Loughborough Design School

Design for Sustainable Behaviour: Feedback Interventions to Reduce Domestic Energy Consumption

Garrath Thomas Wilson

Doctoral Thesis

Submitted in partial fulfilment of the requirements for the award of
Doctor of Philosophy of Loughborough University

June 2013

Abstract

Design for Sustainable Behaviour (DfSB) is an emerging research area concerned with the application of design strategies to influence consumer behaviour during the use phase of a product towards more sustainable action. Current DfSB research has primarily focussed on strategy definition and selection, with little research into formalising a mature design process through which to design these behaviour changing interventions. Furthermore, understanding the actual sustainability and behavioural impact yielded through such investigations is limited in addition to the suitability and transferability of evaluation methods and results having seldom been discussed. This thesis investigated how DfSB models and strategies can be implemented within a structured design process towards a sustainable change in user behaviour. This was achieved by focussing a case study within the UK social housing sector with the aim of reducing domestic energy consumption through behaviour changing intervention, whilst maintaining occupant defined comfort levels.

Following an in depth study of physical and behavioural control mechanisms as well as comfort and energy within the research context, a behaviour changing prototype was developed through an augmented user-centred design process, resulting in a physical manifestation of one specific DfSB strategy – feedback; a user agentive performance indicator. In order to evaluate this feedback prototype, an evaluation framework was developed, targeted at the three fundamental questions that arise when faced with the evaluation of a DfSB strategy led intervention: (1) Did the produced design solution function for the specified context? (2) Has the user's behaviour changed as a consequence of the design intervention? (3) Is the change in user's behaviour sustainable? Applying these core questions in practice through focus groups and user trials resulted in an evaluation of unparalleled depth.

The findings of this thesis illustrate the success of using this augmented design process and tripartite questioning strategy towards the design and evaluation of a DfSB strategy led intervention, building a vital knowledge platform for the formalisation of transferable DfSB theory, design and evaluation methods.

Acknowledgements

For their outstanding support and supervision, no matter how crazy things got, I first and foremost would like to give a special thank you to:

Professor Tracy Bhamra and Dr Debra Lilley

This doctoral study would not have been possible without help from the following people, who I would like to thank:

Dr Darren Southee, Kate Eastwood, Dr Emma Hinton and the CCC team

For their financial support, I would also like to thank:

Engineering and Physical Sciences Research Council (EPSRC) and E.ON UK

I would also like to acknowledge the contribution of my examiners:

Dr Vicky Lofthouse and Professor Casper Boks

Without the loving support and encouragement of family, I would not be half the man I am today, so a big thank you goes to:

Garry and Barbara Wilson, Carl Wilson and Valerie Webb

Finally, an extra big thank you goes to the longest suffering partner in the world - a girlfriend/fiancée/wife to this perennial academic:

Naomi Webb/Wilson

Publications

WILSON, G. T., BHAMRA, T. A. & LILLEY, D. 2010. Reducing Domestic Energy Consumption: A User-Centred Design Approach. In: WEVER, R., QUIST, J., TUKKER, A., WOUDSTRA, J., BOONS, F. & BEUTE, N., eds. Proceedings of Knowledge Collaboration & Learning for Sustainable Innovation ERSCP-EMSU Conference, Delft, The Netherlands, 25th-29th October 2010. 200-222.

WILSON, G. T., LILLEY, D. & BHAMRA, T. A. Design Feedback Interventions for Household Energy Consumption Reduction. Proceedings of ERSCP-EMSU 2013 Conference, Istanbul, Turkey, 4th-7th June 2013. Sustainable Development and Cleaner Production Center, Boğaziçi University.

LILLEY, D. & WILSON, G. T. In Press. Integrating Ethics into Design for Sustainable Behaviour. *International Journal of Design Research*.

Table of Contents

List of Figures

List of Tables

1 Introduction

This section outlines the research context, as well as the aim and objectives of this research project. This section concludes by framing this research project within the doctoral research system and other parallel inquiries to which this research is attached.

1.1 Research Context

In order to maintain the ecological, social, and economic base for the societies of today and tomorrow, responsibility must be taken to manage the ways in which natural systems are exploited *(Bhamra and Lofthouse, 2007)*. The Climate Change Act 2008 *(UK Parliament of the United Kingdom, 2008)* set out the target of achieving a UK reduction of greenhouse gases by 2050 to at least 80% of those recorded in 1990. To reach this objective the '*carbon budget*' for the '*budgetary period*', up to and including 2020, is to be at least 34% lower than the 1990 baseline *(UK Parliament of the United Kingdom, 2009).* By 2008 the total UK greenhouse gas emissions by end-user's had dropped by 19.1% *(DECC, 2008)* compared to the 1990 baseline, thus signalling that much work is still required in order to even reach the 2020 target. The residential sector accounted for 24.3% of the total UK greenhouse gas emissions in 2008 *(DECC, 2008)*, presenting domestic energy consumption as a salient target for energy and greenhouse gas reduction.

Domestic energy consumption by end use in 2007 can be further granulated thus: 43.9% to space heating, 30.0% to lights and appliances, 22.3% to water, and 3.7% to cooking *(DECC, 2009),* however, given the sociotechnical nature of the relationship between energy supply and consumption, energy expenditure in two identical homes can lead to a factor of two difference *(Darby, 2006).* The behaviour of the inhabitant plays an equal or greater role in domestic energy consumption than the specification of the technological devices that populate them. Furthermore, the recent economic downturn has seen a decline in the building of new housing stock and more efficient central heating systems *(Mintel, 2009).* The installation of system upgrades in existing stock to more energy efficient systems is also on the decline unless deemed essential *(Mintel, 2009)*. Solving the problem of reducing domestic energy consumption through new product efficiency (for example, a condensing boiler uses 37% less energy than a standard boiler *(Energy Saving Trust 2006)*), can therefore not be seen as a 'silver bullet' solution. The ways in which inhabitants interact with their current energy using domestic systems and context, such as in the attainment of domestic comfort, is therefore a more tangible target to achieve any feasible reduction in domestic energy consumption.

Current domestic thermal standards promote energy intensive consumption in order to be comfortable, which in tandem with the low adoption of more energy efficient technologies, places the attainment of domestic comfort on an unsustainable trajectory *(Chappells and Shove, 2005)*. Technical standards that guide the building industry propose that comfort can be defined through a narrow band of physiological '*comfort conditions*' *(Shove, 2003)*, through functions such as; clothing, activity, and environmental variables *(Cole et al., 2008)* in order to generate '*thermal neutrality*' *(Fanger, 1970)*. Furthermore, the standards rooted in the early laboratory experiments of physiological comfort researchers such as Fanger *(1970)*, perceive the inhabitants as passive recipients of their environment *(Cole et al., 2008)*, with little or no feedback, control or understanding required by the occupant of their thermal conditions. Inhabitants, however, have been shown to not be passive recipients of their environment as the standards suggest, but are active in the optimisation of their environment through interaction and control based on their climatic and cultural context *(Chappells and Shove, 2004)*. Such contexts include cultural traditions, gender and power interplays, social normative values and status, as well as symbolic values such as aesthetics *(Chappells and Shove, 2004)*. Comfort, as Chappells and Shove *(2005)* state, is a contextually derived dynamic entity.

In order to support a *re-contextualisation of comfort (Cole et al., 2008)*, to move away from the energy intensive practices produced by the current narrow banded laboratory derived standards, there has to be an understanding of the contexts and behavioural mechanisms through which comfort driven interaction, mediation, and consumption is shaped and takes place. Through this socio-cultural and behavioural understanding of comfort, design opportunities become available to influence the inhabitant's domestic energy consumption towards a more sustainable goal.

1.2 Project Context

The primary role of this research investigation is to support the research student's doctoral thesis submission in partial fulfilment of the requirements for the award of Doctor of Philosophy of Loughborough University.

The secondary role of this work is to support Loughborough University's contribution to the *Carbon, Control and Comfort* [CCC]*: User-centred control systems for comfort, carbon saving and energy management* project, funded through the E.ON and Engineering and Physical Sciences Research Council [EPSRC] Energy Efficiency panel *(EPSRC, 2010)*. The CCC project, as represented in Figure 1-1, is an interdisciplinary UK project attempting to reduce domestic energy use by 20% in social housing, through the user-centred design of feedback interventions to change behaviour.

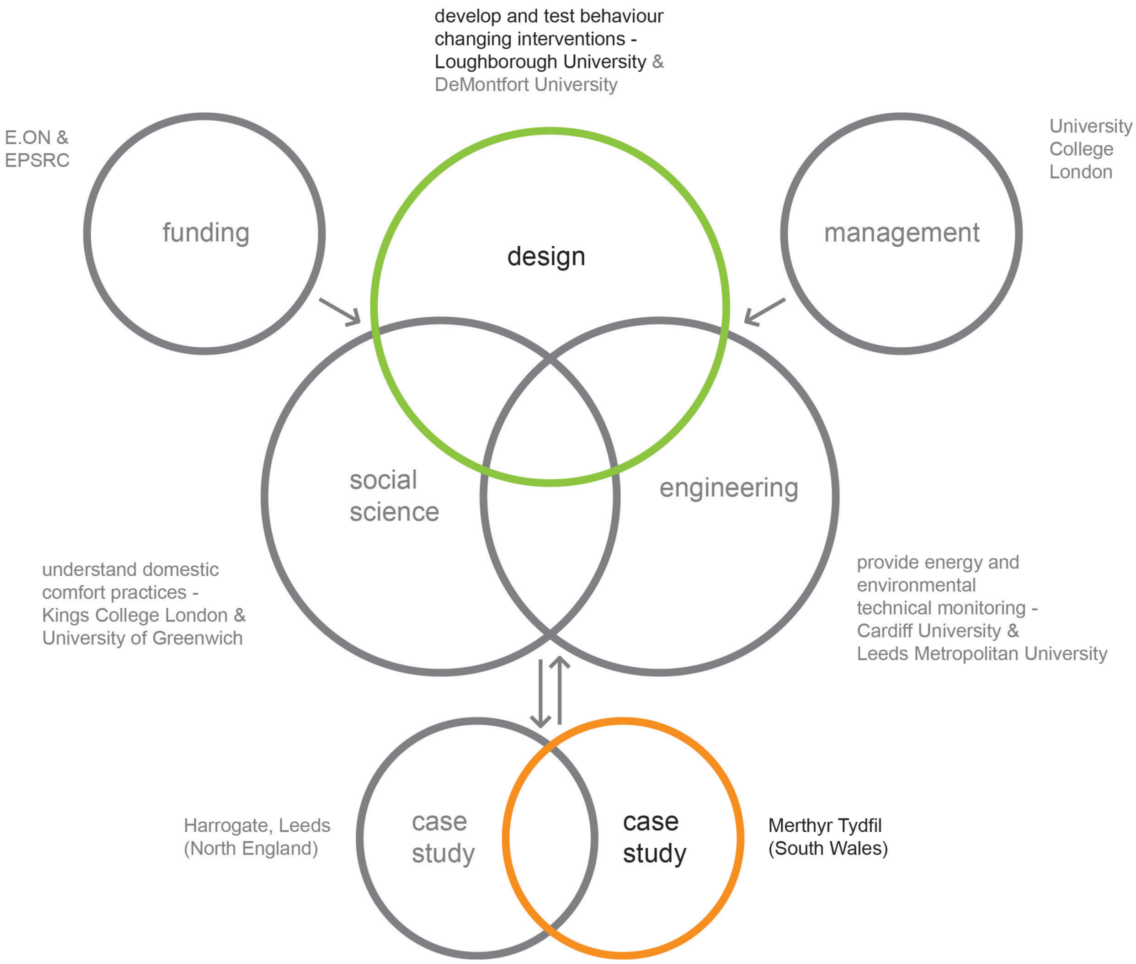


Figure 1-1 The CCC Project and the Two Areas of Focus for this Thesis

Social housing within the UK can be defined as *"housing that is let at low rents and on a secure basis to people in housing need" (Shelter, 2012)*. The CCC project focusses on two social housing sites within the UK, in Merthyr Tydfil and Harrogate, although discussion of the Harrogate site is outside of the scope of this thesis. Focussing on social housing helps in understanding a diverse social segment, which is possibly financially constrained, to comprehend better their energy consumptive actions and comfort needs. Furthermore, engaging with social housing property owners provides access to a forum or community of occupants and dwellings with a similar base level of living quality and built environment.

Due to the interdisciplinary approach to the project, several different schools/departments across multiple UK universities were responsible for managing different aspects of the CCC project at different sites. Whilst Loughborough University were principally responsible for the user-centred design and evaluation of behaviour changing feedback interventions, the institutions most relevant to this thesis, aside from Loughborough University, are the Welsh School of Architecture at Cardiff University and Kings College London [KCL]. The Welsh School of Architecture directed the case study sample selection at the Merthyr Tydfil site as well as the selection, installation and management of the energy and domestic environment data recording equipment. KCL was also involved in the Merthyr Tydfil case study, assisting in the collection and analysis of qualitative data.

Although this doctoral research is not beholden to the CCC project, the close alignment of key project management aspects has resulted in several methodological directions and outcomes that may not have occurred if the doctoral research was wholly independent. It is worth presenting these decisions and limitations up front, as they have substantial bearing upon the direction of this thesis.

The choice of feedback intervention as the mechanism by which to pursue a reduction in domestic energy consumption was a conscious decision by the CCC project and adopted by this researcher, based on energy savings as reported by researchers such as Darby *(2006)* (discussed in section 2.4). Due to the prevalence of on-going research concerning the selection of a Design for Sustainable Behaviour strategy (discussed in section 2.6), it could be construed that a limitation of this research is a lack of consideration or proposition of terms or criteria through which the use of the behaviour change mechanism of feedback intervention was selected. It could further be debated that feedback intervention, for example, may not be the most effective strategy to change the observed behaviour. However, this author would argue that by not engaging with this phase of strategy selection, the design process and evaluation of feedback interventions specifically has been explored in greater depth and resolution than previous when compared to case studies of similar duration that attempt to explore strategy selection and all behaviour changing mechanisms in parallel (see section 2.6 for examples).

A limitation of this research, which probably has had the most impact upon the results and discussions contained within this thesis, was the lack of technical monitoring data available, concerning both energy consumption and the domestic environment. The quantitative evaluation of the initial contextual study and impact of the installed intervention in terms of raw data or analysis was not provided to this author by project partners throughout the duration of the CCC project. As such, although it was anticipated, and to an extent planned for, the quantitative evaluation of the interventions impact upon energy consumption is missing and therefore not discussed. Had the data been available, the answer to the question *is the change in the user's behaviour sustainable* would have been more empirically quantified (as discussed in section 6.6). This would need to be addressed in any further iterative design and evaluation cycle.

Please refer to the relevant sections of Chapter 3 for further details on the impact of these institutions upon the research methodology and case study contained within this thesis. Please refer to section 8.5 for a discussion on the further limitations of this interdisciplinary approach.

For further information on the CCC project, please refer to EPSRC reference EP/G000395/1 via the EPSRC's Grants on the Web facility *(EPSRC, 2010)*.

1.3 Researcher's Context

Having established the research and project context, it is worth presenting the background and perspective of this researcher, as the researcher's personal context and motivation impacts and resonates throughout this thesis.

The author of this research holds a BSc, Product Design, First Class (Hons) from the University of Central Lancashire and an MSc, Industrial Design, Distinction from Loughborough University, in addition to experience as a design engineer and product designer in industry and design consultancies across the UK. It was during the Industrial Design masters course when this researcher first became interested in Design for Sustainable Behaviour, working on sustainable design course projects under the tutelage of Professor Tracy Bhamra and the DfSB case study within Dr Debra Lilley's thesis; two academics who would later go on to be this researcher's supervisors. Following a two year absence from academia whilst working in a product design consultancy that specialised in medical equipment, this researcher returned to Loughborough to commence work on this doctoral study, spurred on by interest in the growing field of DfSB and the impending greenhouse gas reduction requirements as codified within the Climate Change Act 2008 *(Parliament of the United Kingdom, 2008)*. This doctoral research capitalises upon this researcher's experiences and skill set, with a specific interest to develop and explore theoretical issues through practical design investigation.

1.4 Aim and Objectives

The aim of this doctoral research is to investigate how Design for Sustainable Behaviour [DfSB] models and strategies can be implemented within a structured design process towards the reduction of domestic energy consumption within social housing properties.

In order to achieve this aim, the following objectives will be completed:

1. *To execute a comprehensive literature review that will cover factors that influence household energy use, strategies that promote behaviour change, DfSB theory and practice and the ethical implications of changing behaviour through design.*

2. *To understand how inhabitants of social housing properties define and control comfort and its associated impact on their domestic energy consumption.*
3. *To design and produce a feedback intervention prototype that intends to reduce domestic energy consumption whilst maintaining inhabitant defined comfort levels.*
4. *To evaluate the feedback intervention prototype, using assessment criteria developed from the literature review.*

1.5 Thesis Structural Overview

This thesis is comprised of eight chapters. This thesis structural overview, along with definitions of the research and project contexts, and research aim and objectives form the initial introductory chapter to this research, *Chapter 1 Introduction*. The following seven chapters are outlined below; illustrated in Figure 1-2.

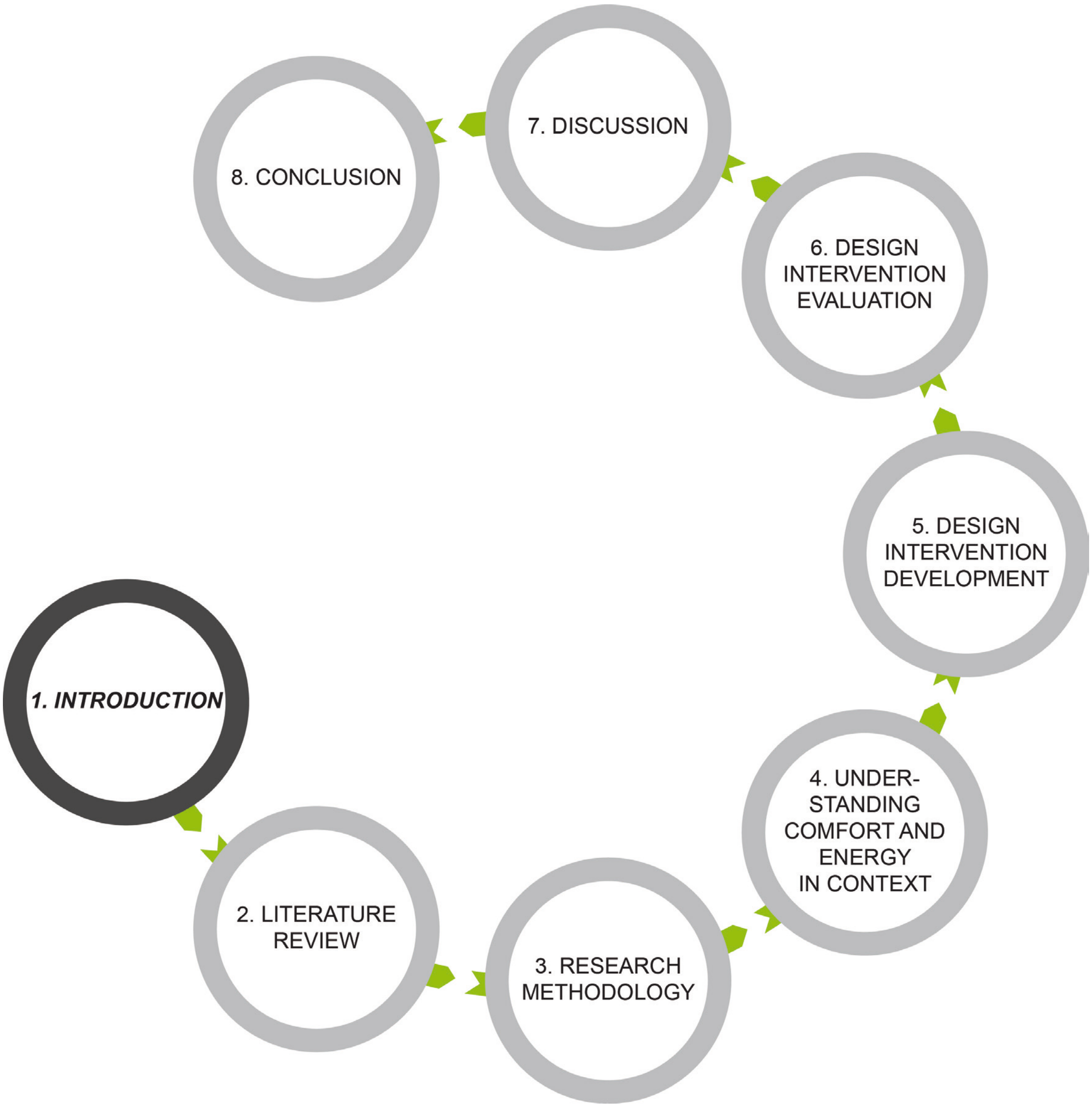


Figure 1-2 Overview of Thesis Structure

The second chapter, *Literature Review*, draws together research pertaining to the issues defined in the research aim and objectives; factors that influence household energy use and the strategies available that promote a change in behaviour, including feedback. It then moves on to discuss DfSB theory and the ethical implications of designing for behaviour change. The chapter concludes with a summary of the gaps in knowledge, and the areas of investigation that the ensuing research will have to pursue in order to bridge these gaps.

Chapter 3, *Research Methodology*, covers the research's purpose and type, as well as the strategies that define the method required to answer the questions set out in the research aim and objectives, and to bridge the gaps raised in the literature review.

The fourth chapter, *Understanding Control, Comfort and Energy in Context*, presents the results of the context case study, which builds a picture of how the social housing participants in Merthyr Tydfil define domestic comfort. This analysis includes a classification of the physical and behavioural mechanisms through which the participants practice this defined comfort, as well as how these interactions shape their energy consumption.

Chapter 5 *Design Intervention Development* explores the design process, and how the body of data and analysis recorded in Chapter 4 were used to generate insights and opportunities that were developed into feedback intervention design briefs, and in the second half of this chapter, into selected design solutions and prototypes.

