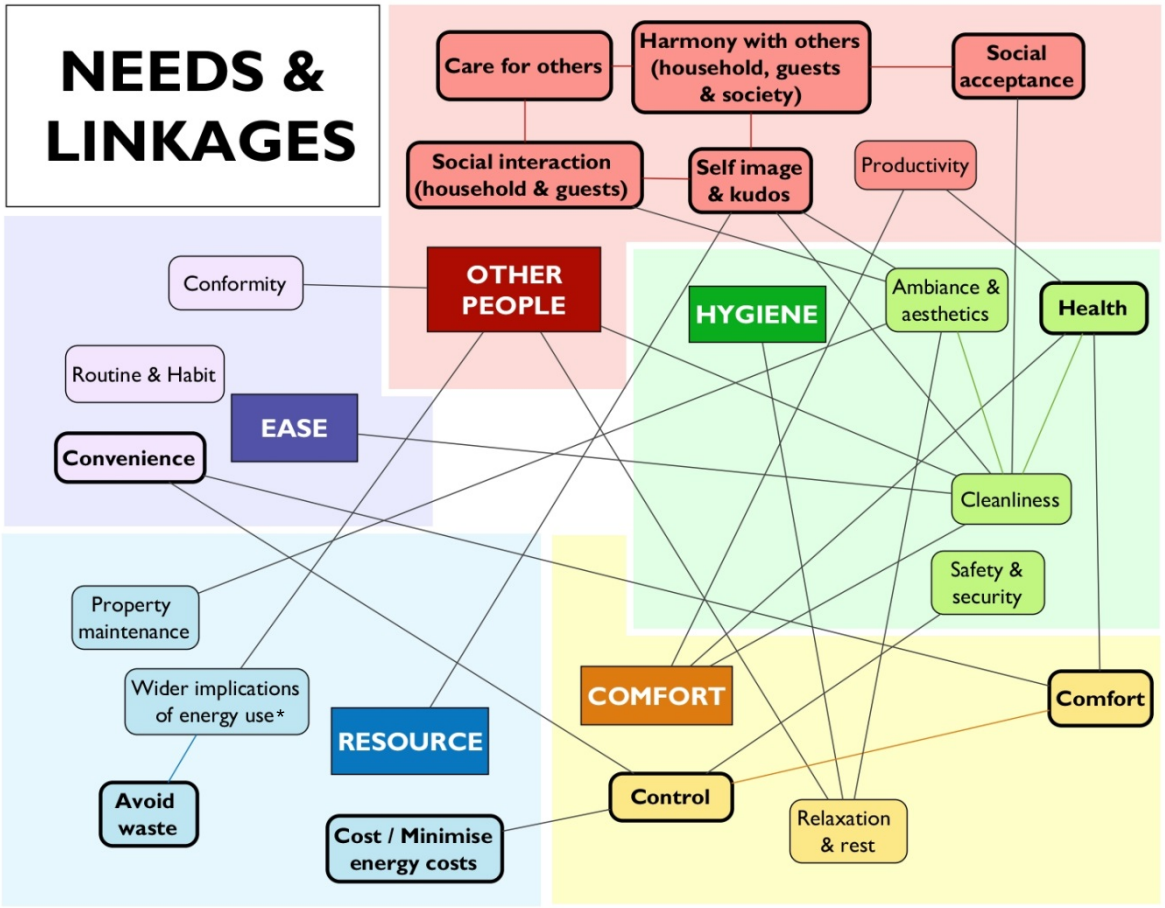
Appendix A – Detailed Needs Linkages

The diagram below highlights how different needs cluster and link based on our research findings. The table on the following page shows how a longer list of needs, emergent from the literature review, references against each of the condensed list of needs in the diagram below. These two diagrams illustrate the complexity and breadth of consumer needs relevant to smart energy solutions and, therefore, should be considered in addition to the smaller categories of needs referenced in the main body of this report.