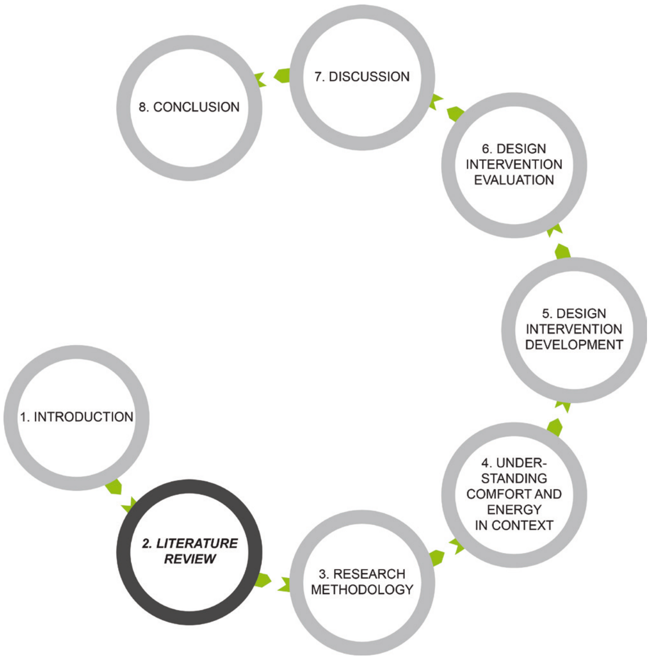
The sixth chapter, *Design Intervention Evaluation*, evaluates the prototypes developed in Chapter 5 against the context case study baseline that formed the foundation of the design work in Chapter 4. The evaluation discusses the functionality of the device, changes in the participant's behaviour, aspects of sustainability, and ethical ramifications raised and discussed in the literature review.

The penultimate chapter of this thesis, Chapter 7 *Discussion*, discusses the research presented in chapters 3 through to 6, against the literature review in the second chapter. Such discussions focus on the pursuit of fresh air, the considerations and limitations of feedback as a behaviour changing strategy, and ends with a comparison between the developed design intervention process and extant DfSB theory.

Chapter 8 *Conclusions and Future Work* is the final chapter of this thesis. This chapter draws together the discussions of the previous chapter and constructs conclusions against the research aim and objectives as defined in Chapter 1. The contribution to knowledge is clearly outlined, and future work is discussed.

2 Literature Review

2.1 Introduction



This chapter draws together and reviews a body of literature from the fields of interest relevant to completing the aim and objectives of this doctoral study. In order to be able to achieve this task, it is important, therefore, to understand existing research and the research context in which they have been applied.

2.1.1 Research Questions

The following research questions were formulated to guide the literature review:

1. How is energy consuming behaviour influenced and perpetuated by internal and external factors?
2. What theories and strategies exist that explain and promote changes in behaviour?
3. How can feedback be used as a behaviour change mechanism?
4. Can products be specifically designed to change user behaviour towards more sustainable action, and if so, what design methods and tools exist and are they successful?
5. What are the ethical implications of changing behaviour through design and can this ethical dimension form part of a controlled design process?

2.1.2 Scope and Direction

As discussed in 1.1 Research Context, in order to influence a change in a user's behaviour towards more sustainable consumption through design, there has to be an understanding of the contextual and behavioural elements that form the act of consumption. The scope and direction of this literature review, as presented in Figure 2-1, is to draw together and discuss the factors of research relevance.

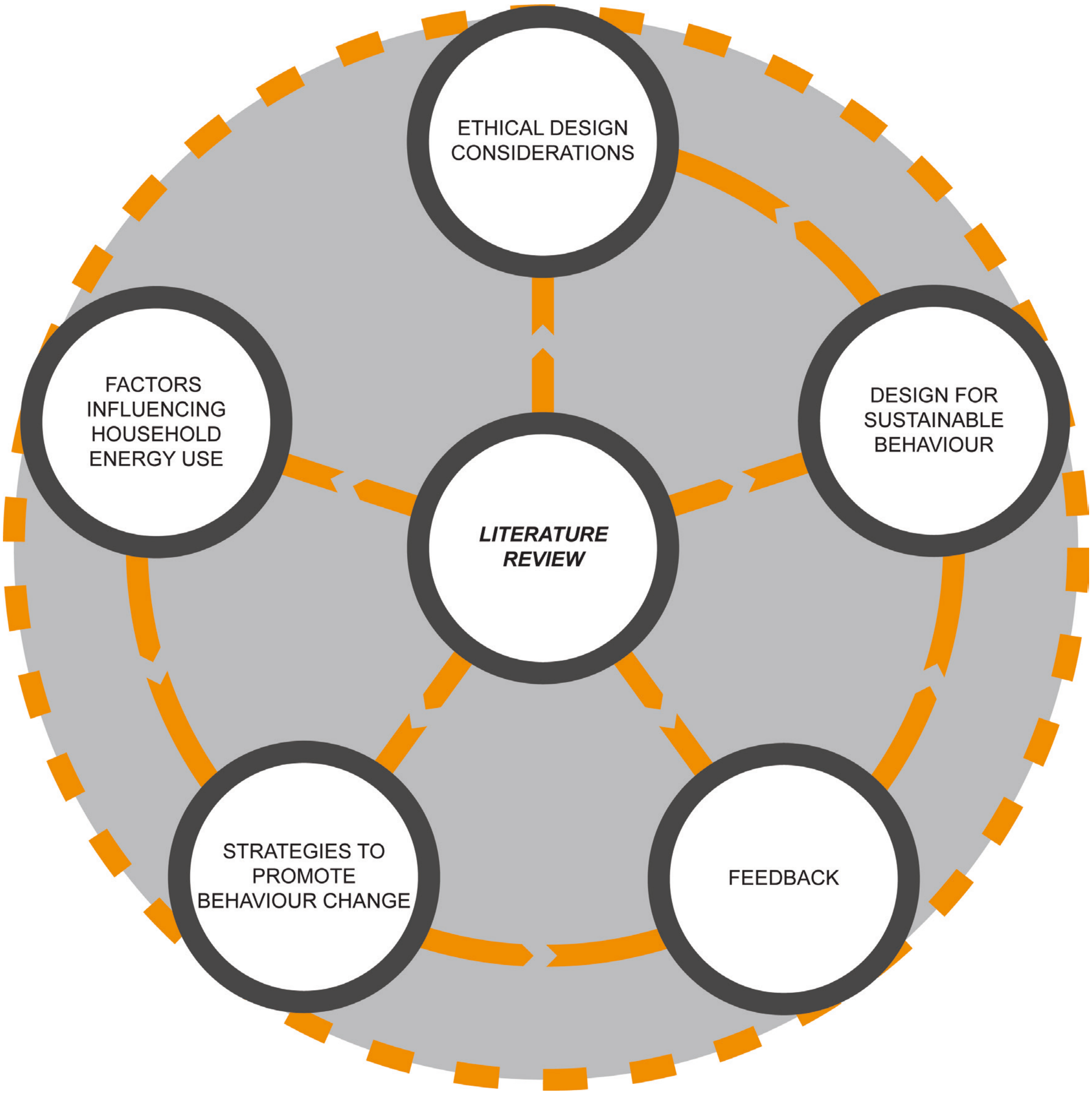


Figure 2-1 Scope and Direction of Literature Review

To this end, the initial section of this chapter considers the factors that influence household energy use. Understanding the influencing factors revolves around understanding what the user's knowledge and perceptions of energy are and how these are shaped by motivations and norms. The chapter then considers antecedent and consequence interventions; strategies that may promote a change in this user behaviour. Following a focus on the considerations and challenges of a specific behaviour change strategy, feedback, this chapter discusses the current position of Design for Sustainable Behaviour (DfSB) theory as a framework of strategies in order to design and implement behaviour changing interventions. The final section of research interest within the scope of this literature review is to discuss the ethical implications of changing behaviour through design, an issue pertinent to the real world research application of knowledge garnered through this literature review.

2.2 Factors Influencing Household Energy Use

In order to promote a change in domestic energy use, it is critical to understand and diagnose the *problem* as well as the underlying *factors* that lead to their realization *(Abrahamse et al., 2005)*. It is also important to consider that we cannot rely on technological innovation alone to reduce domestic energy use, as technical efficiency gains tend to be superseded by an increase in consumption *(Steg and Vlek, 2009)*.

This section outlines the factors that influence consumption, focussing on the individuals' knowledge and perception of energy and the various models of understanding.

2.2.1 Attitudes Towards Energy

According to recent literature, energy, to the individual, is *invisible* and *abstract* in its nature, conceptually perceived differently to other forms of consumer goods *(Burgess and Nye, 2008, Fischer, 2008)*. The cognitive framework developed by the individual relies on its associated activities, its *indirect* consumption, through disparate domestic actions such as cooking or heating *(Fischer, 2008)*. This can lead to incorrect cognitive links between energy and product use and operation, such as the heuristic that the size of an appliance dictates its amount of energy use, and the underestimation of the amounts of energy involved in domestic practices *(Steg, 2008)*.

Furthermore, energy is generally regarded as of *low interest* product due to its relatively low share of a household's expenditure, its constant and featureless supply, as well as the consumer's lack of fear over diminishing stock. It is also not a product of status, nor is it attributable to a lifestyle choice in the same way as, for example, organic produce *(Fischer, 2008)*. Despite energy being a "*basic human need*" *(Darby, 2000, P.2)*, in general, energy is not consciously considered *(Burgess and Nye, 2008)*.

2.2.2 Models of Understanding

The use of models within the context of human behaviour helps one to explore and understand the multiple facets of behaviour through a simplified *representation* of complex social and psychological *structures (Chatterton, 2011, Oxford English Dictionary, 2012)*. By disaggregating the behavioural process into a heuristic framework of multiple parts, understanding of the underlying formation of behaviour is increased whilst also providing numerous points for further study or intervention. Such models may also provide a framework against which to assess intervention *(Jackson, 2005, Chatterton, 2011)*. It is important to consider, however, that these models are not perfect mathematical representations of behaviour; rather, they aid understanding in a simplified and theoretically descriptive manner. The results and understanding accrued through the application of a single model can also not be said to be indicative of the behaviour of every person and at all points in time, as the social and psychological underlying structure of each individual differs and changes *(Darnton, 2008, Chatterton, 2011)*.

Models of behaviour not only differ in their approach and representation of underlying structures, but also may differ in their theoretical perspective. To expand, models may consider the psychological rational antecedents of an individual's behaviour, focussing on the *actor*, or it may take the sociological position of how societal elements form and define *action*, or *practice (Chatterton, 2011)*. The following sections look at these disparate perspectives in detail.

2.2.2.1 A Sociological Approach to Practice

From the theorist Bourdieu's *(1977)* dense work through to the more recent advocates of practice theory, such as Reckwitz *(2002)*, Schatzki *(2001)*, Warde *(2005)* and Shove *(2010)*, the conceptualisation of *practice* has been central to a sociological discussion of understanding what shapes action. Taking Shoves definition of practice, which as will be discussed is the definition that has made the furthest foray into design process thinking; practice decentralises from the concept of studying groups of individuals acting rationally and independently, the *actor*, towards units of *doings* or *actions* shaped through non-linear interconnected elements of *materials*, *competences* and *images (Chappells and Shove, 2005, Kuijer and De Jong, 2012)*. The term *materials*, does not relate to the physical fabric of which a product is constructed, rather the item, object or equipment itself *(Shove et al., 2007)*, and more specifically, relates to the devices that facilitate action and provide infrastructure *(Chatterton, 2011, Darnton et al., 2011)*. *Competences* are the skills or knowledge required to perform an action, and *images* or meanings are the interpretations or perceptions of how and when to perform an action *(Darnton et al., 2011)*. Taking these spheres from Shove's Three Elements Model and applying it as a mapping exercise tool, Darnton *(2011)* presents a worked example of practices in relation to line drying as created by DEFRA, Figure 2-2.

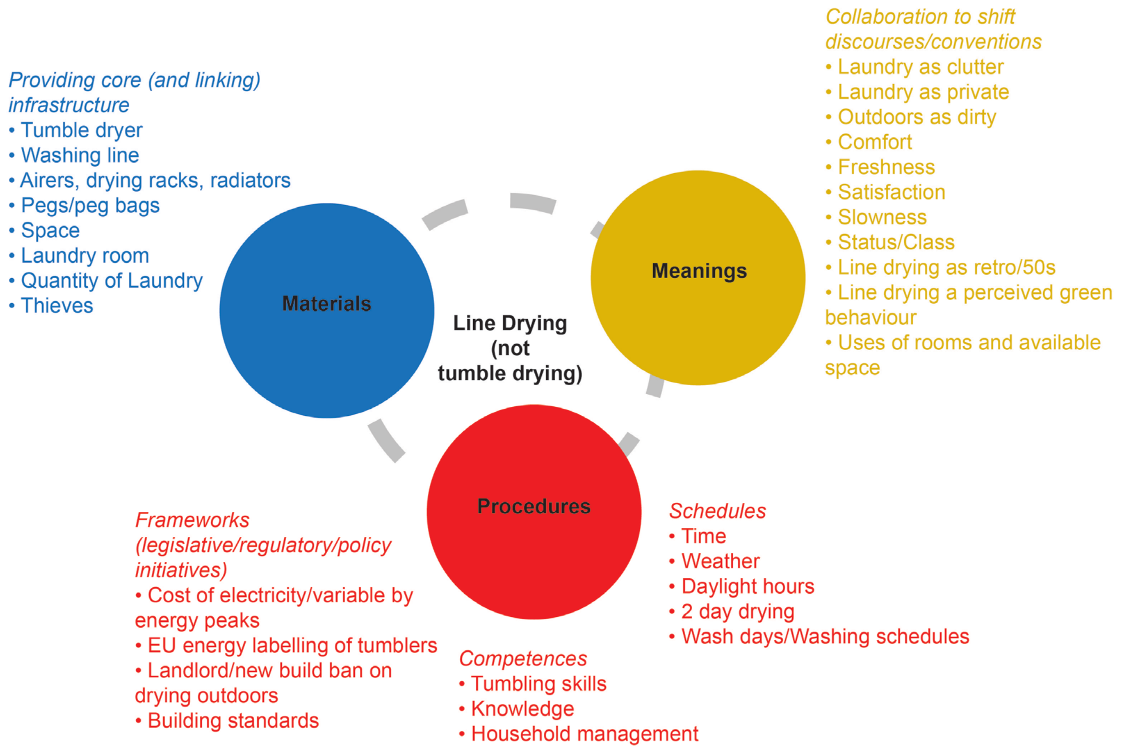


Figure 2-2 Example of the Three Elements Model (Darnton et al., 2011) (edited from original)

Research into practice has further intensified recently due to the inclusion of design aspects *(Shove et al., 2007, Shove et al., 2008)*, thereby moving the notion of practice from a reflective study or understanding, to a proactive design process for dealing with sustainability issues, such as bathing, thermal comfort and home improvements *(Kuijer and De Jong, 2009, Scott et al., 2009, Haines et al., 2012, Kuijer and De Jong, 2012)*.

Although Shove's Practice Orientated Product Design manifesto *(Shove, 2006)* begins the design debate, arguing that design process is fundamentally flawed as if it focuses on individual products and users, this has only recently started to be applied to aspects of design process by research academics *(Kuijer and De Jong, 2009, Scott et al., 2009, Haines et al., 2012, Kuijer and De Jong, 2012)*. These initial studies demonstrated that using such an approach emancipates and empowers participants towards an understanding of what *pushes* them to act, yielding several practice-based concepts, in parallel with methodological learning (such as the need for action orientated methods and real world longitudinal testing).

Despite the limitations of these first forays into combining practice theory with design process, they have illustrated that the inclusion of aspects of practice theory can offer a new perspective of understanding away from the traditional user centric view of products. It is debatable, however, whether the argument that product design is focussed on isolated, individual and non-temporal components is as valid as Shove suggests in modern design practice and research. User Centred-Design in particular, focuses extensively on the user's relationship and the external and internal factors that define and impact upon their context of use and experience *(IDEO, 1999, British Standards Institution, 2010, McClelland and Suri, 2005).* Defining design in such a limited way is a very out-dated way of considering design, and would be unlikely recognised by modern design practitioners and researchers. Ultimately, the real test to come is for practice-orientated design to invoke a large scale, society wide change through design that will generate its own materials, meanings and procedural contexts and understandings for future sustainable interactions.

2.2.2.2 A Psychological Approach to Behaviour

An alternative approach to practice exists within social psychology, centralised on the individual as the origin or *actor* of *behaviour*. Behaviour from this perspective is viewed as being within a *rational decision making process* (rational in terms of being a process with known variables and deliberation).

Given a set of internal or external prompts, attitudes and values within certain constraints, the individual would make their intention to act, resulting in behaviour *(Jackson, 2005, Chatterton, 2011)*. Models that attempt to formalise this approach tend to be described as being *linear* models, which follow an *Attitude-Behaviour-Choice/Context/Constraint* [ABC] structure *(Shove, 2010, Chatterton, 2011)*.

Darnton *(2008)* presents an abridged collection of thirty-five models, each with the intention of explaining facets of individual behaviour. Since 2008, the number of models has continued to increase, signalling two things; firstly, the cognitive processes underlying the nature of behaviour are of a high level of complexity, thus requiring multiple disaggregated models in order for them to be of use, and secondly, there is no single unified approach to understanding behaviour *(Chatterton, 2011)*. Given the wealth of models available and the limited scope of this review, two models in particular will be discussed as they are frequently cited and have solid histories of application. These are Ajzen's Theory of Planned Behaviour and Triandis' Theory of Interpersonal Behaviour *(Jackson, 2005)*.

The Theory of Planned Behaviour [TPB] put forward by Icek Ajzen revolves around the central concept of *intention (Ajzen, 1985, Ajzen, 1991)*. The intention of an individual to act is taken as the individuals' willingness to perform. The motivational antecedent structure to determining intention is driven by *belief* - rational cognitive decision making by the individual, through the weighing of relevant costs and benefits *(Ajzen, 2002, Abrahamse et al., 2005, Jackson, 2005, Abrahamse and Steg, 2011)*. As illustrated in Figure 2-3 *(Ajzen, 2011)*, the belief structure can be disaggregated to include *behavioural beliefs*, *normative beliefs* and *control beliefs.*

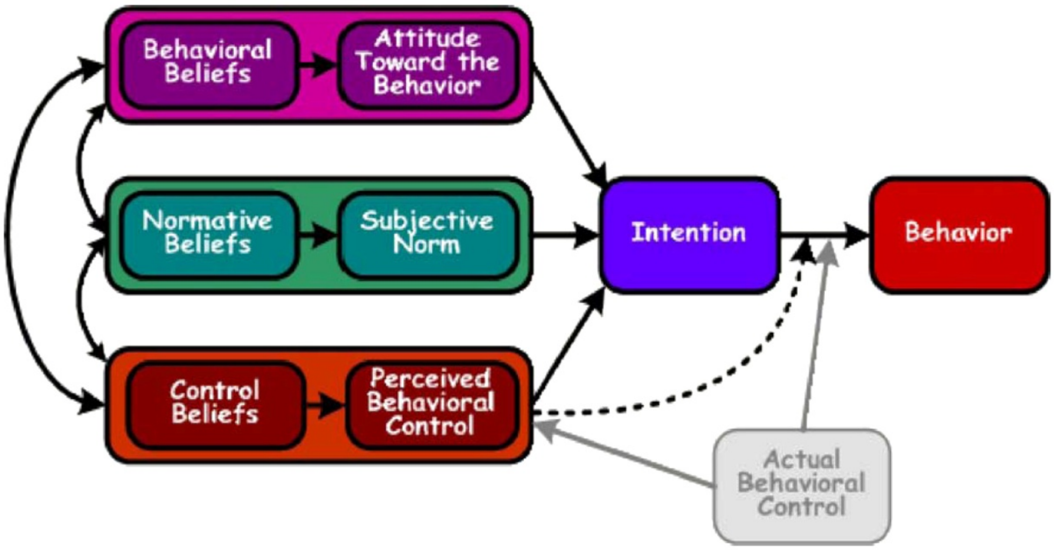


Figure 2-3 Theory of Planned Behaviour Diagram (Ajzen, 2011)

Behavioural beliefs can be defined as beliefs concerning the predicted subjective consequence of enacting the behaviour, which in turn generates a positive or negative attitude towards the behaviour. Normative beliefs are a perception of the expectations of how significant others may perceive your enactment of the behaviour, influencing the individuals' perception of social pressure. Control beliefs are determined by the individuals' perception of factors that may enable or inhibit the enactment of the behaviour. Control beliefs influence the individuals' perceived ease or difficulty in behavioural control *(Ajzen, 2002, Abrahamse and Steg, 2011)*. Aside from intention, a further direct antecedent to behaviour is *actual behavioural control (Ajzen, 2002)*. The three tiered belief system posits that the stronger the positive attitude is towards the behaviour, and the more favourable the subject norms are perceived to be in parallel to an acceptable level of perceived control, the stronger the intention to enact the behaviour becomes *(Ajzen, 1985, Ajzen, 1991, Ajzen, 2002)*. The caveat to this model is that this is only true for those behaviours where perception of control is equal to or less than actual control, as the skills and resources required to enact the behaviour may be limited leading to a high control belief, but in fact, resulting in limited actual control *(Ajzen, 2002)*. As such, actual control has been included within this model to account for this misalignment.

Whilst the TPB is a well-known and applied model of behaviour *(Jackson, 2005)*, it does negate certain factors that may contribute to the formation of behaviour that may not be explicitly linked to belief or even intention, such as *emotions* and *affect*, and *habits (Darnton, 2008)*. Ajzen's Theory of Planned Behaviour places belief as the primary determinant of intention that results in behaviour, Triandis' Theory of Interpersonal Behaviour [TIB], however, places *habit* as the priority factor, over *intention* and *facilitating conditions (Darnton, 2008)*.

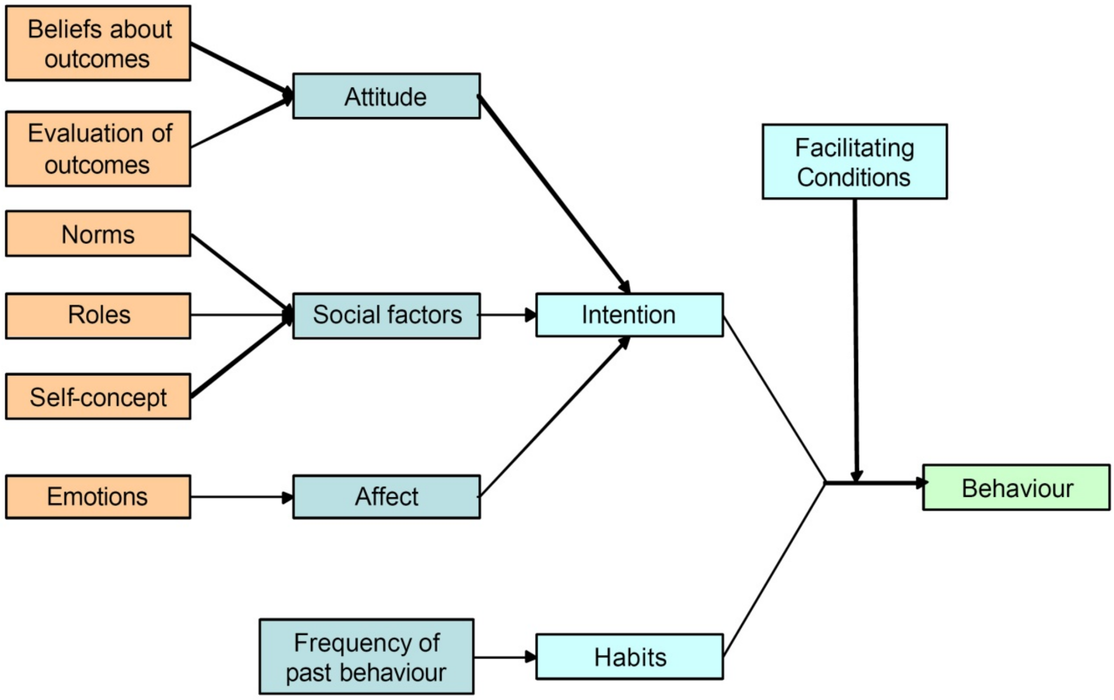


Figure 2-4 Theory of Interpersonal Behaviour Diagram (reproduced from (Jackson, 2005))

TIB, Figure 2-4, posits that *intention* (composed of *attitude*, *social factors* and *affect*) is a direct antecedent to behaviour. The critical difference between these two models (aside from the role of affect – emotive influence) lays in the inclusion of habits, which intercedes between intention and behaviour, acting as a key determinant of the actual enactment of intention, the ensuing behaviour. Both intention and habit are in turn both ruled by the facilitating or constraining conditions, the external factors that enable or constrain behaviour *(Jackson, 2005, Chatterton, 2011)*, such as birth attributes, acquired capabilities, situational context , public policy, and economic variables *(Stern, 1999)*.

Habits within this model are seen as routinized action enacted without conscious intention, hence its distinct mediating branch outside of intention *(Chatterton, 2011)*. However, despite habit being positioned within the TIB as a prominent causal factor, its reliance on *frequency of past behaviour* as its sole antecedent factor is not in line with current research on the formation of habit, as discussed below.

Three characteristics construct a habit. Firstly, a goal must be present and achieved. Secondly, if the achieved goal is satisfactory, the same action is repeatable. Thirdly, a habitual response is governed by the cognitive process that develops through frequency and association of the context and intentional factors. Habits therefore may be identified and assessed through the cognitive decisions made and not through the frequency of the action *(Polites, 2005, Lally et al., 2009, Steg and Vlek, 2009)*. Verplanken *(2006)* expands upon this standard definition of habit, stating that the strength of a habit is not determined just by the frequency of past behaviour (frequency based cued learning), but is also constructed of four further parts, based on Bargh's definition of automaticity; lack of awareness, efficiency, difficulty in controlling behaviour and identity *(Bargh, 1994, Bargh, 1999)*. Lack of awareness is a lack of conscious decision-making, delegating of control of the act to environmental cues. Efficiency relates to the freeing of mental capacity to do other things at the same time through the application of expectation filters. Difficulty of controlling behaviour suggests a habit in principle is controllable, but it is difficult to implement deliberate thinking and planning to overrule. Identity is the reflection of one's own identity and personal style *(Verplanken et al., 2005, Verplanken, 2006)*. Triandis' Theory of Interpersonal Behaviour augmented with Verplanken's model of habits will be the model of understanding taken forward within this thesis (Figure 2-5).

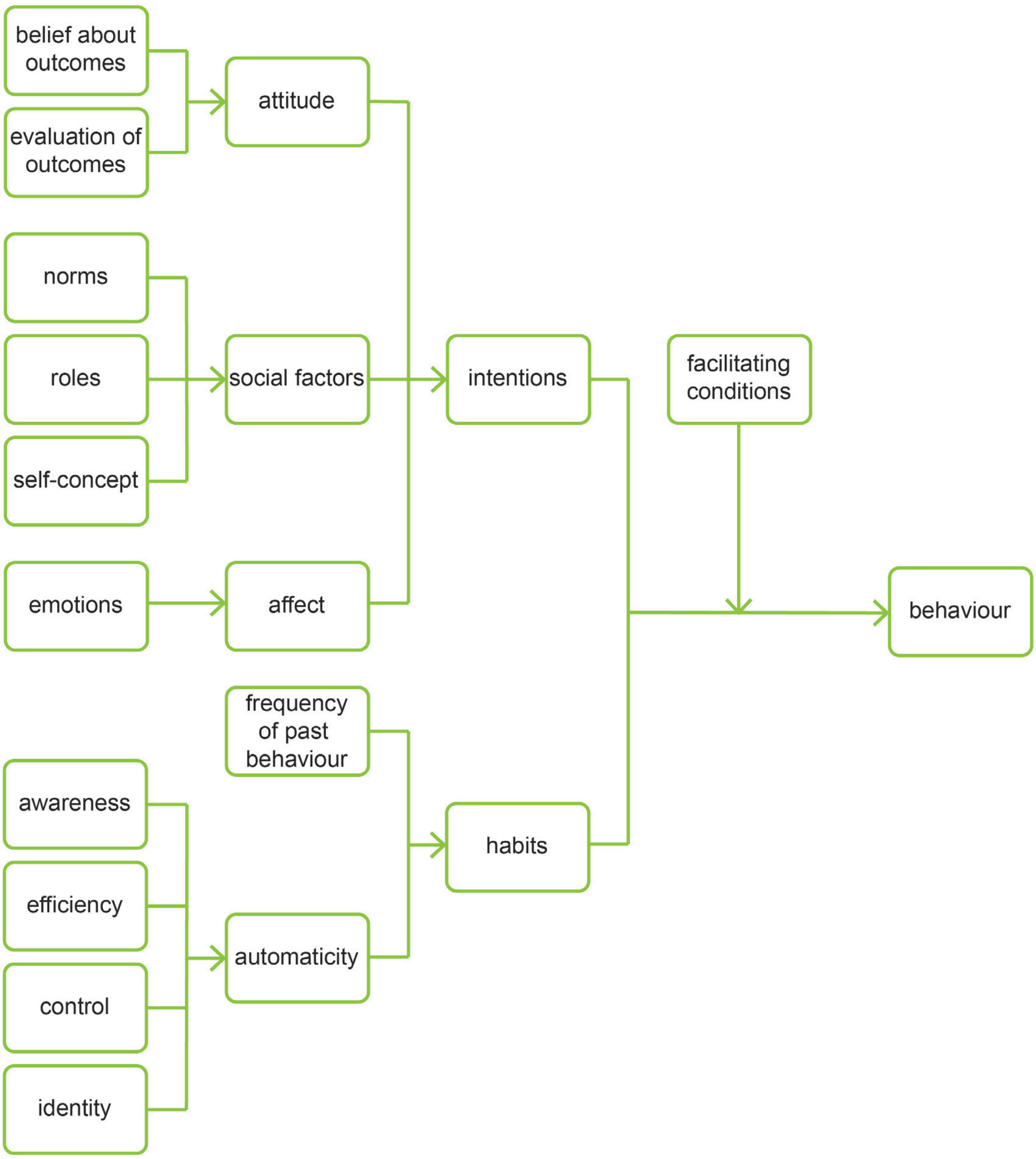


Figure 2-5 Augmented Model of Behaviour

This psychological approach to behaviour, once augmented, provides the most defined model of behavioural understanding with a robust history of application in the field of psychology, in addition, offering a shared domain or ontology and terminology aligned to the core of present design thinking (centred on the individual/user, attitudes, goals, habits etc.). A practice approach will not be taken due to the limitations as previously outlined and its lack of robust definition and application currently within design.

2.3 Behaviour Change Interventions and Strategies

The previous section has shown that there are multiple factors to think about when considering what determines an individual's behaviour and actions. Intentions, habits and facilitating conditions all possess important roles in affecting the selection of choices that form behaviour. Several strategies exist that build upon these psychological theories in order to promote a change in behaviour, discussed in this section.

2.3.1 Antecedent Interventions

The objective of an *antecedent intervention* is to influence the cognitive antecedents of an action *prior* to its enactment. Research shows that there are several types of strategy to consider which may provoke a change in thought process, including commitment, goal setting, informational and structural strategies *(Abrahamse et al., 2005)*.

2.3.1.1 Commitment Strategies

The use of *commitment strategies* can be implemented one of two ways; either as a *private promise* self-administrated in line with personal norms, or as a *public pledge* governed by social norms, which in turn affects intention *(Jackson, 2005, Chatterton, 2011)*. A commitment, or statement of one's intent to change, has been shown to be an effective mechanism by which to reduce energy consumption over a long-term and post intervention, especially when combined with information, goal setting and foot-in-the-door techniques. By accepting a small commitment, such as filling in a questionnaire or leaflet, a higher rate of uptake is facilitated when followed by an associated larger commitment, such as agreeing to a reduction target based on the initially received leaflet *(Abrahamse et al., 2005)*.

2.3.1.2 Goal Setting Strategies

Goal setting provides a strong motivation to engage with an activity due to the sense of satisfaction or achievement that it affords. This strategy usually works in parallel with other strategies, such as the use of feedback or commitment, with research indicating that a combination of goal setting with both of these other strategies yields a higher saving compared to goal setting alone *(Abrahamse et al., 2005)*. By supplying a target or a goal, a *commitment* *strategy* can be considered and implemented based on normative considerations, with feedback providing a comparative reference or direct attention towards a level in a goal hierarchy (the feedback intervention theory [FIT] *(McCalley, 2006)*). It appears that by setting a difficult target to achieve, a higher saving can be made in comparison to a lower target, however, an unrealistic goal may disenfranchise the individual from motivation, with a goal set too low limiting the effectiveness of such a task. A low target may not stimulate the need to re-evaluate cognitive processes or actions in order to reach the target *(Abrahamse et al., 2005, Wood and Newborough, 2007)*.

McCalley *(2006)* proposes that there are four mechanisms by which goal setting affects action: firstly it provides a *concentration* of the individual's attention toward the goal-related activity; secondly it cognitively and physically *motivates* the individual; it prolongs the *effort* required to attain the goal set; and finally it increases the chance of *retrieval* or the *creation* of pertinent knowledge or strategies required for goal achievement.

2.3.1.3 Informational Strategies

Informational strategies can be targeted, implemented, and dispensed in numerous ways. Information can help in changing the antecedents of intention without a change in facilitating conditions *(Steg and Vlek, 2009)* through the *defining* of a problem or a solution, or by *providing knowledge* on how to mitigate or implement them *(Abrahamse et al., 2005)*.

Informational strategies have three main aims. Firstly, information may be provided to *increase knowledge* of a problem, its consequences, and possible alternatives, thereby encouraging a normative or attitudinal change, which may ultimately propagate through intention into a positive behavioural change. A second mode of implementation is as a *persuasive tool*. Information in this context is used to support or strengthen a personal normative value or commitment strategy. The third role of information is as a social normative reinforcement and *framework* agent *(Steg and Vlek, 2009)*, through methods like *modelling*. Modelling is the provision of information on recommended behaviours that is rewarding whilst being relevant and understandable by the target individual. Modelling has been shown to yield moderate success in behavioural change and in raising awareness around an issue, although follow-up studies show this not to have been maintained *(Stern, 1999, Abrahamse et al., 2005)*. Modelling and informational strategies in general must captivate the individuals they are aimed at, as well as gain involvement and demonstrate credibility, and positively show the benefits of modifying one's actions *(Stern, 1999)*.

In general, informational strategies are cost efficient with regards monetary, temporal, and effort considerations, and render little byway of social disapproval. Strategies in this informational sphere are also most effective when the desired behavioural result is relatively convenient, with weak external constraints or barriers to action *(Stern, 1999, Steg and Vlek, 2009)*.

In order for an informational strategy to be successful and to avoid short or/and long term failure, it must also be presented at the *time* of behavioural occurrence, be able to be *validated* by the individual, come from a *trusted* source, as well as gain their *commitment (Stern, 1999, Steg and Vlek, 2009)*. Poor *communication* has also been shown to hinder informational strategies *(Ofgem, 2010)*. Informational strategies may also not always be sufficient when working independent of other intervention strategies *(Ofgem, 2010)*, indeed, combination with these other strategies, focussed at either the individuals intention or the facilitating conditions, may prove to be more effective *(Abrahamse et al., 2005)*.

Three methods by which informational strategies may be implemented include workshops, mass media campaigns and tailored information. *Workshops* are an organised group event through which information is dispensed through leaflets and advice, however as Abrahamse et al *(2005)* discuss, an increase in awareness and knowledge does not necessarily translate into action. The same has been shown for *mass media campaigns*, that an increase in awareness and knowledge of energy issues did not provide strong evidence of energy reduction *(Abrahamse et al., 2005, Darby, 2006).* Darby *(2006)* suggests that the key concern is trying to keep the information relevant to the individual in order to convince them that their change in behaviour is to their advantage. *Tailoring* addresses these issues, providing a selection of information only the individual would find relevant to their intentions. Home audits by energy auditors, as a form of tailored advice, has shown to increase knowledge of energy conservation issues and a reduction in energy use over time, whereas the use of tailored information alone has shown mixed results *(Abrahamse et al., 2005)*. Education through *schools* may be a further method of disseminating information towards family behaviour changing means, however as Darby *(2006)* points out, it is difficult to assess its effectiveness due to the complexity of isolating data.

2.3.1.4 Structural Strategies

A *structural strategy* aims to *change* the context or facilitating conditions by which decisions are made through either a change in products or services, situational context, and capabilities or a change in policy, legislation, and pricing *(Stern, 1999)*. A change in facilitating conditions, as previously discussed, may *facilitate or constrain* direct action, *motivate* a change in intentions and foster habits, provide behavioural *alternatives* or *activate* goals *(Steg and Vlek, 2009)*.

Product or service led strategies can force a physical or infrastructural change in context. These changes may include the promotion or enforcement of energy efficiency, however, the motivational norms of the individuals should also be considered to increase uptake *(Steg, 2008)*. Although policy changes and pricing strategies may lead to an increase in environmental quality, such as the banning of environmentally damaging propellants in domestic spray cans *(Steg and Vlek, 2009)* they may also bring about ethical issues, such as a reduced level of quality in other personal aspects including freedom or money *(Steg, 2008)*.

It is also worth considering government attempts to replace incandescent light bulbs with compact fluorescent lamps [CFL]. CFLs are still widely rejected by individuals despite them being a relatively cheap and well-promoted energy-efficient intervention. Government policy and manufacturer claims imply that CFLs are a direct replacement for traditional bulbs although this is not the case. Despite the provision of free CFL light bulbs, it has been found that individuals will not use them, or only use them in restricted circumstances, as they are seen to be a compromise of personal norms and values *(Crosbie and Baker, 2010)*.

2.3.2 Consequence Interventions

Consequence interventions shift the focus towards the positive and negative *consequences* of behaviour and action, rather than focussing on the physiological and physical constructs prior to behaviour. By attaching either a positive or a negative consequence to behaviour, the behaviour becomes a more or less attractive option within the series of mediated intention antecedents *(Abrahamse et al., 2005)*.

Strategies within this intervention group include the use of rewards and feedback.

2.3.2.1 Rewards

Rewards generally can be considered to fall into two camps, financial and non-financial, and are considered an incentive from outside of the behaviour (as opposed to a direct result of the behaviour). Rewards are considered to be more effective than penalties or sanctions, as rewards are considered to be more psychologically aligned with the positive attitudes required for behaviour change *(Steg and Vlek, 2009)*.

Financial rewards such as rebates, high price incentives and monetary rewards for recycling have all shown that if the incentive is large enough, a change in action may occur *(Stern, 1999)*, however, this change is contingent on the reward, and is not a normative change, thereby tying the action to the specific presence of the financial motivator *(Steg and Vlek, 2009)*. Analysis of the Ofgem *(2010)* trials suggests that financial rewards based on a per cent reduction in energy use can motivate, on both an individual and community scale, a reduction in energy consumption. However, it is also noted that once this motivator is removed, that the initial savings fall away. It is also unclear whether rewards alone or a combination of rewards and information help to induce savings *(Abrahamse et al., 2005, Ofgem, 2010)*.

Non-financial rewards may include savings based upon other costs and benefits of the personal domain, such as a saving of time or effort. An example of a convenience reward may be the provision of centralised road side pickup of domestic recycling. The reward, or saving, is realised in comparison with the time and effort it would have taken transporting the recycling personally to a recycling centre. Combining monetary reward with nonfinancial incentives, such as convenience, has also been shown to be particularly effective *(Stern, 1999)*. It has also been shown that once a reward is acted upon and considered of benefit, that it may be of more use to increase knowledge surrounding the action to increase other motivation factors, as opposed to increasing the reward *(Stern, 1999)*.

Incentives such as monetary and emotional rewards, as previously discussed, may also help to stimulate the motivation to conserve energy. Feedback may be presented as either a financial saving through a reduction in energy, and therefore, cost expenditure, or as a payment through energy saving that is independent of cost expenditure (e.g. a lump sum payment for reaching a consumption target) *(Wood and Newborough, 2007)*. Wood and Newborough *(2007)* point out that although the use of payments and financial rewards help to promote a reduction in energy-using behaviour (although as previously noted this effect may revert after the reward is removed), there is little evidence to suggest that individuals will reduce consumption based on emotional rewards. This, however, suggests a tailoring issue with regards the individual's norms and intentions rather than a failure of rewards in general.

2.3.2.2 Feedback

The final consequence intervention of note is the use of feedback. In essence, feedback theory suggests that by providing the individual with feedback, a performance indicator based on the results of an enacted intention or habit, the individual can make associations between the behaviour they enact and its consequences *(Abrahamse et al., 2005)*. Through a process of cognitive evaluation, future intentions, habits and behaviours may be influenced *(Abrahamse et al., 2005, Burgess and Nye, 2008)*.

The individual's knowledge and perception of energy, as discussed previously, can be weak due to energy's abstract and invisible nature. The result of this perceptive difficulty manifests itself as incorrect heuristics and a lack of conscious consideration in its consumption. In order to frame the behaviour within an attitude-social-affect intention structure *(Jackson, 2005, Chatterton, 2011)*, a substantial amount of information is required to put it in the context of its consequences and alternative options *(Fischer, 2008)*. Feedback as an educational instrument can be employed in two ways. As a tool to illustrate the actual cost (such as time or money) of consumption and generate reflection on *intention* and *attitude*, feedback can be used to tangibly present and frame the *problems* caused through behavioural action. A suitably framed problem, presented through the feedback's form and delivery content may therefore influence the *intention* process *(Fischer, 2008)*. Information is taken in, is acted upon, and an interpretation is made *(Darby, 2006)*. Alternatively, appliance specific feedback can be used to link a specific interaction with a product or system to energy consumption, thereby increasing an individual's product/system understanding and increasing individual's consciousness of their own behaviour *(Fischer, 2008, Darby, 2010)*. By allowing individuals the ability to explore their own energy use and its effects, the concern/action gap can be bridged, promoting efficiency as opposed to trying to generate an intangible sense of social obligation *(Darby, 2008, Darby, 2010)*.

2.4 Categories of Feedback

Darby *(2006)* proposes five categories of feedback**:** direct feedback; indirect feedback; inadvertent feedback (education though association); utility-controlled feedback; and energy audits (education through an understanding of the energy capital of a building). Direct, indirect and utility controlled feedback types are summarised in Table 2-1. According to Darby *(2000)* direct feedback either by itself or in partnership with other strategies, such as additional information, is the most effective form of feedback. The role of indirect feedback discussed in the same paper claims that despite a rise in interest and awareness, this did not translate to savings of an order comparable to those found in direct feedback studies *(Darby, 2000)*. In a later review on the same topic, immediate direct feedback is again argued as being the greatest saver of energy in relation to daily, non-heating behaviours. This is due, it is claimed, to greater visibility of the consequences of action *(Darby, 2006)*. In this latter study, Darby shows that energy savings of between 5-15% is possible from direct feedback, with indirect feedback providing evidence of savings between 0-10%.

Category of Feedback	**Summary Description**
Direct Feedback Direct feedback is feedback presented immediately to the individual without processing, either from a meter or from an associated device.	
Basic Metering without Separate Direct Display Monitors	Energy meters in the UK provide consumption feedback, usually measured in a single unit with the meter often kept out of sight. Information is not benchmarked, and the individual would need to keep a manual record of this information for comparative purposes against estimated bills.
Key Meters and Keypad Meters	Key or keypad meters form part of the prepayment system of paying for energy prior to its consumption. Energy tariffs tend to be more expensive, however, prepaying for energy may be more conducive with saving energy.
Direct Display on Monitors Separate from the Meter	A direct display, physically remote from the main meter with data communicated unidirectionally showing the direct consumption of energy. Typical displays allow for the showing of frequently updated data or information from a previous term.
Use of TVs and PCs for Display	TV and PC displays can been used to show historic and current consumption data, with relevant environmental or social comparisons. The use of interactive online facilities could help to facilitate a self-appraisal of energy consumption.
Ambient Devices	Ambient devices tend not to show numbers or text that is directly attributed to energy use; rather they illustrate or alert a change in energy consumption through sensory indicators, such as a change in colour or sound.
Indirect Feedback Indirect feedback is feedback presented to the individual after being externally processed (for example, bills processed by a utility company).	
Informative Billing	Energy bills in the UK tend to be based on estimated consumption rather than physical meter readings and provide a comparative benchmark by which to evaluate previous terms energy expenditure, or a means by which to see the effect of any domestic or technical changes to the dwelling.
Utility Controlled Feedback Utility-controlled feedback concerns the control and provision of data of an individual's energy consumption data back to both the individual and the utility provider. This two-way communication of information is typically termed *smart*.	

Table 2-1 A Summary of Three Categories of Feedback (Darby, 2006)

A spectrum proposed by the Electric Power Research Institute [EPRI] and based on the initial categorisation work of Darby *(2006)* posits that there is a spectrum of *information availability* and *cost to implement*, with *standard billing* at the *low* end, running through from indirect to direct feedback, with *real-time plus* at the *high* end *(EPRI, 2009)*, Figure 2-6.