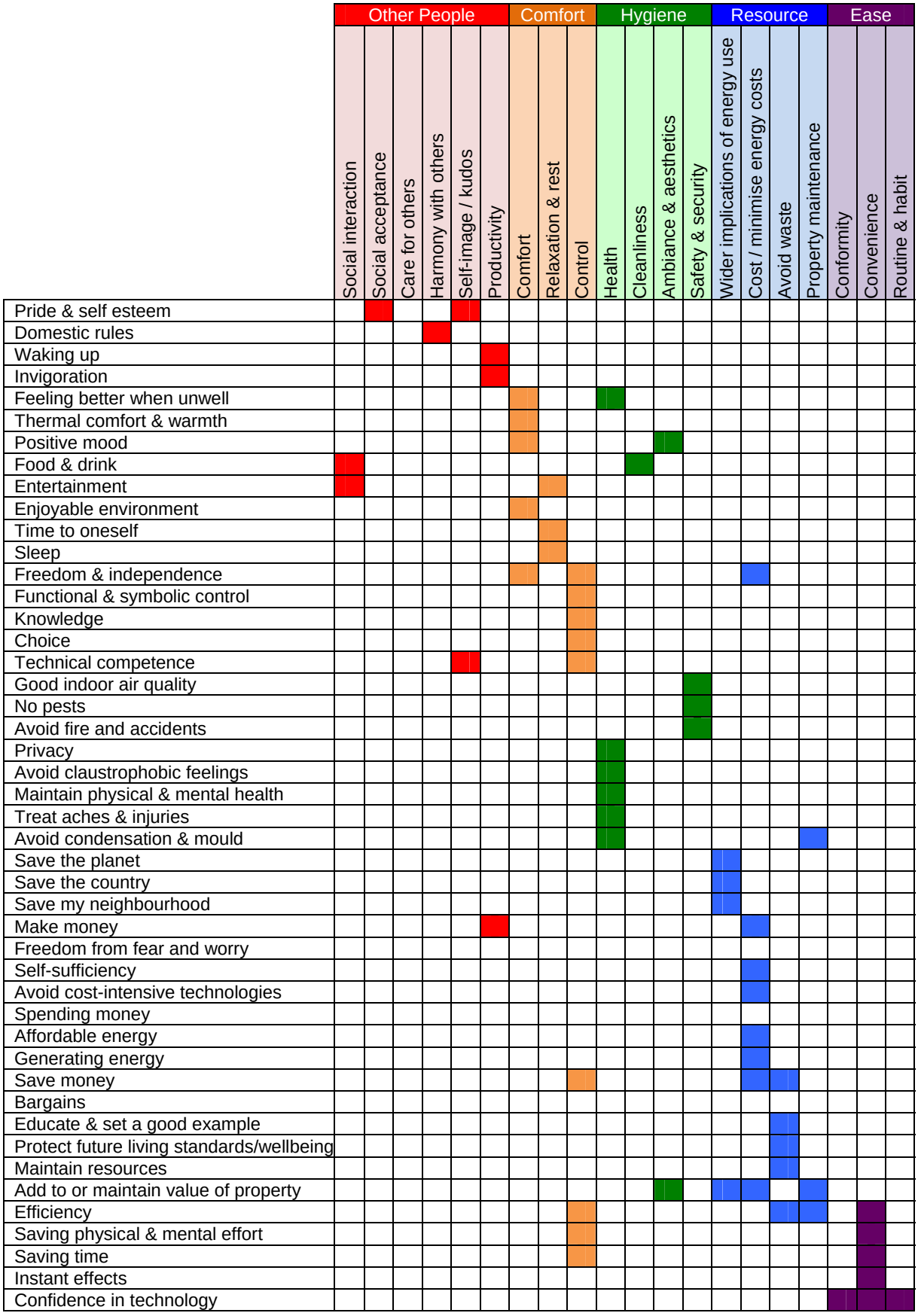


Key

Darker boxes with larger, white font indicate the five underlying dimensions of need as emergent from our **quantitative** research.

Boxes with bold outlines indicate needs that align with the "top eight" needs identified in the **qualitative** research. These are shown in full in the figure but simplified later in the text to "Harmony" (other people in the households) and "Hospitality" (other people outside the household).

* Includes concern for: climate change & CO_2 emissions; pollution & environmental damage; depletion of resources; extreme weather; energy security; and nature.


Other People
Comfort
Hygiene
Resource
Ease
Social interaction
Social acceptance
Care for others
Harmony with others
Self-image / kudos
Productivity
Comfort
Relaxation & rest
Control
Health
Cleanliness
Ambiance & aesthetics
Safety & security
Wider implications of energy use
Cost / minimise energy costs
Avoid waste
Property maintenance
Conformity
Convenience
Routine & habit
Pride & self esteem
Domestic rules
Waking up
Invigoration
Feeling better when unwell
Thermal comfort & warmth
Positive mood
Food & drink
Entertainment
Enjoyable environment
Time to oneself
Sleep
Freedom & independence
Functional & symbolic control
Knowledge
Choice
Technical competence
Good indoor air quality
No pests
Avoid fire and accidents
Privacy
Avoid claustrophobic feelings
Maintain physical & mental health
Treat aches & injuries
Avoid condensation & mould
Save the planet
Save the country
Save my neighbourhood
Make money
Freedom from fear and worry
Self-sufficiency
Avoid cost-intensive technologies
Spending money
Affordable energy
Generating energy
Save money
Bargains
Educate & set a good example
Protect future living standards/wellbeing
Maintain resources
Add to or maintain value of property
Efficiency
Saving physical & mental effort
Saving time
Instant effects
Confidence in technology