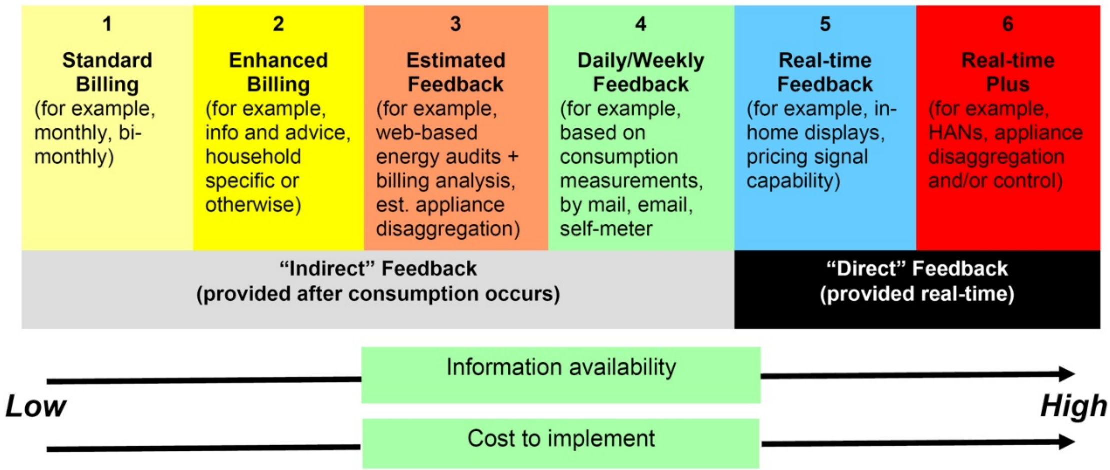


Figure 2-6 Feedback Delivery Mechanism Spectrum (EPRI, 2009)

The key axis of note on this spectrum is information, as information is central to the concept of learning and establishing context, without which the individual will not be influenced to reduce consumption through increased awareness of actions or influenced intent. Such an axis rightfully, however, does not present a taxonomy whereby information equates directly to learning, behavioural action or savings (as the way in which this information is *presented* is instrumental in motivating change). What this diagram does suggest, however, is that information provision back to the individual on their actions is highest with forms of direct real-time feedback. Therefore, with the correct format of representation and tailoring, feedback types towards this end of the axis may be designed to facilitate a higher degree of learning, and by extension, the larger *possibility* of behavioural change, supporting the findings of Darby.

Prior to discussing what makes feedback effective, or *feedback considerations*, it is worth briefly discussing the type of feedback most prominent in research at present; *utility controlled* feedback or *smart metering.* Smart metering concerns the control and provision of data of an individual's energy consumption data back to both the individual, to provide tailored and accurate information as a learning mechanism, and the utility provider, who benefits from the increase in understanding of consumer consumption *(Darby, 2008)*. It is also suggested that the use of such technology could reduce the requirement for expensive prepay meters and tariffs, thereby helping to combat fuel poverty *(Burgess and Nye, 2008)*.

The reason for this prominence in recent research is in part due to the UK government in October 2008 stating that there would be a mandatory roll out of smart meters to all UK homes by the end of 2020 *(Department of Energy and Climate Change 2009)*. Functionality includes features such as *"remote provision of accurate reads/information for defined time periods*, *two way communications to the meter system* [and] *remote disablement and enablement of supply" (Department of Energy and Climate Change, 2009, P.27).* In preparation for the start of this roll out in 2014, Ofgem on behalf of the Department of Energy and Climate Change [DECC], have been launching large-scale trials across the UK, the Energy Demand Research Project [EDRP] *(AECOM, 2011, Ofgem, 2011)*. The impact on feedback design resulting from the findings of these studies is discussed in the following section (Feedback Considerations).

There are, however, a few potential issues with such a system. As Darby *(2008)* points out, through integration with a *smart grid* system, the utility provider has the power to turn on/off domestic appliances to cope with energy grid overload or high prices; an issue that many consumers may find unattractive or unethical. From a utility provider's perspective, the rolling out such a national network is quite a logistical challenge, dependant on coordination and cooperation between utilities *(Darby, 2008)*.

2.5 Feedback Considerations

There are several ways by which feedback can influence the energy consuming behaviour of an individual through the provision of information, but as Wood and Newborough *(2007)* point out, information alone is not enough to promote action, rather it is the way in which this information is conveyed and how that *motivates* the individual to act.

This section outlines the considerations required when designing a feedback intervention, optimising feedbacks potential as a behaviour changing intervention, discussing the findings from several key reviews of feedback studies, including Fischer *(2008),* Abrahamse *(2005)* and Darby *(2006)*, and supplementing their analysis with findings from recent feedback studies including the EDRP.

2.5.1 Frequency and Duration

Ideally, the latest update of information should be present when the individual *performs* an energy-consuming act and may be open to a change in behaviour, and secondly when the individual chooses to *acknowledge* the feedback. Wood and Newborough *(2007)* point out that not all energy consuming activities may require the same level of *frequency*, with an activity such as cooking requiring a higher frequency of updates than, for example, using a washing machine.

Further research shows that quick feedback after an action improves the cognitive linking between action/effect, thereby reinforcing the consequences of the action, and lowering consumption *(Abrahamse et al., 2005, Darby, 2006, Fischer, 2008)*. Hargreaves *(2010)* and Fitzpatrick and Smith *(2009)* have shown several ways in which consumer interaction is motivated by frequency of information displayed. They report behaviour such as using the device *hot*, using the constant feedback provided to go around the home switching devices on and off in exploration.

The *duration* displayed by the feedback device is also an important consideration. Wood and Newborough *(2007)* suggest that on a display local to an action, the information should be succinct to maintain immediate interest; a centralised display would show a larger time span, such as consumption over a week. Hargreaves *(2010)* found that using too short a time base may inhibit conservation or promote consumption and that too long a time base may stamp out high energy using appliance spikes. Interestingly, Anderson and White *(2009)* found *rate of spend*, a predicted unit, to be a concept which all of their participants could recognise and relate to, suggesting that information needs to be *meaningful* over necessarily being *realistic*.

2.5.2 Accuracy

If one of the aims of feedback is to form a cognitive bridge between action and effect, it is important, therefore, that the information is not only frequent but is also *accurate (Fischer, 2008)*. Estimated feedback disassociates the individual with the consequences of their behaviour, and furthermore, removes any time of use prompts to frame or challenge their action *(Hargreaves, 2010)*.

2.5.3 Metrics

Energy consumption feedback can be presented to the individual through *energy units*, *cost*, *environmental impact*, and/or *behavioural units*. Each of these unitary types uses a different language to frame the context of energy consumption, thereby activating different norms and intentions within the individual *(Fischer, 2008)*.

Energy units, such as kWh, are a standard measure for the use of electricity and gas consumption and are generally perceived to be too abstract or difficult to relate to everyday actions *(Burgess and Nye, 2008, Anderson and White, 2009, Hargreaves, 2010)*. Precise understanding, however, may not be necessary, rather it is the real time relative movement of the energy displayed that helps a consumer "*learn what is normal, and what is not" (Anderson and White, 2009, Fitzpatrick and Smith, 2009, p.43)*. Furthermore, as Wood and Newborough *(2007)* point out, a scientific unit may instil a sense of trust. Research suggests that *cost* may be a more relevant and understandable metric, relatable to an allocated financial budget *(Burgess and Nye, 2008, Hargreaves, 2010, Ofgem, 2010, AECOM, 2011)*, however, those on a low-income may find the emphasis on monetary concerns stressful *(Hargreaves, 2010)*. Although understandable, the use of cost as a metric may not necessarily always motivate a reduction in consumption if the perceived cost of energy due to granularity of information or in comparison to other household expenditures is considered trivial or worthless *(Wood and Newborough, 2007, Fitzpatrick and Smith, 2009, Hargreaves, 2010)*. The use of *environmental impact*, for example carbon units, may be used to promote the link between action and environmental consequence. The issue with this type of metric appears to be that the average individual does not know how to interpret the unit in comparison to their own energy consumption *(Anderson and White, 2009, Fitzpatrick and Smith, 2009)*, and furthermore, the unit itself is based on estimation *(Wood and Newborough, 2007)*. *Behavioural units*, such as time spent on an activity or the number of times an appliance has been used could be employed to motivate the individual based on a personal or social norm *(Wood and Newborough, 2007)*.

The research illustrates that there is no single metric that satisfies every user in terms of both understanding and intention, and that the selection of metrics should, therefore, be *tailored* to the intentions and capabilities of the target individual *(Fischer, 2008)*.

2.5.4 Breakdown

Trials of energy display devices have shown them to be a well-received educational tool *(Hargreaves, 2010)*. By allowing the individual to decide which appliance to place the sensing device on, three categories of use emerged; to measure devices that they felt they had control over, to measure large load devices, and also to measure those devices that they had no control over *(Hargreaves, 2010)*.

2.5.5 Presentation Medium

The *medium* by which information is presented also has an effect on its ability to engage with the individual, and thus be comprehended, reflected upon, and effectual *(Fischer, 2008)*.

Electronic media used for feedback provides flexibility of control and display, and rapid processing capabilities allowing for the presentation of real-time data. Complex devices may, conversely, be difficult for those of with a low level of education, technical ability or free time to understand or engage with *(Fischer, 2008)*. Anderson and White *(2009)* found that certain individuals are uncomfortable with devices that require interaction, fearing an exploration of options beyond the default display. Furthermore, the EDRP trials found that 32% of energy monitor users had difficulties in changing the default settings *(AECOM, 2011)*.

Written materials, by contrast, require a lower level of education or technical ability to engage with *(Fischer, 2008)*. Feedback information accompanying a bill can also be expected to receive more careful consideration *(Fischer, 2008)*. Despite the high visual quality of modern electronic displays, paper had been shown to be a preferred reading medium due to its *haptic quality* and freedom in how and where it is read *(Holzinger et al., 2011)*. The medium by which information is presented should be framed within the intentions and capabilities of the individual targeted.

2.5.6 Presentation Mode

In order to engage the user with the information generated, careful consideration must be given to the way in which this information is *visually presented*, with comprehensibility and clarity of presentation remaining clear and unambiguous.

Wood and Newborough *(2007)* suggest that frequency and location of the information presented may affect the selected visual presentation, with numerical data better suited to frequent updates on local displays, with less frequent updates on central displays better suited to graphical data. In addition, children may find graphical data easier to understand, potentially increasing *pester power (Hargreaves, 2010)*. Hargreaves *(2010)* found that the more complex the information offered, the higher the demand for active involvement, which may negate any immediate motivation to engage, a finding supported by Fitzpatrick and Smith *(2009)*, that the preferred local display device in their trials allowed for *at-a-glance* information.

The selection of charts should be based on the information that is trying to be conveyed, with bar charts being better suited for accurate, comparative data than pie charts, which are better matched to presenting general patterns *(Wood and Newborough, 2007)*. Research also shows a form of *speedometer* or *traffic light system* to be useful. Should the display go *into the red*, investigation may be prompted *(Hargreaves, 2010, Ofgem, 2010)*. A focus group run by Anderson and White *(2009)* found that these displays show the scale, direction of change and relative position simply; emphasising that it's the *movement* that grabs your attention *(Anderson and White, 2009)*.

The presentation mode and layout of controls, should *keep it simple*, although this may be in contradiction to some individuals desire to investigate information in more detail *(Anderson and White, 2009)*. Fischer *(2008)* suggests that the presentation of information should be *undemanding* in comprehension, and not involve any additional materials to aid understanding.

2.5.7 Ambience

Studies suggest that the use of ambience alone to convey energy consumption is perceived as being ambiguous unless the ambience feature has distinguishable characteristics that can be easily cognitively mapped *(Fitzpatrick and Smith, 2009)*. Ambience may also be construed as energy wasting or may also *contradict* values, such as found with the *power-aware cord (Backlund et al., 2006)*, a light-emitting power cable drawing attention to itself when in use, when social normative values suggest that it should be concealed from view *(Fitzpatrick and Smith, 2009)*. Investigating the effects of the same light-emitting device, Löfström and Palm *(2008)* found that this use of ambience supports feedback as a provider of information and cues *"at a glance, from a distance" (Löfström and Palm, 2008, P.938).*

The use of ambient persuasive technology has been defined by Ham et al. as being *"able to influence attitudes or behavior* [sic] *without conscious attention to that persuasive technology by the person being influenced" (2009, P.1).* The results of their study showed that presenting individuals with *subliminal* (25ms duration of display for non-conscious perception) or *supraliminal* (150ms duration of display for conscious perception) weighted information, has an effect on behaviour attributed to either an assigning of positive and negative value associations or through the non-conscious priming of information that affected the goal pursuit *(Ham et al., 2009)*. Furthermore, Maan et al. *(2011)* found that light feedback realised greater energy savings than numerical feedback and that additional and unrelated cognitive load affected the time it took to process and evaluate numerical information, but not light information. This supports the theory of ambience as a provider of *easy to process* feedback around a central principle of *implicit evaluation* that does not require the individual's undivided attention.

2.5.8 Location

If an action requires instantaneous feedback in order to improve cognitive connections between action/effect, the device must be *located* in such a position as to afford this information. Fitzpatrick et al *(2009)*, Anderson and White *(2009)* and the EDRP trials *(AECOM, 2011)* all found that a central location, namely the kitchen, living room or main hallway were preferred locations for immediate feedback where they could be easily accessed. It was also found that individuals preferred not to have their appliances each fitted with their own feedback display *(Fitzpatrick and Smith, 2009)*.

The location of a device can also have an effect with regards its *aesthetical acceptation*, which is vital in order to support regular interaction which may encourage a behavioural change *(Fitzpatrick and Smith, 2009, Hargreaves, 2010)*. By fitting in aesthetically with the individual's chosen location, the device is more likely to be accepted and incorporated into the individual's routines *(Fitzpatrick and Smith, 2009)*. The location of the device may also be *transient*, which brings its own set of design issues *(Anderson and White, 2009, Fitzpatrick and Smith, 2009)*, however, as Anderson and White *(2009)* point out, after initial mobile exploration with a device in different rooms, its location eventually became static.

2.5.9 Technical Expectations

If there is a failure during technical installation of a feedback device, or with the provision of accurate information, interest in the feedback or the perception of it may be reduced or damaged *(Crosbie and Baker, 2010, Hargreaves, 2010)*. The EDRP trials report that the installation and presence of a smart meter alone may prompt energy savings, showing that savings of around 3% on gas consumption was attributable in two of their trials to the *experience* only *(AECOM, 2011)*. The explanation given is that the installation and receiving of the device generated initial action, such as reducing thermostat settings. If a negative perception is given during the installation of these devices, it is plausible that initial efforts to save may be reduced.

If the expectations are also proved to be *inaccurate* (e.g. promised savings not realised), or based on *irrelevant* motivations or norms (e.g. emphasis on environmental issues when monetary expenditure is desired), then negative perceptions may restrict future use *(Crosbie and Baker, 2010)*. In order to maintain the individual's expectations, Crosbie and Baker *(2010)* suggest that information provided should be *realistic*, *comprehensible*, and easily *available*; that interventions must be *professionally* administrated and implemented; and finally that the contractors and technology must be *reliable* and able to meet the *expectations* of the individual.

2.5.10 Historic and Normative Comparisons

By providing a *historic* (a comparison of current against previous consumption) or *normative* (a comparison against factors that may instil normative motivations, such as other households, activities, appliances, fuel types, temporal frames or family members) comparison to the individual's own, immediate and localised consumption, a context is provided by which to assess, evaluate and compete *(Abrahamse et al., 2005, Wood and Newborough, 2007, Fischer, 2008)*.

Historic comparison may trigger a more detailed analysis of one's own behaviour and may stimulate a need to self-diagnose any perceived fluctuations, in addition, it has also been shown that the accuracy of this information is relatively unimportant, so long as *relative patterns* can be observed *(Fitzpatrick and Smith, 2009)*.

Normative comparison may feedback the individual's consumption level in comparison to that of relevant others, although this approach has been shown to be quite undesirable *(Wood and Newborough, 2007, Fischer, 2008)*. Hargreaves *(2010)* found conversely in his study that those with high energy awareness and *motivation* wanted to be able to compare consumption with other households as a relative scale of performance, indicating that normative values and motivation affects desired information.

The use of comparative information is contingent, however, on there being a *rise* in consumption, as a lower or steady consumption rate does not provide a change or challenge to investigate *(Fischer, 2008)*. Low energy consumers have been shown to increase energy use if compared to higher energy consumers *(Abrahamse et al., 2005)*, but as Wood and Newborough *(2007)* suggest, this may encourage the low energy users to investigate alternative ways of reducing energy beyond behavioural acts, such as the purchasing of more efficient appliances.

2.5.11 Additional Information, Comparisons and Instruments

The information dispensed through feedback works twofold; firstly as a supplement by which to *frame* consumption, and secondly to enhance the conscious *connection* between action, energy use and its effects. Feedback itself therefore must be considered within this educational system as a means of displaying consumption, and not necessarily a means to provide the motivation level required to do so *(Darby, 2006, Fischer, 2008)*. In order to enhance the potential of feedback to promote motivation and awareness of how to manage energy consumption, additional information and further instruments may be required.

Both Darby *(2006)* and the EDRP trials *(AECOM, 2011)* illustrate that by combining meter or monitor readings with supplementary information on energy use, a greater reduction in consumption can occur compared with feedback alone. Additional information provides the *how to* conserve aspect that feedback lacks *(Fischer, 2008)*. It is furthermore argued that the use of feedback alone may not necessarily activate the motivational concerns that lead to energy conservation *(Darby, 2006, Fischer, 2008)*, and that additional instruments may be required to enhance the *incentive* to do so.

Goal setting as a mechanism can generate *concentration* toward an activity, physically and cognitively *motivate* the individual, *prolong* the effort required to attain the goal and increase *knowledge* retrieval or creation in order to achieve the goal *(McCalley et al., 2011)*. An unrealistic goal may disenfranchise the individual from motivation, with a goal set too low limiting its effectiveness *(Wood and Newborough, 2007)*. The role of feedback in this context is to benchmark progress against goal attainment, with studies showing that by providing a goal along with relevant feedback as a point of reference, more energy can be saved than through the provision of feedback alone *(McCalley, 2006, McCalley et al., 2011)*.

Incentives such as monetary and emotional rewards may also help to stimulate motivation. Feedback may be presented as either a *financial saving* through a reduction in energy, or as a *payment* (e.g. a lump sum payment for reaching a target) *(Wood and Newborough, 2007)*. Wood and Newborough *(2007)* point out that although the use of rewards helps to promote a reduction in energy-using behaviour there is little evidence to suggest that individuals will reduce consumption based on emotional rewards (although this suggests a tailoring issue with regards the individual's intentions).

The following table (Table 2-2) briefly summarises the feedback considerations that could affect the efficacy of the intervention to change behaviour.

Frequency and Duration Quick feedback improves the cognitive link between action and effect, dependent upon when the individual performs the action and chooses to acknowledge the information. Local displays should provide short time base information with central displays providing a longer time base.
Accuracy Accurate information strengthens the cognitive link between action and effect and provides time of use prompts. Inaccurate information disassociates consequences from action.
Metrics Energy consumption can be framed with energy or behavioural units, cost, or environmental impact. The metric should be tailored to the intentions and capabilities of the individual.
Breakdown Disaggregating feedback allows the individual to explorer actions and consequences in isolation, facilitating the benchmarking and framing of actions, consequences and expectations.
Presentation Medium Energy consumption can be framed through flexible electronic media (with/without the need for user interaction) or rigid written materials. The medium selected should be within the intentions and capabilities of the individual.
Presentation Mode Determined by the frequency and location of the information presented, the complexity of the presentation mode should be framed within the intentions and capabilities of the individual. It should be undemanding and not involve any additional tools to aid understanding.
Ambience Ambient features must be distinguishable and easy to map cognitively to action and its effect, thereby allowing for implicit evaluation by the individual with minimal effort or focus.
Location The local or central location of the feedback is dependent upon when the individual performs the action and chooses to acknowledge the information. Location requires aesthetical acceptance.
Technical Expectations A positive installation and performance of a feedback device can stimulate or maintain interest, whereas a negative or below expectations experience can reduce or damage perceptions. Inaccurate or irrelevant information weakens the cognitive link between action and effect.
Historic and Normative Comparisons Comparative information is dependent on there being a negative compared to a positive consequence or state. A converse relationship may prevent challenge or increase actions.
Additional Information, Comparisons and Instruments Feedback as an educational tool frames and improves the cognitive link between action and effect; it does not provide motivation for change. Incentives, goal setting or further information may provide this motivation, dependent on the intentions and capabilities of the individual.

Table 2-2 A Brief Summary of Feedback Considerations

2.5.12 The Rebound Effect and Other Challenges

The provision of feedback and other forms of information does not always lead to a reduction in energy, as both Fischer *(2008)* and Abrahamse et al *(2005)* discuss, as if an individual is made aware of how cheap energy is or that they use a lower amount by comparison to others, they may actually *increase* their energy consumption. Sorrell *(2007)* presents the following classification of energy related *rebound* effects, Table 2-3:

Classification of Rebound	**Summary Description**
Direct Rebound Increase in consumption because of the cost required to provide the efficiency measure.	
Substitution Effect	The level of on-going consumption is maintained despite switching to cheaper products or services.
Income Effect	Increased income through efficiency savings is spent on the same product or service, increasing on-going consumption.
Indirect Rebound Increase in consumption because of implementing an efficiency measure.	
Embodied Energy	The energy required to produce and install the efficiency measure.
Secondary Effects	Savings from the purchase of the efficiency measure may be used to purchase other consuming products and services.

Table 2-3 Classification of Rebound Effects (Sorrell, 2007)

A further challenge explored by Van Dam et al *(2010)* is the concept of *background relations*, and how a feedback device whose objective it is to relate the energy profile of these invisible, background technologies may in effect become one itself. This has been attributed to a *relapse* into previous behaviours, the *increase* in new energy consuming technologies and the *rebound* effect *(Van Dam et al., 2010)*.

Further challenges may include: appliances deemed as *necessities* cannot, therefore, be reduced or removed; energy use may become framed as negative thus increasing *guilt and stress*; domestic temporal *rhythms* and natural consumption *patterns* need to be considered; conflicting domestic relationships and practices may be *gendered* or *generational (Hargreaves, 2010)*; consumption behaviours may become *distorted* (using a gas kettle because only electricity use is measured); and each individuals intentions and habits are *unique (Fitzpatrick and Smith, 2009).* The *context* will also influence the selection of technologies (installing a clip on meter in a flat may be problematic due to the location of the meter) *(Ofgem, 2010)*.

The objective of the following section of this literature review is to understand if products can be *specifically designed to change user behaviour towards more sustainable action, and if so, what design methods and tools exist and are they successful?* (section 2.1.1, Research Questions). As such, this section will discuss DfSB models and strategies present in the literature, going on to explore how they have been implemented within a design process.

2.6 Design for Sustainable Behaviour

Design for Sustainable Behaviour [DfSB] is a branch of sustainable design theory concerned with the application of design strategies that attempt to *influence* consumer behaviour, during the *use phase* of a product, towards more *sustainable action (Lilley, 2009b)*. DfSB strategies when applied to the interface between a user and their goal – the product, can be used by the designer to shape an individual's *perception, learning, and interaction (Tang and Bhamra, 2009b)*. This affords the opportunity to the designer to challenge the individual's intentions, facilitating conditions and affect habit formation, which as discussed previously, could influence the individual's domestic consumption of energy.

2.6.1 Models and Strategies

There is no single design approach or strategy for changing the behaviour of an individual towards more sustainable action *(Lilley et al., 2006, Bhamra et al., 2008)*. The number of DfSB approaches that have recently been advanced, since Lilley et al.'s seminal paper concerning *designing for behavioural change (Lilley et al., 2006)*, is testament to the growing interest and number of researchers active in the field of DfSB, Figure 2-7.

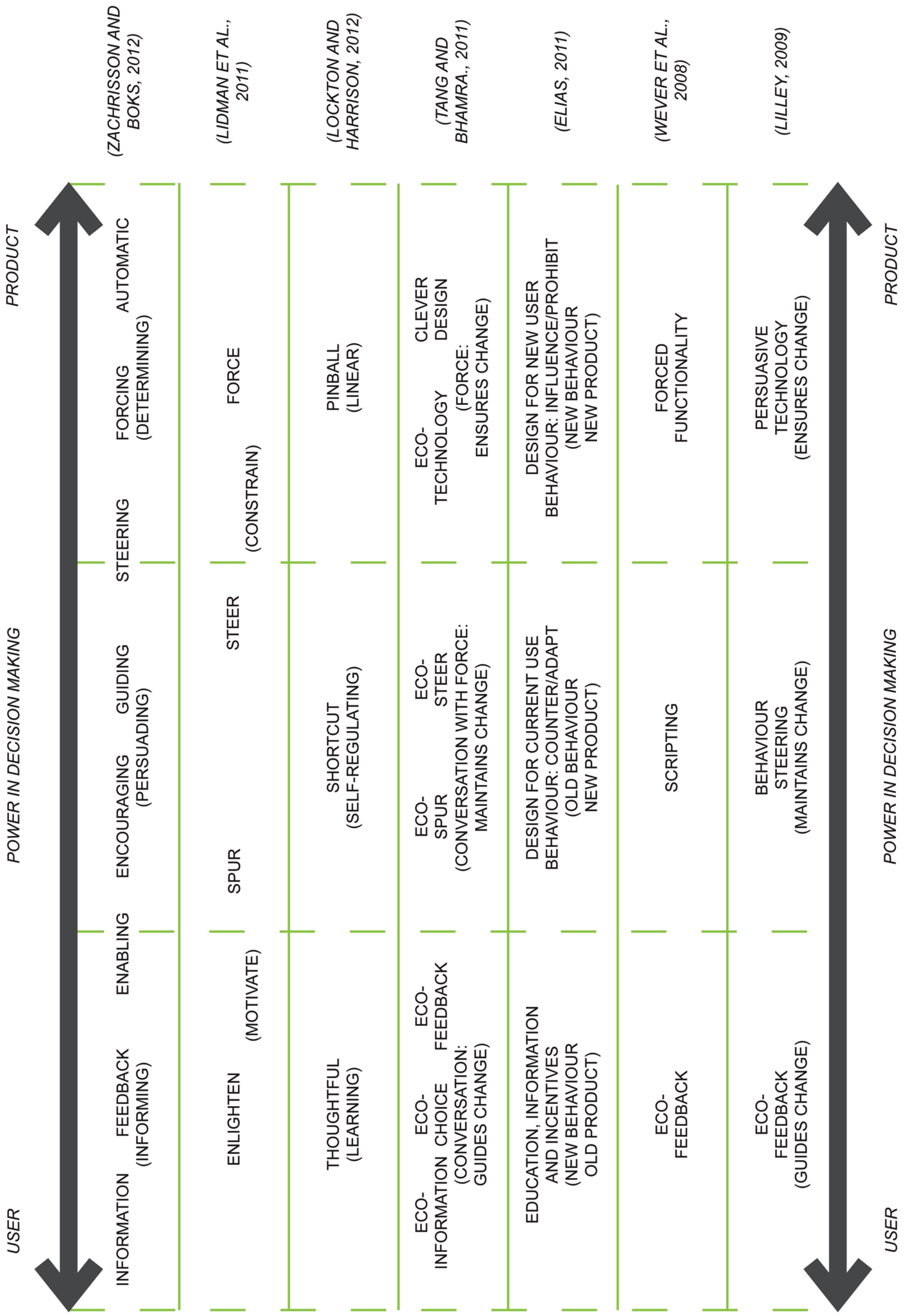


Figure 2-7 DfSB Strategies represented against the Axis of Influence (Lilley et al., 2006)

However, when untangling the theories, it is clear that the majority of these structures revolve around a central concept – a linear spectrum or axis that concerns control or power in decision-making, with the user or individual at one end and the product or designer diametrically positioned at the other. Strategies within these structures are distributed according to their theoretical and relative weighting of control or power.

Lilley *(2006)* was the first to argue that there is an *axis of influence* between a product and a user, that determines where the decision making power lies. Towards the *user agentive* end of this scale, is *eco-feedback*. Feedback, as previously described, is a method by which a product employs an overt visual, tactile, or aural indicator in order to inform the user as to their actions. Eco-feedback would fit within this research context as a means by which to indicate environmental, economic or social resource consumption. Due to its non-coercive approach, eco-feedback is considered to be a *guide* to change, enabling control of decision making to reside with the user and their individual interpretation of the feedback offered *(Lilley, 2009b)*. In the centre of this proposed axis is *behaviour-steering (Lilley, 2009b)*, an approach based on Jelsma and Knot's *(2002)* definition of *scripts* but expanded to include Norman's *(1988)* notion of *affordance*; concerning the way in which a designer uses the physical characteristics of a product to prescribe a desired behaviour. By consciously *scripting* a product through the use of affordances (explicit potential actions), and constraints (explicit potential limitations), a designer can control the users interaction without forcing action *(Jelsma and Knot, 2002)*. At the opposite end of the scale from eco-feedback is *persuasive technology*. Persuasive technology, as defined by Lilley *(2009b)*, includes Fogg's *(2003)* theory of *captology* (a synthesis of computer products and persuasive techniques) however differs by definition through the inclusion of coercive strategies to *ensure* change, such as intelligent *context aware technologies* and *ubiquitous computing* which negate the users decision making processes *(Lilley, 2007, Lilley, 2009b)*.

In a similar vein to Lilley, Wever et al. *(2008)* propose another tripartite taxonomy, *eco-feedback*, *scripting* and *forced functionality.* This axis is augmented with a second branch to the model, *functionality matching*; the *mismatch* between the users' *desired* functionality, and the functionality the product *delivers* – a design strategy recently sub-grouped with *ecodesign* and *enabler* by Lidman et al. *(2011a, 2011b, Lidman and Renström, 2011)* to form a category of product rather than behavioural adaption. Elias *(2011)*, conversely, proposes a matrix with new user behaviour and existing products matched to *user education* and *feedback* and *incentives*, new user behaviour and new products matched to *influencing or prohibiting*, and old behaviours and new products matched to *countering or adapting* strategies. However, if one was to lineate the matrix according to an axis of control, the three categories align with those proposed by Lilley *(2009b)* and Wever et al. *(2008)*.

Despite the lack of common vocabulary, which Boks *(2011)* observes along with a lack of formalised data collection methods as stumbling blocks to cross-case study analysis, Lilley, Wever and Elias all acknowledge an axis related to the control or decision-making power that exists between the individual and a product. However, determining which strategy is most appropriate to implement with a given behaviour to change is not explicit within these models. Suggestions include the use of qualitative data and multidisciplinary teams, a consideration of the designers' intent, an observation of the consequences of product use or misuse, an evaluation of the associated ethical dynamics, as well as contemplating the intrusiveness of the intervention and the context of application *(Lilley et al., 2006, Elias et al., 2008a, Wever et al., 2008)*. Although these suggestions are a starting point, they do not explicitly provide any guidance as to which intervention strategy to select, only how to design the selected strategy more appropriately. Elias et al. *(2008a)* propose a base line for assessment, the *theoretical minimum*, whereby deviation through *bad* or *good* behaviour results in *bad* or *good* energy-efficiency. Products, however, are not always used in the same way by different people, or as the designer may have intended *(Pettersen and Boks, 2008)* - a *bad* behaviour, as Elias et al. would term it, that may in quantitative terms be perceived as user inefficiency, in reality may be an indication of a need for functionality matching rather than behaviour change. As Boks *(2011)* also points out, conducting extensive life cycle impact assessments for all user behaviours and interactions with a product is not a quick process. It may be more logical, therefore, to consider the underlying cognitive and physical structures through which the individual operationalises action in parallel to the consequences of this action.

Tang and Bhamra *(2011, Bhamra et al., 2008)* propose an expanded model, integrating Triandis' TIB *(Jackson, 2005)*, Anderson's framework for the *acquisition of cognitive skill (Anderson, 1982)*, and the axis of influence as presented by Lilley *(2009b)*, Figure 2-8. The intention of this model is to relate the habitual strength of an identified problem to a granulated axis of design strategies or approaches.

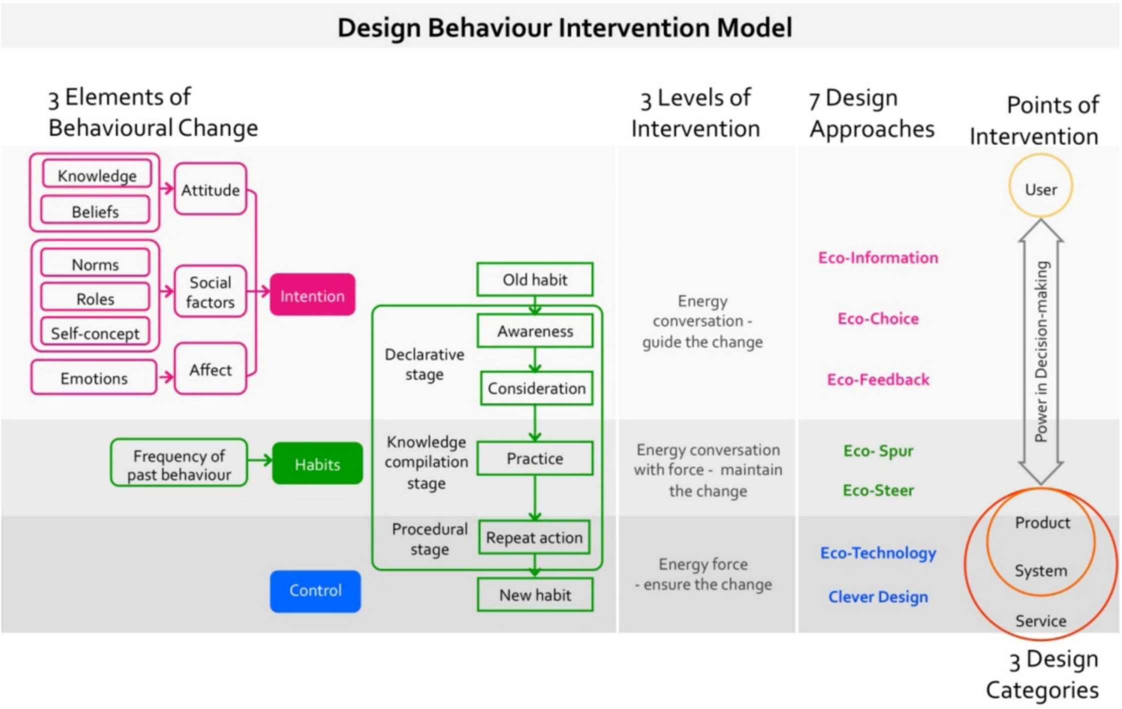


Figure 2-8 Design Behaviour Intervention Model Diagram (Tang and Bhamra, 2011)

The seven design strategies or approaches of Tang and Bhamra *(2011)*, from *eco-information* which educates the user through making consumables visible in order to provoke reflection, through to *clever design*, self-controlling technology which eradicates user engagement, are sub divided into three levels of intervention. Although the exact psychological mapping of how the three theories interact and when to apply each specific strategy is unclear, what is suggested is that *information*, *choice* and *feedback* should be applied to influence the *intention* of behaviour, to *guide the change*. This should be applied when the habitual intention of the user is in the *declarative stage*, the early stage of habit formation when the user still maintains a sense of awareness and consideration of their actions. If the user has emerging *habitual* routines and is in the *knowledge compilation stage*, the stage where repeated practice streamlines cognitive thought and process, strategies that are more coercive should be applied, such as *spur* and *steer,* which *maintain the change*. If the user has ingrained habitual routines and is in the *procedural stage* of habit formation, then strategies that focus on the *control* mechanism or context should be applied that negate the users involvement, such as *technology* or *clever design,* that *ensure the change (Anderson, 1982, Tang and Bhamra, 2011)*.

Although introducing habitual behaviour is a valuable step taken in developing this axis, the alignment of the three theories upon which this model is based is invalid. The sum of the *three elements of behaviour change*, intention, habits and control *is* behaviour, which is a complex *process* present, to a lesser or greater extent, in *all* action. A change in control or facilitating conditions may activate normative goals through the provision or removal of a service, changing ones behaviour. A change in attitude could influence how one perceives technologically agentive products, resulting in a positive or negative behaviour change. The current representation of this model focuses on habitual strength and conflates it with the entire antecedent structure of behaviour, which is not the same thing.

What this model does suggest, however, is that the relative stages of habitual formation dictate the individual's receptiveness to information, with the early stages of habit formation allowing for a greater intake of new information than the later, cognitive streamlined, stages of habitual action. Although not specifically linked to behaviour theory by the authors, Lockton and Harrison *(2012)* explore this issue of cognitive receptiveness, tentatively proposing three models of the *human system*, using the metaphors *pinball*, *shortcut* and *thoughtful* to represent what they term *linear models* (given a specific input or cue, no cognitive decision-making is performed, with the resulting behaviour being routine and automated), *self-regulating models* (semi-rational operative) and *learning models* (fully rational operators aware of their actions through a reasoning process). Whilst this approach presents the resultant behaviour created by an individual's behavioural antecedents and matches it to a corresponding level of intervention, it still fails to address and understand the core of why the user enacts behaviour in a certain way. If users, taking one of

Lockton's examples, *"cannot or do not make decisions for themselves"*, displaying a linear model of human system, it is suggested that the corresponding "*model of artefact system"*, the product, should be learning *(Lockton and Harrison, 2012, P.14)*. By excluding or not pairing this model with a full understanding of the behaviour framework, the decisions made by the product may not be in line with the actual intention of the user, and furthermore the delegation of the learning act to the product, may negate or impinge upon the education or motivation of the individual. In order to align a behavioural intervention with the prerequisite behavioural action, *all* the antecedents of behaviour formation need to be considered rather than a focus on just the resultant action or habitual behaviour.

The approach taken by Zachrisson et al. *(2011)* builds upon the work of Tang and Bhamra *(2011)*, but adds to the value of this model by exploring the psychological antecedents of behaviour in order to generate a set of principles or guidelines for strategy selection.

Figure 2-9 Distribution of Control Spectrum (Zachrisson et al., 2011)

The axis or spectrum presented by Zachrisson et al. *(2011)*, Figure 2-9, is a similar convention to those discussed thus far, although its exact axial designation (for example, *control* or *obtrusiveness*) is determined by how the resulting strategy will impact upon the individuals behaviour *(Zachrisson et al., 2011)*. The top level approaches of *informing*, *persuading* and *determining* are analogous to those proposed by Lilley *(2006)* and Wever *(2008)*, with the granulation of strategies presented within this axis similar to those presented by Tang and Bhamra *(2011)*, and exclude an *eco* prefix. The use of the designation eco suggests that the product only considers the environmental impact, whereas sustainability actually considers the environmental and social impact of the product *(Bhamra and Lofthouse, 2007)*. The division between which strategies fall has been removed to present a fluid spectrum rather than an absolute categorisation. As Tromp et al. *(2011)* point out when discussing their own dimensions of *force* and *salience*, where an influencing product sits within these dimensions is not fixed but is dependent on the user, as different individuals may place the influencing device within different categories differently over time, as their perception of the intervention alters.

Whereas the work of Tang and Bhamra *(2011)* attempts to provide a guide to selecting strategies based on a single antecedent of behaviour, habit, Zachrisson expands this basis to include further antecedents and factors relevant to the Comprehensive Action Determination Model [CADM], Figure 2-10.

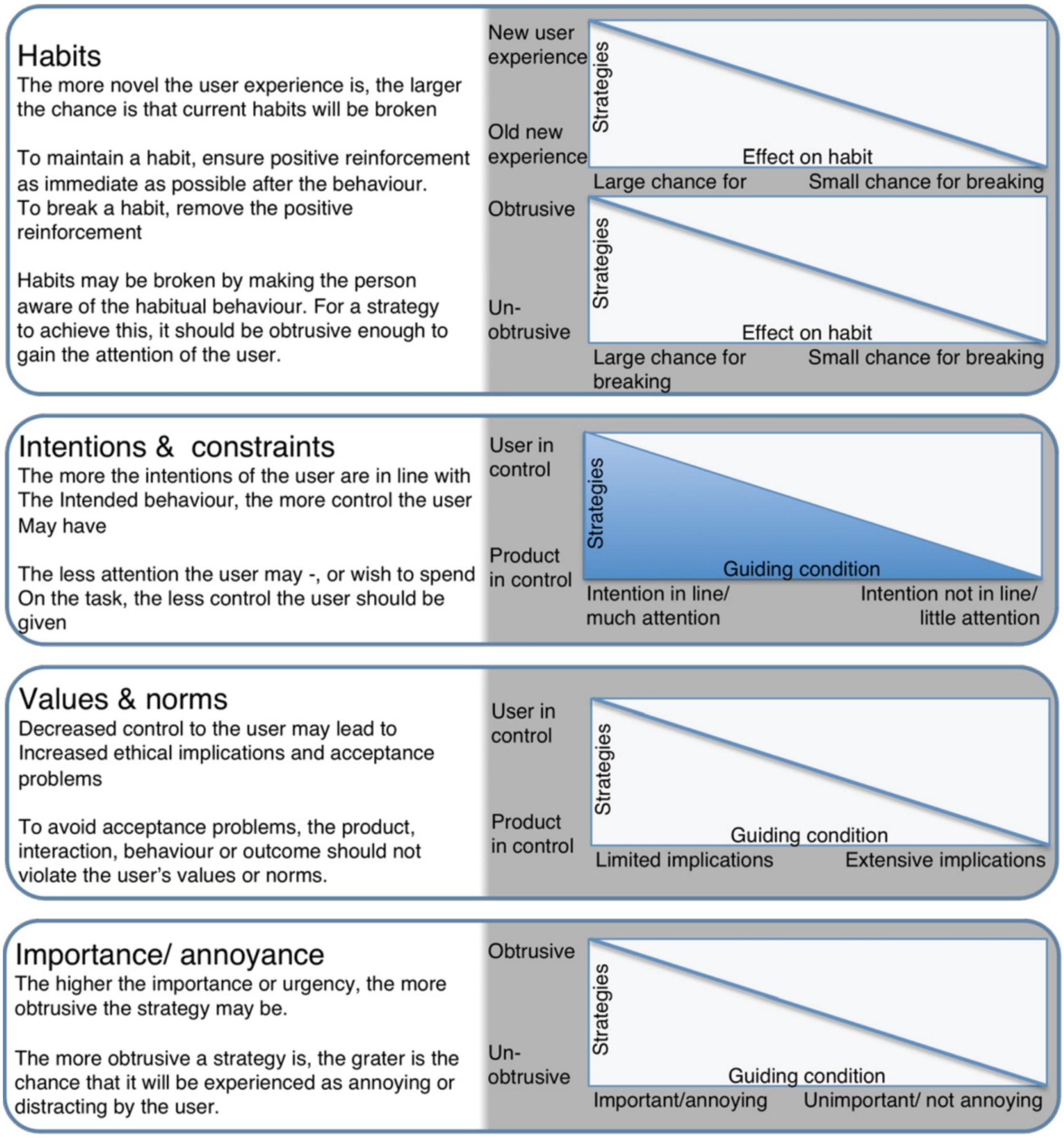


Figure 2-10 Design Guidelines for Selecting Design Strategies (Zachrisson et al., 2011)

Within each of these guideline constructs, labelled as *habits*, *intentions and constraints*, *values and norms*, and *importance/annoyance*, guidance is provided from a psychological perspective on how to achieve the desired change. Each guideline supplements its advice with a graphical depiction of a plane in which the intended strategy and the *guiding condition* for that specific antecedent construct would correlate. Along the Y-axis sits the strategy definition within the familiar user/product control axis (although in terms of habits, this axis has been replaced with *experience* and *obtrusiveness*), and in the X-axis is positioned the relevant condition. For habits, the guiding conditions are *chance for breaking*, for intentions and constraints, the condition is *intention alignment*, for values and norms, the condition is *ethical implications*, and for importance/annoyance, the X-axis is scaled in terms of relative *importance* or *annoyance (Zachrisson et al., 2011)*. Through a disaggregation of the composite parts of behaviour, the designer can begin to understand the relative impact of their decision in terms of relevant behaviour antecedents, which in term may foster a greater understanding and application of the aggregate behavioural impact of the designed product.

As noted in recent literature *(Zachrisson et al., 2011)*, the guidelines provided by Zachrisson et al. are a promising start to tackling the issues of combining the antecedents of behaviour and behaviour change with design strategy; however, there remain a few challenges. Through the models application in an oral health care case study, Zachrisson et al. *(2011)* found that specificity might be an issue as the variation in behaviour and its antecedents may differ between individuals. The designer, when faced with multiple individuals with divergent behavioural antecedent values, it is suggested, will have to determine which is the most important to carry forward to focus the design. The second issue highlighted is that there may be a conflict between what the guide suggests as a behavioural product treatment, and what the individual desires. In the given example, a heuristic error on the part of the user who wants control (the first suggestion) may require a solution that places corrective control with the product (the second suggestion). The two suggestions presented by the guidelines are diametrically opposed *(Zachrisson et al., 2011)*. A solution to this dichotomy may be for the designer to frame the suggestion in terms of its relative impact (a value cost, such as environmental impact, time or money) and to select the most appropriate strategy in conjunction with the relevant stakeholders.

Within the literature reviewed, it is clear that despite the progression of DfSB as a theory and the recognition of a product/user axis, the defining of terminology and classification of strategies around which future academic and/or design work and discussions may revolve is still incomplete, with a lack of common consensus potentially inhibiting fruitful cross-case study development *(Boks, 2011)*. Furthermore, determining which behaviour to target and which strategy to apply is complicated by the complexity of human behaviour and action, which results in the consumption of resources.

2.6.2 DfSB and the Design Process

The initial focus for behaviour change case studies was not on the implementation of a structured design process per se, rather they sought to define the more basic blocks and theory of what was to become DfSB; *how* to assess the behaviour of the user and the relative impact of their actions. Rodriguez and Boks *(2005)*, the Interactive Institute's Static! Project *(Ludvigsson, 2005, Backlund et al., 2006)* and Lilley et al. *(2006, Lilley, 2009a)* explored how design methods and tools could be implemented to gain qualitative insights into user behaviour through techniques such as the use of cameras and user diaries, interviews, video recorded observational data and shadowing, and cultural probes. Despite the lack of commonality on which methods to use for which behaviours studied, an issue still on going *(Boks, 2011)*, the use of qualitative research techniques, particularly those that observed and interacted with the individual in context, was identified within these early case studies as being one of the key mechanisms that designers may employ in understanding user behaviour and action. Elias et al. *(2008a, 2008b)* and Wever *(2010)* offered a different perspective, illustrating the use of quantitative techniques in establishing an understanding and measure of action and behavioural impact; quantifying behaviour, such as the length of time a refrigerator door is open or the number of products correctly disposed of, offers direction for evaluation and redesign. Although the quantitative techniques lack the in-depth understanding of behaviour afforded through qualitative investigation (behaviour is not measured just by number of repetitions of action (section 2.2)), both of these approaches offer different perspectives on how to assess the behaviour of the user and the relative impact of their actions. Only more recently, however, have these methods been considered more fully within structured design process models of application.

The work of Selvefors et al. *(2011)*, Tang and Bhamra *(2009a, 2009b, 2011)* and more recently Zachrisson et al. *(2011)* and Lidman et al. *(Lidman et al., 2011a, Lidman and Renström, 2011)* augment design process models in order to generate products that change the users behaviour toward more sustainable consumption, Figure 2-11, Figure 2-12 and Figure 2-13. These *process models* are representations of design strategy; defining the management of the design and development of a product or system in a standardised manner *(Dubberly, 2004, McClelland and Suri, 2005)*. If the intention is to implement the DfSB framework towards the design of products in a systemic and rigorous manner, then understanding the design process through which it is put into practice is essential.

Tang and Bhamra *(2009a, 2009b, 2011)* explore how DfSB can be used towards reducing the domestic energy impact of refrigerators in a UK case study, using their design process model around which to frame discussion (Figure 2-12). Working with IKEA of Sweden, Selvefors et al. *(2011)* take a case study approach looking at the actions and habits that surround the use and charging of small, mobile electronic devices, identifying and implementing six steps within their design process (Figure 2-11). Although the details of the project are confidential to IKEA, highlighting the paradoxical problem of collaborative research with corporate entities, it is still possible to discern the research and design stages within this study. The guidelines developed by Zachrisson et al. *(2011)*, as previously discussed in section 2.6.1, were tested through a qualitative case study in collaboration with Philips Research, looking at Norwegian and Dutch oral health care behaviours (Figure 2-13). Lidman et al. *(2011a)* consider the overdosing of washing detergent in a domestic context.

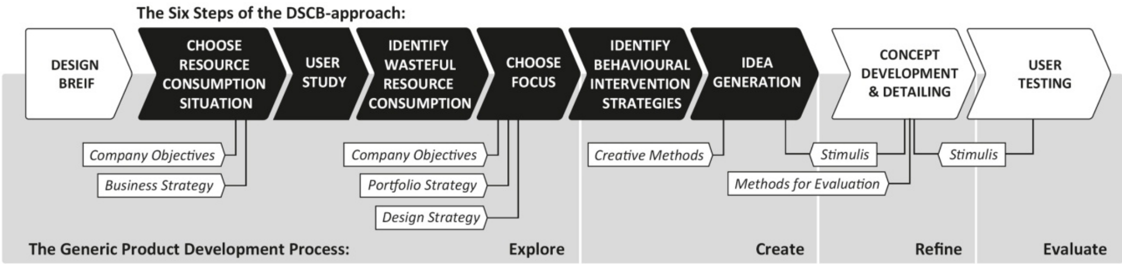


Figure 2-11 DSCB-approach Integrated into a Design Process (Selvefors et al., 2011)

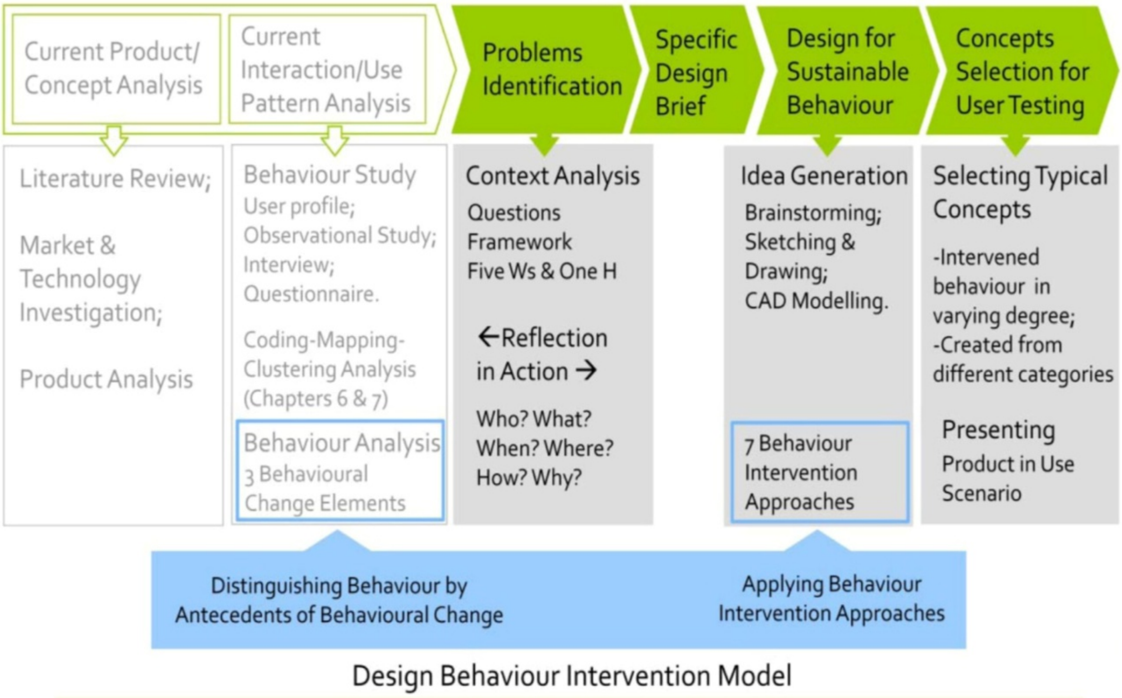


Figure 2-12 Design Behaviour Intervention Model Design Process (Tang and Bhamra, 2011)

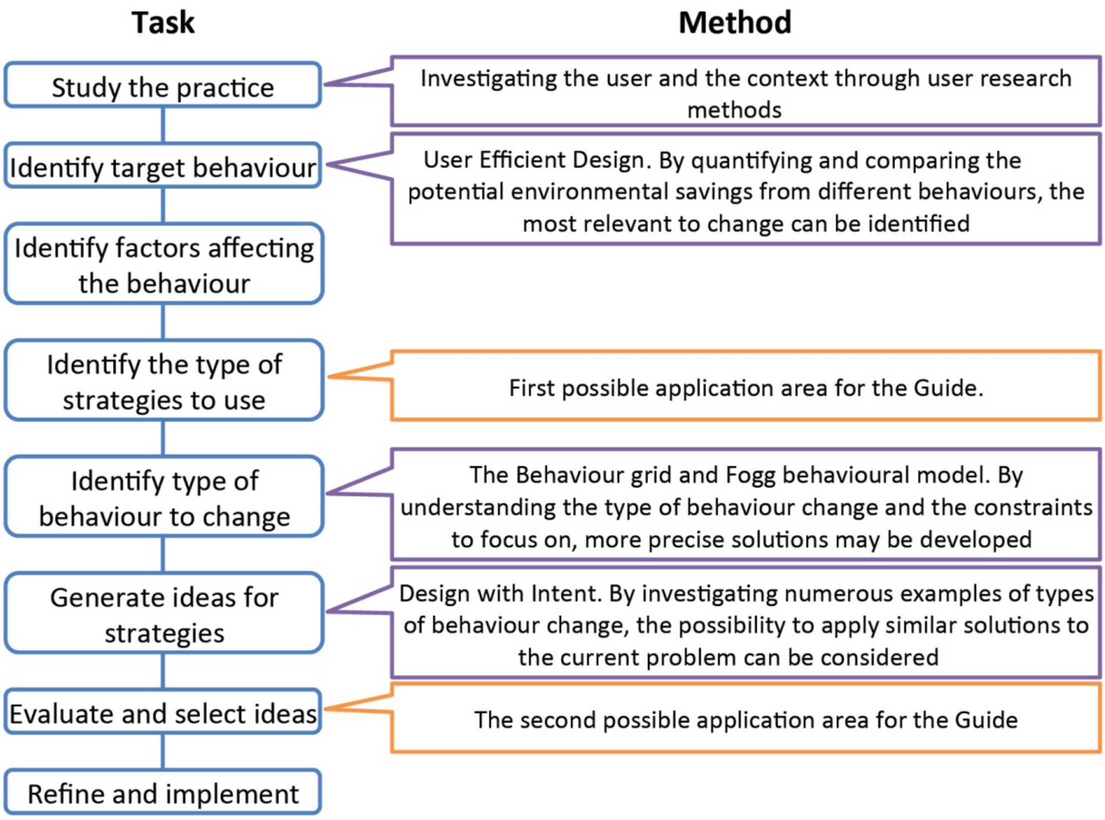


Figure 2-13 Zachrisson et al.'s (2011) Proposed Design Process (edited from original)

Despite the small number of DfSB case studies available, the areas in which this knowledge is applied, although all domestic, represent a breadth of socially ingrained, consumptive activities.

The initial steps of all the afore mentioned design processes begin with defining the intervention context; identifying the behaviours relevant to target and the physical and cognitive factors that affect and perpetrate that activity. In defining this context, the cornerstone against which to design behavioural interventions is established. The process employed by Selvefors et al. *(2011)* suggests that the initial focus of the project is determined by product analysis, a comparison of the product against a theoretical behaviour model to determine how the designer *expects* the user to act and the energy consuming consequences. Only in the second step, *analysing user habits*, are qualitative interviews and observational techniques applied. One would expect, however, that an issue with narrowing the focus prior to interviewing and observing the user may be that certain energy consuming actions and habits are effectively ruled out before they may have even been analysed, although this questions the feasibility and the level of depth that may be possible through a more open investigation. In the third step of Selvefors et al.'s *(2011)* model the energy consuming aspects of the identified behaviours were considered, leading to step four, the selection of the behavioural action to target based on its resource impact and the greatest *potential* for change, echoing elements of Elias et al.'s *(2008a, 2008b)* quantitative priority method. Tang and Bhamra *(2009a, 2009b, 2011)* in defining the context of use, also use several user-centred research techniques, namely questionnaires, and in a similar vein to Selvefors et al., semi-structured interviews and observational studies. Again, a specific product or interaction is selected prior to behavioural analysis. Zachrisson et al. *(2011)* explore a myriad of UCD research techniques within their collaborative project, such as interviews, overt and covert (hidden camera) observational studies, the use of cultural probes and the analysis of blogs *(Boks, 2011, Zachrisson et al., 2011)* within their initial phases; *study the practice*, *identify target behaviours*, and *identify factors affecting the behaviour*. The use of UCD techniques within these research projects has been fundamental to forming an understanding of the user's action and cognitive activities and associated impact, therefore illustrating the necessity of such UCD techniques at the front end of the design process.

With the scope of research reduced and target behaviour defined, and more critically, understood, the next phase is to determine the intervention strategy to apply and to design product interventions accordingly. Selvefors et al.'s *(2011)* fifth and sixth steps, *identifying suitable intervention approaches* and *developing product concepts*, involve the use of UCD creative development techniques anchored around the designers understanding of behavioural strategies and their creative problem solving abilities, shunning the use of guides that relate a specified intervention to a specified behaviour. With the needs, context, actions and *hidden factors* identified, Tang and Bhamra *(2009a, 2009b, 2011)* generated insights which were framed as briefs and several paper-based design solutions were produced using their Design Behaviour Intervention Mode for guidance. Zachrisson et al. *(2011)* use their guidelines in order to select the design strategy appropriate for changing the target behaviour, bookending the design process to provide guidance and focus before commencing design, and in addition, focussing the evaluation in order to identify the designs appropriateness and potential in relation to identified behavioural antecedents.

Zachrisson et al. *(2011)* also propose the use of external models and methods, namely Fogg's Behaviour Grid and Fogg Behavioural Model *(Fogg, 2009, Fogg and Hreha, 2010)*,as well as Lockton's Design with Intent cards and method *(Lockton et al., 2010a)* to aide in the defining or constraining of behaviours to target and the selection of strategies. However the use of external models and methods cannot be used without an in-depth knowledge and understanding of the behaviour that the designer intends to change, as the models and methods themselves do not provide any support to understanding the antecedent, cognitive structure to the behaviour *(Wilson et al., 2010)*. Designer awareness and knowledge of the 'problem' throughout the design process is critical to the successful execution of the design process (and resulting intervention).

Although the evaluation phase proposed by Zachrisson et al. *(2011)* does not discuss input from stakeholders, the use of a guide may offer direction towards the areas of antecedent or habitual change that the designer may use to focus such investigation with relevant individuals, missing in other process models. Interestingly, the evaluation of the concepts produced by Selvefors et al. *(2011)* is considered to be outside of the remit of their Design for Sustainable Consumption Behaviour-approach, noting only that the most relevant concepts were evaluated *"in relation to the company's product portfolio, the company objectives, and to the competition on the market" (Selvefors et al., 2011, P.6)*. No indication of how the concepts would influence the behaviour of identified users or the behavioural acts that they perform is given or methods suggested. Tang and Bhamra *(2009a, 2009b, 2011)* used focus groups in order to validate their concepts, which although produced useful insights cannot be shown as categorical evidence that the concepts are effective; in other words, that the designed interventions changed behaviour over time in context. Lidman et al. *(2011a)* turn towards a longer period of contextual study and evaluation, a key advantage of which is that the behavioural change itself becomes more apparent, is rigorously documented, with a longitudinal baseline recorded prior and post intervention for quantitative and qualitative comparison. An interesting finding of this study and that of Wever *(2010)* was that after the interventions were removed, several individuals returned to prior, problematic techniques of dosage or waste disposal, indicating that the change in behaviour was contingent on the continuing presence of the intervention itself. This suggests that the length of installation may affect habit formation, and furthermore, the evaluation should extend to include post intervention residual effects. Consideration of the evaluation phase of the design process, the assessment criteria and how the information can be iteratively fed back into the design process in most of these design process models and case studies is, for the most part, absent.

In summary, it is clear that there is a consensus model of DfSB design process forming that follows a structure of:

- forming an understanding of behaviour in context;
- the informed selection of a behavioural target;
- the selection of a corresponding behavioural intervention strategy;
- the designing of appropriate behavioural interventions;
- finally, the evaluating of the behavioural intervention against the initial understanding of behaviour in context.

This tentative model, however, is yet to be standardised across DfSB research and is critically lacking in several areas, such as the defining of a suitable evaluation strategy for behaviour changing interventions. Although ever increasing, the lack of case studies, especially those that implement the entire design process from initial investigation through to evaluation or cyclical iteration, constrains the evaluation of these design processes to predominantly theoretical discussion with few results to debate.

2.7 Ethical Design Considerations

The question of ethics in design, as Albrechtslund *(2007, p.66)* states, *“is not optional”*, as technology has ethical connotations whether prescribed towards sustainable ends or not by the designer. Both Vries *(2006)* and Dorst *(2006)* explore the parallels between the design process and moral problem solving, concluding that by considering design problems and ethical problems as *ill-*

structured (no clear goals or defined or comparable alternatives, with solutions developed during the solving of the problem), the abilities, techniques and processes inherent to the designer and design process, are generally applicable to the creative solving of ethical problems. Designers do not pick a single solution, but develop new solutions that attempt to reconcile abstract conflicts. Designers are therefore ideally positioned to deal with the dual development of technological interventions and the solving of ethical issues.

This line of ethical questioning is further intensified when we consider the goal of sustainability. If we are to reach the target of reducing UK greenhouse gases by 2050 to at least 80% of those recorded in 1990 *(Parliament of the United Kingdom, 2008)*, does this provide the designers of behaviour changing technology with energy reducing motivations ethical justification? What if the readiness of the stakeholders to surrender their values differs from that expected by the designer *(Pettersen and Boks, 2008)*?

2.7.1 Designers Motivations, Intent and Methods

Fogg *(2003)* proposes that one criterion by which to assess the ethics of a persuasive product is to understand what the designers original *intent* was, as an unethical intent may translate to an unethical technology. Intentions may be highly ethical such as the promotion of health and safety, or unethical such as the promotion of violence. It is also important to consider that the *motivation*, the prompt for action, and *intent,* the aim of action, are not the same *(Berdichevsky and Neuenschwander, 1999)*.

The method of persuasion employed by the designer, the technological intervention, can also have ethical consequences. Fogg *(2003)* states that certain *methods* are *clearly unethical*, such as the use of *deception* (false promises that never get delivered) and *coercion* (enforced change to the benefit of the product and not the user). Methods such as *operant conditioning* (promotion of behaviour through reinforcement or punishment) and *surveillance* (monitoring system with weighted repercussions) are ethically subject to the method by which they are implemented, such as whether they are overt and harmless or covert and harmful. Strategies that promote the understanding of cause-and-effect relationships are generally considered ethical if they empower and benefit an individual. The use of *emotion* to persuade an individual may be deemed ethically questionable if it exploits an individual's emotive reaction or if it is aimed at vulnerable groups *(Fogg, 2003)*.

Ethical issues related to *trust*, *privacy* and *security* are also paramount. Certain persuasive technologies are only effective whilst the user is unaware that they are being persuaded, and users tend to trust technological products, and do not expect to be lied to, have information purposefully falsified or to be misinformed by them. The users detection of false information may weaken trust and foster mistrust with further devices *(Berdichevsky and Neuenschwander, 1999, Fogg, 2003)*. Behaviour changing technologies, furthermore, often require contextual inputs concerning the user's behaviour and personal information. This information needs to be handled in line with the user's expectations *(Lilley and Lofthouse, 2010)*.

The majority of methods used by technology, however, do share common ground with those used by human agents *(Berdichevsky and Neuenschwander, 1999)*. Fogg questions, *"If a human were using this strategy to persuade me, would it be ethical?" (2003, p.221).* By considering a technological device as a hypothetical *human mediator*, ethical parallels can be drawn as to the acceptability of the technology's methods *(Gowri, 2004)*. Berdichevsky et al *(1999)* propose a set of principles against which it may be possible to ethically evaluate the motivations, intent and method of a persuasive intervention, Table 2-4.

Ethical Principles Of Persuasive Technology
I. The intended outcome of any persuasive technology should never be one that would be deemed unethical if the persuasion were undertaken without the technology or if the outcome occurred independently of persuasion.
II. The motivations behind the creation of a persuasive technology should never be such that they would be deemed unethical if they led to a more traditional persuasion.
III. The creators of a persuasive technology must consider, contend with, and assume responsibility for all reasonably predicted outcomes of its use.
IV. The creators of a persuasive technology must ensure that it regards the privacy of users with at least as much respect as they regard their own privacy.
V. Persuasive technologies relaying personal information about a user to a third party must be closely scrutinized for privacy concerns.
VI. The creators of a persuasive technology should disclose their motivations, methods, and intended outcomes, except when such disclosure would significantly undermine an otherwise ethical goal.
VII. Persuasive technologies must not misinform in order to achieve their persuasive end.
VIII. The Golden Rule of Persuasion. The creators of a persuasive technology should never seek to persuade a person or persons of something they themselves would not consent to be persuaded to do.

Table 2-4 Berdichevsky et al (1999, p.52) Ethics of Persuasive Technology

Implementing the principles, however, is not anchored to any universal moral framework, and in addition, is not all encapsulating as it negates issues concerning the unintended outcomes from a persuasive technology *(Pettersen and Boks, 2008).* Such principles, however, do serve to highlight the complexity of the moral subjectivity associated with behaviour changing technologies.

2.7.2 Distribution of Moral Responsibility and Democracy

Technological devices can be used to shape action and perception as a context dependant negotiator between a user and their goal; perception and interpretation of reality can be manipulated for emphasis, actions can be suggested *(Verbeek, 2006)*. Whilst devices are not neutral in terms of transforming action and perception, the technologies themselves cannot be considered moral agents as the technology embodies the motivation and intent of the designer, and as such is the responsibility of the designer. A technological device has no perception of decision-making or morality *(Berdichevsky and Neuenschwander, 1999, Fogg, 2003, Pettersen and Boks,* *2008)*. *Moral responsibility* resides with the designer and the user (or purchaser) of the technological device who has freedom of choice and action.

Such devices may also be considered to be *antidemocratic*, with human decision making replaced by technological problem solving; with users losing control and freedom to technology *(Verbeek, 2006, Pettersen and Boks, 2008)*. Determining the extent to which the designer can restrict choice or use coercion before human rights are irrevocably violated by *technocracy* is complicated further by the argument that such interventions may be more effective in generating sustainable action than user agentive technologies; creating a balance (or conflict) between effectiveness and acceptability *(Lilley and Lofthouse, 2010)*. The societal concept of a greater or common good suggests that it may be possible to balance short-term restrictions at the technological agentive end of this axis against the moral wealth of society. If *DfSB* seeks to achieve the long term aim of sustainable action by persuading the actions of an individual towards a prescribed set of goals and values not necessarily in line with their own, individual freedoms may potentially over the short term *need* to be restricted through technological interference or automation *(Pettersen and Boks, 2008)*. However, if the user's cognitive process is negated, cause is further separated from effect, which is fundamental to the user's learning and understanding of the consequences of their behaviour and actions, therefore reducing the potential for spill-over sustainable behaviour *(Pettersen and Boks, 2008)*. Restricting freedom short term may therefore run counter to longer term sustainable intentions.

2.7.3 Intended and Unintended Outcomes

The ethical responsibility of a designer does not end with the purchase of the designed technological device but continues into the products use phase. It is vital, therefore to consider the user's interactions when presented with such technology.

The belief that a designed technology will be used as the designer intends is considered a problem as it does not account for the unpredictable nature of the user and the operational context *(Albrechtslund, 2007)*. Technologies can be considered to be *multistable*, with no fixed meaning other than that which is interpreted by the user and the cultural, historical and social context in which it finds use *(Verbeek, 2006, Albrechtslund, 2007)*. The multistability of technology presents a problem to the designer of technological interventions as the ethical uncertainties of *intended* use are compounded with the ethical uncertainties of *unintended* use, Figure 2-14.

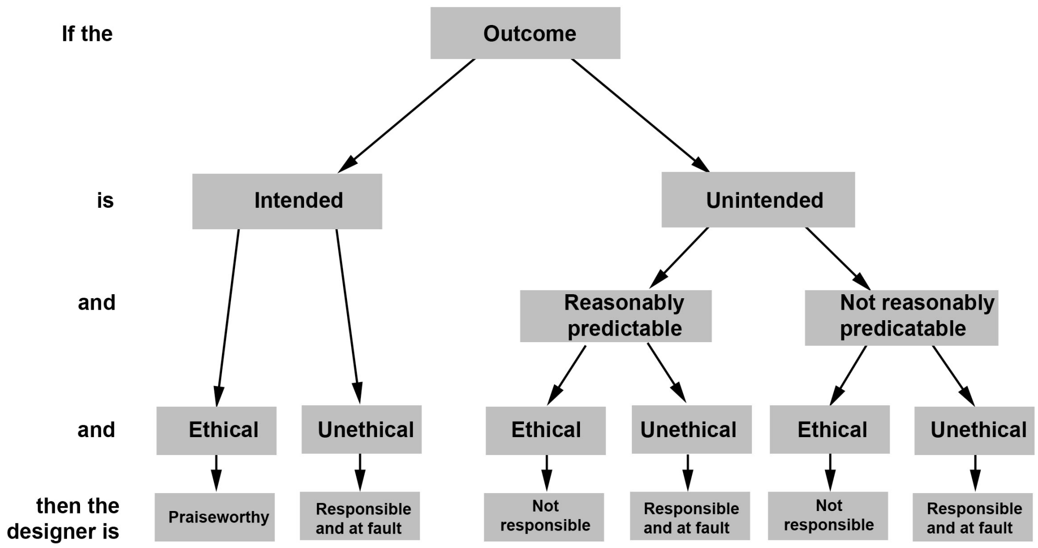


Figure 2-14 Responsibility for Intended and Unintended Outcomes (Berdichevsky and Neuenschwander, 1999)

Unintended use behaviour could manifest itself as rebound effects or the intentional disabling or circumventing of technology functions *(Lilley and Lofthouse, 2010)*; both of which may be hard to predict and have negative ethical repercussions. In order to design a behaviour changing intervention based on DfSB theory ethically, it becomes clear that it is the responsibility of the designer to anticipate and account for the multistable nature of technology concerning the technology's use.

2.7.4 Ethics and the Design Process

In response to the lack of specific tools available to the designer, Lilley and Lofthouse *(2010)* propose the use of a weighted ethical matrix and checklist, Figure 2-15, by which the designer can evaluate the designers intent and methods in relation to the targeted behaviour for change, with consideration of the intended and unintended impact upon all relevant stakeholders.

Part A : Evaluation of Behavioural Issues Identified

	IMPACT			EFFECT		PERMANENCY	
Behaviour identified through user observation studies	*L*	*M*	*H*	*Short Term*	*Long Term*	*Reversible*	*Irreversible*

Part B: Ethical Evaluation of Re-designed Product /System

		IMPACT			EFFECT		PERMANENCY		OCCURANCE		
How could the product/system be used?	*What would be the impact/consequences of this behaviour on stakeholders?*	*L*	*M*	*H*	*Short*	*Long*	*Reversible*	*Irreversible*	L	M	*H*

Figure 2-15 The Ethical Evaluation Matrix (Lilley and Lofthouse, 2010, p.62)

Part A of the ethical matrix concerns the designer evaluating the *existing* behaviours of the user, uncovering and identifying interactions through user centred techniques. Such behaviours are then recorded and rated against societal and environmental impact, the duration of the behavioural effects produced, as well as the permanency of such effects. Part B of this matrix is concerned with assessing the ethical impact of the *redesigned* product. Again, the impact, effect and permanency of the behaviour is recorded, along with the probability of said behaviour occurring *(Lilley and Lofthouse, 2010)*.

An issue of concern is if the scales were to be used to provide relative weighting between ethical issues as this does not relate to how ethics are accounted for. Human agents are not rated by aggregate scales but each positive and negative act independently *(Gowri, 2004)*. Scaling moral impacts with a strength rating may lead one to believe there to be an attainable net positive impact of a design, with the strength of a single positive outcome outweighing several negative outcomes of a lower moral *value*. Furthermore, this may imply that all values and issues are on the same linear scale; what may be morally negative for one individual, may be positive for a different individual. Analysis of impacts and consequences should be qualitatively assessed with all moral issues discussed with all stakeholders, with rank and prioritising avoided *(Gowri, 2004)*.

Part B of Lilley and Lofthouse's *(2010)* matrix explicitly demands the designer to consider the ways by which their product *may* be used, down to prediction on the part of the designer as to how the technology will be adapted within its use context; its *multistability*. The prediction process can be constructed in one of two ways; either by the designers own imagination, or by a systemic involvement of stakeholders *(Verbeek, 2006, Pettersen and Boks, 2008)*. The designer can use their imagination and inherent skills to predict and design for the user and use contexts associated with a technological device. By envisaging the roles and demands that the device will play, future scenarios can be iteratively designed for. The limitation with such a technique is that it relies on the designer's innate imagination and empathic ability, as well as their interpretation of what they perceive to be the user and use context.

To fill this gap in knowledge and to supplement and inform this forward-facing technique, designers need to actively engage with all potential stakeholders. By empowering stakeholders and directly feeding their experiences and expectations into the design process, decision making moral responsibility can be shared to provide a democracy of power and a discursive platform to examine opposing values to ensure that the diverse requirements and interests of all are accounted for and a consensus is reached *(Verbeek, 2006, Pettersen and Boks, 2008)*. Potential users can get involved in the early investigatory stages of a design process to help uncover tacit knowledge and provide insights into how and in what contexts future technology may be used *(McClelland and Suri, 2005)*. The selection of design options, refining of solutions and evaluation processes can all involve the users input to some degree, to help the designer to shape the potential ethical future of the technological device as well as broaden the potential of uncovering undesirable multistable outcomes. A device designed through user centred design methods may still lead to a device that negates the end users decision making ability, however, the device may still be considered to be democratically sound (and not technocratic), as the democratic user input and decision making is still present, but its point in the product cycle has shifted. By improving this understanding, better predictions can be made by the designer or the stakeholder as to how the technology will be interpreted and appropriated into society, although it should be acknowledged that this prediction could never be guaranteed or in consideration of every eventuality.

2.8 Conclusions

Having drawn together and reviewed a large body of work from the fields of interest relevant to completing the aim and objectives of this research project, the conclusions formed are framed by the research questions that guided this investigation. Despite the ever growing wealth of knowledge assembled and critiqued here, several key issues or gaps in knowledge have been found and presented within this following section, indicating areas of research that require further investigation.

2.8.1 Factors Influencing Household Energy Use

> *How is energy consuming behaviour influenced and perpetuated by internal and external factors?*

The factors that influence the individual's attitude and behaviour towards interaction with energy consuming domestic products are complicated. Although, as Darby emphasises, energy is a *"basic human need" (2000, P.2)*, studies have shown its consideration by the individual to be very low with minimal interest *(Burgess and Nye, 2008, Fischer, 2008)*. In addition, it has been recognised that the mental frameworks of energy that the individual develops are formed through levels of *indirect* consumption, dependant on interaction with products and an interpretation of the associated benefits *(Fischer, 2008, Steg, 2008)*, emphasising that that study of energy use is intrinsically linked to the use of products. In order to understand energy consumption, it is therefore important to understand the complex behavioural processes that underpin and drive the cognitive structures that form these interactions with energy consuming products.

As has been illustrated, multiple models are available to provide disparate psychological or sociological perspectives into the underlying facets and structures that form behaviour and action or practice. However, the position that has been determined of consequence within this body of work is that postulated by the Theory of Interpersonal Behaviour *(Jackson, 2005)*, augmented with Verplanken's definition of habits *(Verplanken, 2006)*. Within this approach, the individual is central to a rational decision-making process, with behavioural action influenced by internal and external prompts that interact with the intentions (attitudes, social factors and emotions), habits and facilitating conditions unique to the individual and their context *(Jackson, 2005, Chatterton, 2011)*. With a model identified, the energy consuming actions of the individual and their behavioural processes studied can be put into relative context with the strategies available that seek to change or influence this behaviour.

2.8.2 Behaviour Change Interventions and Strategies

> *What theories and strategies exist that explain and promote changes in behaviour?*

Despite the development and implementation of feedback interventions having been inherently linked to this research study by the project context (section 1.2), it was important to identify other theories, strategies and interventions that exist. By understanding and defining the relative position of feedback as a strategy within the context of other intervention and strategy types, the expectations and limitations of the implemented feedback mechanism may be understood.

Broadly speaking, intervention types are split into two categories, antecedent interventions and consequence interventions, of which feedback strategies fit into this latter category. Antecedent interventions, such as commitment, goal setting, informational and structural strategies, aim to influence or change the antecedents of behaviour, namely intentions, habits and facilitating conditions, prior to the enactment of the behavioural action *(Abrahamse et al., 2005)*. Antecedent interventions thus attempt to focus, motivate, educate, facilitate or constrain the individual towards making a desired behavioural action. Consequence interventions, including the use of reward and feedback strategies, take an alternative approach, shifting focus towards the consequences of behaviour, framing the positive or negative resulting impact that behaviour has in relation to the antecedents that motivated that action *(Abrahamse et al., 2005)*.

Through an understanding of feedback strategies within these terms and boundaries, feedback strategies can be defined as an educational tool used to frame energy-consuming issues and problems caused through behavioural action in order to generate cognitive reflection upon and within the intentional, habitual and conditional antecedent structure of the individual.

2.8.3 Categories of Feedback and Feedback Considerations

How can feedback be used as a behaviour change mechanism?

Whichever categorisation one takes of feedback strategies, the key behaviour change mechanism of importance is that of information provision, as information is central to the concept of feedback as an educational tool. Without information, the bridging cognitive connections between action and effect are weakened, as the impact of the action is not linked by the individual to the behavioural antecedents that precipitated that action, negating any form of reflection or increase in awareness *(Darby, 2008, Fischer, 2008, Darby, 2010)*.

What has been shown by the research studies discussed, is that the ability of information to motivate the individual is not only dependant on its content, but also its delivery method, as this helps to frame the information presented to the individual. Several key design considerations have been discussed within this chapter, including the frequency and duration, the accuracy, the selection of metrics and the granularity of the information presented to the individual by the product. Further considerations looked at the presentation medium and mode and the use of ambience depending upon the location of the feedback device.

Consideration was also given to the technical expectations of the individual, the desirements of the user concerning comparisons of data and the potential rebound effects that may be incurred. Although each section analysed these feedback considerations in detail, broad conclusions can be drawn. The key points to conclude are that the information provided by the feedback device needs to be accurate and frequent enough, depending on the context of use, in order to strengthen this cognitive bridge between action and effect. Furthermore, the information presented needs to be comprehensible, undemanding, and easy to cognitively process, with ambience features easy to map cognitively for implicit evaluation. In addition, the use of historic or normative comparisons depends on the motivations and intentions of the individual. Given this myriad of requirements, it is imperative that the feedback device is tailored to the intentions, capabilities and expectations of the individual, failure to do so may lead to potentially damaging rebound effects. Clearly, the process by which these mechanisms are designed needs to consider these requirements and the methods by which this detail may be elicited from the individual.

2.8.4 Design for Sustainable Behaviour

> *Can products be specifically designed to change user behaviour towards more sustainable action, and if so, what design methods and tools exist and are they successful?*

Design for Sustainable Behaviour theory presents a catalogue of design-led strategies concerned with influencing user behaviour, during the use phase of a product, towards more sustainable action *(Lilley, 2009b).* It has been recognised by the majority of researchers working in this field that there exists an axis along which these strategies are positioned, determined by the control or power in decision-making. At one end of this axis are technologically agentive solutions such as intelligent, automatic technologies, whilst the other end of the axis represents user agentive technologies, such as feedback *(Wever et al., 2008, Lilley, 2009b, Elias, 2011, Lidman et al., 2011a, Tang and*

Bhamra, 2011, Lockton and Harrison, 2012, Zachrisson and Boks, 2012). However, as one would expect from a field that is growing rapidly with researchers investigating various facets and definitions of this axis concurrently, there are disagreements on the terminology and classification of these strategies, making future research attempts and cross-research discussions difficult without clear and common agreement. Furthermore, whilst it has been recognised that the antecedent structure of behavioural action is an important consideration in the selection of a specific behaviour changing strategy *(Tang and Bhamra, 2011, Zachrisson and Boks, 2012)*, the representation, complexity and fluidity of these underlying cognitive structures makes informed and targeted selection difficult.

The role of DfSB within the design process is also at present open to academic debate. Whilst a design process model is emerging through consensus *(Selvefors et al., 2011, Tang and Bhamra, 2011, Zachrisson et al., 2011)*, the exact relationship between the phases is yet to become standardised. It is clear, however, that across all the design processes examined that user-centred design research techniques are required prior to the selection of an intervention strategy in order to understand the intervention context, the behavioural antecedents and the corresponding action and effect. This information is then used to select, frame and bound the behaviour in order to focus the selection of the behaviour changing strategy. Concepts are generated within the defined remit of the strategy or strategies selected, evaluated against the behavioural antecedents through longitudinal study. The lack of case studies at present makes it difficult to judge the effectiveness of the design processes suggested as well as the appropriateness of both the targeted behaviour and the selected DfSB strategy. Because of the lack of case studies coupled with the short duration of many of the implemented design processes identified, which tend to focus on the early stages of the design process model and the selection or defining or DfSB strategies, how a DfSB device should be evaluated is also relatively indeterminate.

2.8.5 Ethical Design Considerations

What are the ethical implications of changing behaviour through design and can this ethical dimension form part of a controlled design process?

As has been discussed, the issue of ethics is implicit in design whether intended or not *(Albrechtslund, 2007)*, and the designer is ideally positioned within a design process as a solver of ill-structured problems, a definition within which ethical design clearly resides *(Dorst and Royakkers, 2006, Vries, 2006)*. Considering DfSB specifically, the issue of ethics is intensified, as the expected behavioural change prescribed through the design intervention by the designer in order to reduce energy consumption, may not be in line with the expectations and values of the user *(Pettersen and Boks, 2008)*. Faced with this dilemma, it is suggested that the designers motivations and original intent are investigated *(Berdichevsky and Neuenschwander, 1999, Fogg, 2003)*, and that the methods and strategies employed by the designer are ethically evaluated, considering the intervention device as a hypothetical human mediator to aide in this complex and morally subjective assessment *(Fogg, 2003, Gowri, 2004)*. Furthermore, the body of literature reviewed emphatically states that moral responsibility resides with both the designer and the user *(Berdichevsky and Neuenschwander, 1999, Fogg, 2003, Pettersen and Boks, 2008)*. In order for the designer to ensure human democratic rights are not violated and that the outcomes of interaction by the user with the product are ethically accounted for, users and other stakeholders should be involved within the design process *(Verbeek, 2006, Pettersen and Boks, 2008, Lilley and Lofthouse, 2010)*. Input from relevant stakeholders can lead to democracy of the design process, preventing technocratic infringement, and in addition, such input can be used to envisage the future roles and demands that are placed upon or by the product and its operating context, supplementing the designer’s imagination and empathic skills. Although limited attempts have been made to formalise the ethical evaluation of behaviour changing interventions, what are suggested tend to be along the lines of subjective guidelines with more formalised design tools lacking rigorous evaluation.

2.8.6 Gaps in Knowledge

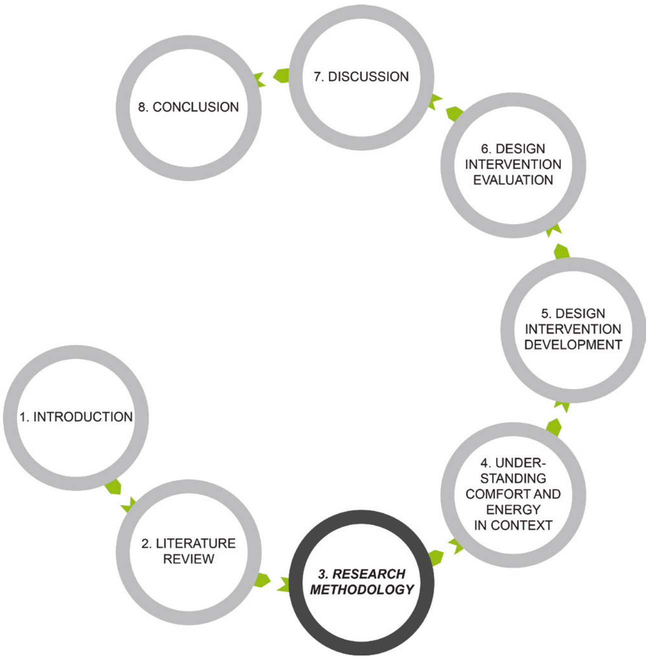
As stated, despite the growing maturation of this field of research, several key issues have not been comprehensively covered or questions that remain largely unanswered by the represented literature, presenting areas or gaps in knowledge requiring further research and investigation. It would be, therefore, useful at this point to succinctly summarise the gaps in literature that this research has identified within these preceding conclusions.

- Whilst it is clear that the energy consuming behaviour of an individual is a complex synthesis of user intentions, habits and facilitating conditions shaped by internal and external factors and influences, it is not clear which research methods within the design process would be the most appropriate for collecting and analysing this data.
- As an extension to the first point, the user's unique definition of comfort due to this complex assemblage of behavioural antecedents is also undetermined within this research context (i.e. social housing in Merthyr Tydfil), therefore requiring investigation.
- Although the categorisation of feedback and the key feedback considerations are relatively well defined within the literature, they have not been applied specifically within this research context or specifically considered within an applied DfSB design process.
- A large gap in the literature concerns the lack of a cohesive user-centred DfSB design process, with those suggested within the literature remaining linear and only partially formed. This is most evident in the lack of any discussion with regards evaluation methods for, or prototyping of, DfSB intervention mechanisms. As a result, there is also a clear deficiency in the number of DfSB practical application case studies.
- A final gap in the literature identified that requires resolution is the need for a formularisation of an ethical design framework concerning DfSB schemas. Whilst limited and subjective guidelines exist, they tend to be

retrospectively considered and not fully embodied and considered within a comprehensive design process. The role of the user and interdisciplinary input has also only been considered theoretically and not rigorously applied.

3 Research Methodology

3.1 Introduction



This chapter outlines the approach and strategy of the research design used throughout this enquiry in order to achieve the aim and objectives as presented in the first chapter of this thesis. With the research purpose, type and strategy defined, the chapter goes on to discuss the procedures used in the collection and analysis of the data. This section concludes with a statement of the research scale, along with a discussion of issues pertaining to the ensuring of research validity and standards of ethical research and practice.

3.2 Research Purpose

The purpose of this *qualitative research* is tied to resolving the aim and objectives of this research enquiry. To *investigate*, *explore* and *develop* how DfSB models and strategies can be implemented within a structured design process towards the reduction of domestic energy consumption, a *case study* research approach is presented.

The central participants of the case study are the *researcher-designer* and the inhabitants, within the *case* of domestic energy use and comfort and the *bounded system* of social housing in Merthyr Tydfil. The initial focus of the case study research is to *understand* through *contextual interviews*, *guided tours* and *thematic analysis* how the inhabitants define and control comfort and domestic energy consumption. The case study moves onto *researcher-designer practice* to produce a feedback intervention prototype, to *explore* and *develop* knowledge through the critical *reflection* of the design development *process* and *outcomes* of the design *practice.* The case study concludes with the evaluation of the feedback intervention prototype with *focus group interviews* and through *user trials* and *contextual interviews* with *thematic analysis* to *develop* knowledge and *understanding*. The following diagram (Figure 3-1) provides a broad overview between chapters and the research process, also illustrating the various third party elements involved with this body of research (for further information, please refer to the respective chapter).

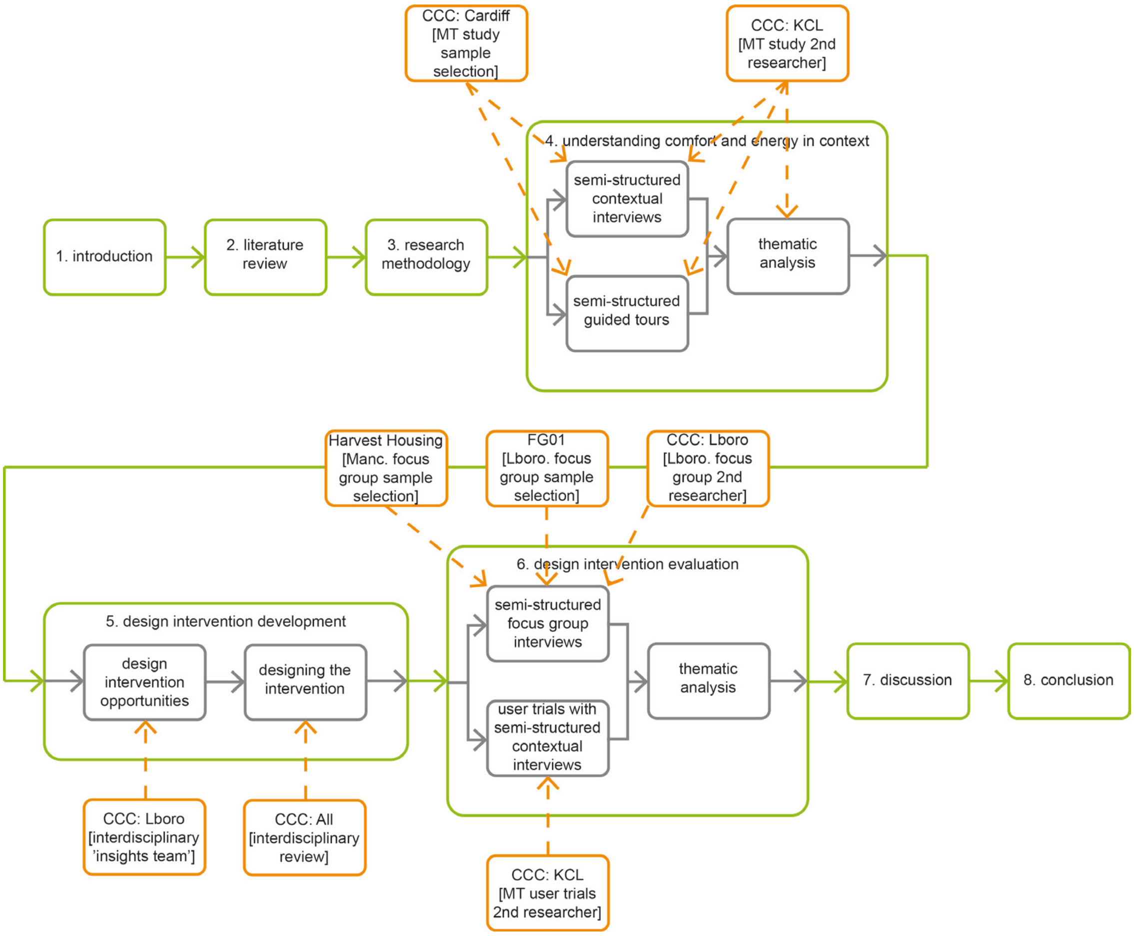


Figure 3-1 The Research Process

Robson *(2002)* presents four categories of research enquiry classification; *exploratory*, *descriptive*, *explanatory*, and *emancipatory*. In brief: an *exploratory* purpose seeks to uncover, question and assess situations and phenomena towards new insights and understanding; a *descriptive* purpose aims to profile an event or context; an *explanatory* purpose seeks to explain a situation or phenomena through an investigation of patterns and relationships;

and an *emancipatory* purpose aims to analyse and provide opportunities within social inequities.

The over-arching framework of this research can be classified as *exploratory*. That is not to say, however, that certain elements within this enquiry cannot be classified as having other purpose *(Robson, 2002)*. By exclusively looking at social housing as a case study and methods by which to reduce domestic energy consumption whilst maintaining comfort, an argument could be made that this potential enrichment or empowerment is *emancipatory* in nature (although this is not the over-arching focus of this research).

3.3 Research Type

Research type falls into two broad categories, *qualitative* research (also referred to as *flexible* research), and *quantitative* research (also referred to as *fixed* or *closed* research) *(Robson, 2002, Yin, 2009)*.

Qualitative research, originating from the social sciences, involves the researcher integrating their self as a tool within the research, focussing on a limited number of studies to discover and subjectively interpret multiple variables. The research strategy, because of this inductive line of reasoning, evolves with the research and involves iterative cycles of data collection and analysis *(Hignett, 2005, Creswell, 2007)*; the research, so to speak, 'unfolds' *(Robson, 2002)*.

Quantitative research, originating from the physical sciences, involves the researcher investigating from outside of the study context and employs objective reasoning to deductively explain predefined hypotheses. Studies within this remit focus on multiple cases with controlled and limited variables, with the research strategy defined prior to the commencement of study *(Hignett, 2005)*. Traditionally, quantitative research is perceived as being the *scientific* type of the two types of research. However, as Robson states, both types of research may be termed to be scientific, as long as they are "*carried out in a systematic, principled, fashion*" *(2002, P.5)*.

It is also worth noting that although flexible research predominately uses methods that result in qualitative *data* (and by extension, fixed or closed research predominately quantitative data), the term flexible or fixed allows for a research framework to involve *mixed-methods*, and therefore the use of terms qualitative or quantitative *research* to describe the framework may be incorrect *(Robson, 2002)*.

In this research enquiry, the research is *predominately* qualitative as the researcher is directly involved as a research tool and the data acquired from the data collection is subjectively analysed, with knowledge inductively gained. The research type will be denoted as *qualitative research* or more specifically, *flexible research* from this point forwards.

3.4 Research Strategy

As Creswell *(2007)* points out, qualitative research is not short of approaches with over thirty approaches identified from multiple disciplines. The five key approaches that Creswell identifies are *narrative research*, *phenomenology*, *grounded theory*, *ethnography*, and *case study*. In summary:

- narrative study is concerned with the study and understanding of discourse, and how it relates to an individual's life and context;
- phenomenological research pertains to the research of individuals within a cultural experience to understand the experiences 'essence';
- grounded theory aims to '*generate or discover a theory*' based in the data generated from the individuals who share the same studied process or action;
- ethnographic research concerns the study of shared culture (defined as twenty or more individuals);
- case studies deal with the study of bounded systems or cases in order to generate an understanding of a specific issue *(Creswell, 2007)*.

The use of a case study approach affords the ability to explore in substantial depth the defined contemporary *case* in qualitative terms, allowing for the practical development and understanding of theory *(Hammersley and Gomm, 2000)*. A case study approach was selected by this researcher for this doctoral study due to these advantageous attributes, allowing the researcher to explore in depth the specific impact of feedback and DfSB theory within a specified case – the aim of this research (rather than being an approach to research as dictated by the aligned CCC project).

There remain, however, several issues with regards to the use and application of case studies, chief amongst these being the claims of lack of rigour and issues relating to generalisation *(Hammersley and Gomm, 2000, Yin, 2009)*. Lack of rigour concerning case study research is associated with the lack of thoroughness in data collection and analysis techniques, and therefore can be addressed through well-designed (and executed) research methods. Generalisation, in terms of how a single case study may be extrapolated for a wider context may be considered a moot point. Yin *(2009, P.15)* states that *"case studies...are generalizable to theoretical propositions and not to populations"*, and that the key is *"analytical generalization"*, not *"statistical generalization"*. Hammersley and Gomm *(2000)* present a slightly different argument, that the relevant issue is whether the findings of the research be transferred between cases based on '*fit*', or how the research contributes to '*naturalistic generalizations*' (a gathering of case studies from which the researcher can 'experience' the phenomena *(Stake, 2000)*).

In terms of this research enquiry, the specific issue/theory of interest is the integration of feedback intervention theory into UCD practice, implemented within the case and bounded system of domestic energy use and comfort, within social housing in Merthyr Tydfil. With regard to case study design, it may be termed as a single *embedded case study design*, with multiple units of analysis *(Yin, 2009)*.

To give this case study a social as well as a geographical context, the county borough of Merthyr Tydfil is located in South Wales, with a population of approximately 56,000 *(Office for National Statistics, 2012)*. Although once a prosperous iron working town due to the abundance of local coal, fortunes have steadily been in decline, with the last iron foundry in the area closing in 1987 *(Merthyr Tydfil County Borough Council, 2008)*. However, despite recent investment and redevelopment of areas of Merthyr Tydfil by the Welsh

Assembly Government *(Merthyr Tydfil County Borough Council, 2008)*, at present, the rate of employment is at 13.4%, significantly higher than the UK rate of 8.1%. Levels of education are also low with the percentage of those with no qualifications (20.1%) being significantly higher than the rest of the UK (10.6%) *(Office for National Statistics, 2012)*. The life expectancy of a male resident in Merthyr Tydfil is also the lowest in Wales at 74.6 years, again significantly lower than the UK male average of 77.9 years *(Office for National Statistics, 2010)*.

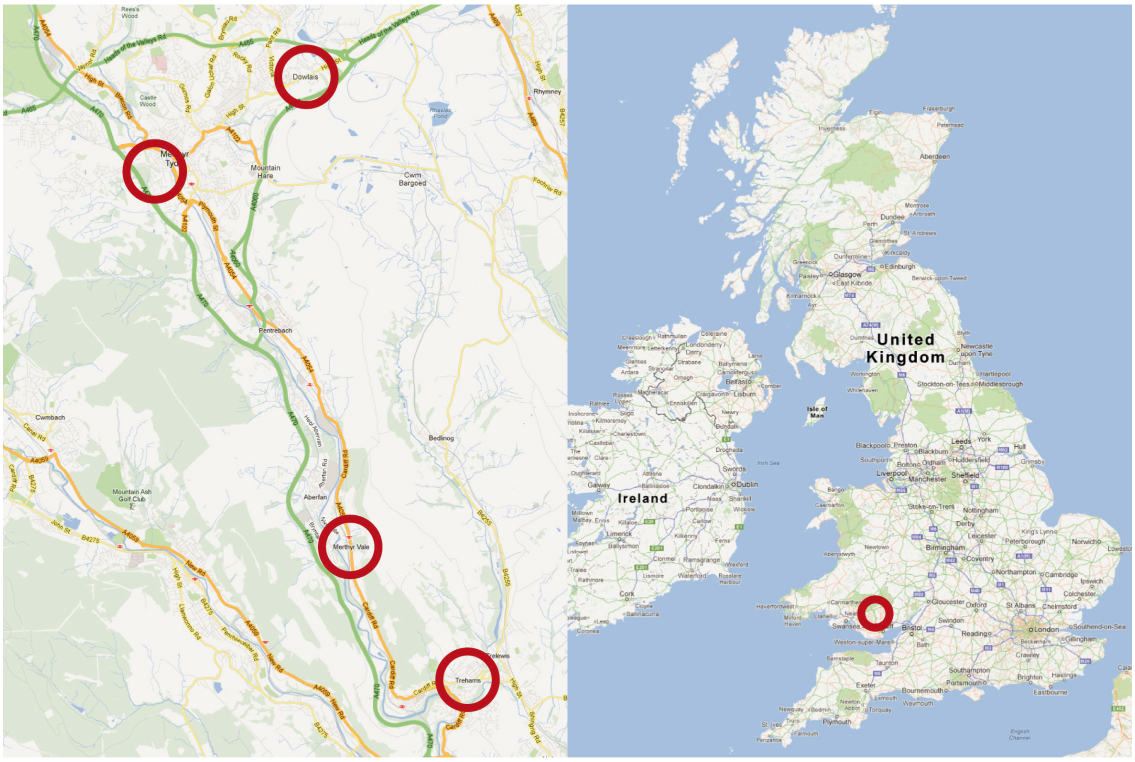


Figure 3-2 Maps Illustrating the Position of Merthyr Tydfil within the UK and the Areas that the Participating Households are Located

The selection of data collection and analysis techniques within a case study is dependent on the research enquiry's focus and the bounded system in which these foci are located. As stated, the primary focus of this body of research is concerned with the implementation of a DfSB framework within a design process and as such, the data collection and analysis techniques selected are appropriate to this.

3.5 Data Collection Techniques

In order to be able to address the research objectives and to understand this case study, data needs to be collected and subsequently analysed. As Robson *(2002, P.385)* bluntly puts it, *“no data – no project”*.

The purpose of this section is to provide an overview of the data collection techniques employed in the various phases of this research study. Each technique is discussed, including a thorough description of its methodology with a comparison of its advantages and disadvantages when compared to other data collection techniques. Each technique overview ends with a short summary of how that technique was put into practice during this body of research.

The techniques used to gather data within this thesis are presented in Table 3-1 Data Collection Techniques, placing each method alongside the chapter in which its application is recorded in detail, as well as the research objective that it sought to address.

Chapter Title	**Research Objective**	**Data Collection Techniques**
Research Study: Control, Comfort and Energy in Context	• To understand how inhabitants of social housing properties define and control comfort and its associated impact on their domestic energy consumption.	• Semi-structured contextual interview • Semi-structured guided tour
Design Intervention Evaluation	• To evaluate the feedback intervention prototype, using assessment criteria developed from the literature review.	• Semi-structured focus group interview • User trials with semi-structured contextual interviews

Table 3-1 Data Collection Techniques

3.5.1 Data Collection Techniques for Control, Comfort and Energy in Context

The initial research study forms the cornerstone of the research project, introducing the main subject for investigation, consequentially determining the direction and structure of the ensuing body of work.

The behaviour change approaches as outlined in the literature review of this thesis propose that the users' knowledge as well as their personal, contextual and behavioural domains shape the users decision-making process and actions *(Stern, 1999, Steg and Vlek, 2009)*. Therefore, in order to fulfil the research objective of understanding how *inhabitants of social housing properties define and control comfort and its associated impact on their domestic energy consumption*, this section presents the two techniques of semi-structured contextual interviews and semi-structured guided tours. Using these two techniques, the psychological as well as the physical aspects and repercussions of user decision-making and user action in this research context were investigated.

3.5.1.1 Semi-Structured Contextual Interview and Semi-Structured Guided Tours – Pilot

Prior to discussing the context study techniques, it is worth briefly discussing the pilot study performed, and its impact. The use of a *pilot study* helps the researcher to identify any potential *flaws* in the design of the ensuing main study and in addition, provides the researcher will valuable *experience* in the use of relevant research techniques *(Robson, 2002, Drury, 2005)*. The aim of this pilot research study was to investigate how selected participants would respond to the two data collection techniques employed, contextual interviews and guided tours, and to develop these techniques in preparation for the main study.

For this pilot study, two UK homes were selected; one with a single adult female with gas central heating in a bungalow, and the second with an adult couple with gas central heating in a semi-detached terraced house. The participants selected were known previously to the investigating researcher, which may have presented a disproportionate favourability in participant response. Although this may have produced a greater willingness for the participant to engage in the tasks and questions presented, this, however, does not necessarily correlate to a better *understanding* of the tasks and questions asked of/to them. Therefore, the questions and their implementation, as well as the technical aspects under investigation remained unbiased.

The following table, Table 3-2, briefly illustrates the changes made to the pilot study:

Semi-structured contextual interview	**Semi-structured guided tour**
Changes to Structure and Format:	
• Protocol reshaped into three parts; information for the participant, the interview, and closing statements	• Changed to emphasise the most and least comfortable spaces • Formatting of protocol sheet for ease of note taking
Changes to Questions:	
• Questions added to understand the built environment and temporal changes, and to determine the participants definition of comfort	• Questions added to record building type, home layout, and research conditions (time, date, weather, those present)
Changes to Management:	
• Secure data handling practices established, including participant coding for anonymity	

Table 3-2 Changes Made to the Pilot Study

The resulting main study interview and guided tour techniques are described in detail in the following sections.

3.5.1.2 Semi-Structured Contextual Interview

Interviews are a method of rich data collection that can gather information that otherwise may not be collected through observation alone, questionnaires or other non-contact qualitative techniques. Through the interview format the researcher can not only present questions and receive the interviewee's verbalised views back, but they can also participate in a dynamic, two-way dialogue thus allowing the researcher to expand upon an issue, to modify or follow up on specific lines of enquiry and take action to avoid non-responses *(Robson, 2002, Lilley, 2009a)*. Despite the apparent disadvantages of interviewing, such as lengthy preparation, travel and potential transcribing time *(Robson, 2002)*, an interview can also provide the researcher with observational data which can work in one of two ways. Observational data can provide non-verbal indications which can alter an answers meaning significantly *(Robson, 2002)*. Furthermore, if the interview is conducted within the environment or context which is the subject of the research (termed a *contextual interview (Stickdorn and Schneider, 2010)*), it can provide observational prompts. These prompts can work in two directions, both to the interviewer as a form of data from which to further extract insights, and more importantly can provide comfort and familiarity to the interviewee as well as being contextual memory prompts *(Stickdorn and Schneider, 2010)*.

The structure of the interview can range from highly or *fully structured* with a predetermined set of questions to ask in a predetermined order, through to open free ranging or *unstructured* interviews whereby the interview is entirely without predetermined formality, and the interview develops around a general area of research interest *(Robson, 2002, McClelland and Suri, 2005)*. A third, hybrid *semi-structured* format exists in which questions are to an extent predetermined but the order and exact content and delivery is subject to the interviewers judgement based primarily upon the interviewee's responses to the preceding questions *(Robson, 2002)*. The advantage of semi-structured interviewing is that it provides flexibility as discussed and can be used when the interviewer has a general understanding of a specific research area, but is unsure as to the interviewees specific response *(Maguire, 2001, Robson, 2002)*.

The opening interview carried out as part of this research study was a *semi-structured contextual interview*. This maximised, through contextual prompts and dynamic two-way dialogue, data gathered concerning the physical and psychological aspects of the user and their context in relation to control, comfort and energy.

In brief, these interviews were carried out by two researchers, one designated 'lead' who asked the questions and formed the discussions with the participants, and one recording the interview with copious note taking of both verbal and non-verbal information, supplemented by dictaphone. A non-rigid interview protocol was produced for the research study, split into three sections; information for the participant, the interview itself, and closing statements. The aim of the first section was to introduce the researchers, the project, and the projects aim to the participants. This section was used to fill in any missing data on the participant (such as heating system type). The second section, the interview, questioned how the participant defines and controls comfort and their built environment, as well as priming the participant for the guided tour. Both of these sections were primarily concerned with building rapport and trust, allowing the participants to feel secure with the interviewers in their homes for the proceeding guided tour, and to further the sharing of personal information and anecdotes. The third section concluded the interview, and informed the participants of the guided tour to follow. The interview guide can be found in Appendix A. Main Study Interview Guide.

Chapter 3 details the results of this technique.

3.5.1.3 Semi-Structured Guided Tours

A *guided tour* is an observational method that involves a participant giving a narrated tour of a research relevant environment to a researcher. The participant explains and reflects upon artefacts, actions and experiences within this environment whilst the researcher attempts to capture with audio-visual methods the phenomenological results and interpretations of these interactions *(IDEO, 2003, McClelland and Suri, 2005, Pink, 2007, Lilley, 2009a)*. Such data recording methods may involve the use of a dictaphone or note taking, but in order to further the capture of multi-sensory experiences and aspects associated with the research, may also involve the use of photography or video cameras *(Pink, 2007, Pink, 2010)*.

Guided tours can also provide similar comfort and contextual memory prompts in much the same way as contextual interviews, allowing participants to recall their actions and motivations whilst providing the interviewer with further information from which to formulate questions and understanding *(IDEO, 1999, IDEO, 2003, Lilley, 2009a)*. The sharing of experiences and actions within the context may also lead to a heightened empathic understanding of the participant and their motivations *(Pink, 2007)*.

Guided tours suffer similar disadvantages as contextual interviews, as far as the time they take to prepare, to travel to the study site and to transcribe and interpret the data *(Lilley, 2009a)*. Furthermore, whilst one of the main advantages of this method is that is captures and defines a temporal moment between a participant and researcher in an environment to great detail *(Pink,* *2007)*, it can therefore not be representative of a wider group, location or time frame *(Lilley, 2009a)*. Overall, however, the advantages afforded by the contextual memory prompts as well as the heightened level of empathic understanding between the researcher and the participant, outweighs the disadvantages. In addition, the photographic and/or videos recorded in tandem with the guide itself provides additional *realistic contextual texture* in the form of design reference material for use throughout the proceeding design stages *(McClelland and Suri, 2005)*. Pictorial descriptions and approximate schematic layouts for each household, for example Figure 3-3, can be found in a larger format in the appendix, Appendix E. Main Study Guided Tour Reference Sheets, with photos taken during the guided tour for each property.

Figure 3-3 Guided Tour Reference Sheet for CA01 Ground Floor

The structure of the guided tour was similar to the contextual interviews, again using a semi-structured format and a non-rigid interview protocol with dual researchers. The protocol was split into three sections; before the tour, the tour, and closing statements. The tour element of the protocol followed leads provided by the participant during the preceding contextual interview, with the lead researcher prompting participants on devices, spaces and household objects that the participant identified as being relevant to their consumption, comfort and energy. Ultimately, the guided tour primarily followed the participant's direction and prompts were only used to maintain a flow of discussion. The guided tour guide can be found in Appendix B. Main Study Guided Tour Guide.

This main study was undertaken in the town of Merthyr Tydfil during spring 2010. In response to the practicalities of fieldwork and the availability of the participants, the investigation was split over the course of two visits to the area by the researchers (this doctoral researcher and a CCC project partner from KCL), with four households visited during March, and three further households visited during April, to provide a total dataset of seven households (the sample is discussed further in section 3.7).

Each interview lasted for approximately an hour, followed by the guided tour of the same approximate length, conducted over the course of two visits (although for participants CA04 and CA07, the interview and guided tour were conducted back-to-back, due to participant availability). All household members were present for the interview in homes CA01, CA03, CA05 and CA07 with households CA02, CA04 and CA06 being attended only by the main participant. For the guided tours, only the main participant was present for all homes concerned.

Chapter 4 discusses the results of this process.

3.5.2 Data Collection Techniques for Design Intervention Evaluation

The data collection techniques presented here sought to address the fourth research objective, *to evaluate the feedback intervention prototype, using criteria developed from the literature review*.

Three questions emerge when evaluating a DfSB strategy led intervention: *Did the produced design solution function for the specified context? Has the user's behaviour changed as a consequence of the design intervention? Is the change in user's behaviour sustainable?* (These research questions are discussed further in section 6.2). The data collection techniques of semi-structured focus group interviews and user trials with semi-structured contextual interviews were employed to consider the above three questions, providing a methodological basis for evaluation as stated by this research objective.

3.5.2.1 Semi-Structured Focus Group Interview

A focus group is an open ended, dynamic interview that takes place between a group of participants and a researcher in order to discuss a specific list of topics; a *focus (Maguire, 2001, Bruseberg and McDonagh-Philp, 2002, Robson, 2002, Lofthouse and Lilley, 2006)*. The key benefit of focus groups over individual interviews is the groups' interaction with one another. Within a focus group, discussions and interactions can take place *between* participants, giving each other prompts and responding as well as providing a more congenial audience for discussion than the lone participant and researcher interview format *(Macnaghten and Myers, 2010)*. The disadvantage over the lone interviewee format is primarily one of control. Once discussions and debates begin to take shape, personalities and certain topics may start to dominate or bias the discussion, losing focus *(Robson, 2002, McClelland and Suri, 2005)*. With good moderation, this can be avoided or at least reduced.

In the context of this research study, the *focus* was on a specific list of user and/or design criteria focused around a design intervention prototype. As stated by Nielsen *(1997, P.94-95)*, with respect to interactive systems development, *"the proper role of focus groups is not to assess interaction styles or design usability, but to discover what users want from the system"*. Focus groups are for exploratory purposes, uncovering opinions, experiences and motivations rather than validating or quantifying design characteristics *(Bruseberg and McDonagh-Philp, 2002)*. Therefore, as an evaluation technique used early within a design process, focus groups can provide feedback as to the users thoughts and opinions on what they *actually* want and their subjective opinion on their physical and cognitive interpretation of the design *(Nielsen, 1997, Bruseberg and McDonagh-Philp, 2002, McClelland and Suri, 2005)*. The researcher can investigate whether their interpretation of the *specified context* and the *users' behaviour* is actually as they understood it to be, and begin to build a better understanding of the potential interactions between a user and the design which can be further fed into the design process.

In brief, two focus groups were run (a pilot and a main study) in two locations; Loughborough and Manchester. Both consisted of questions centred on two videos and a physical prototype, using a similar dual researcher format as the earlier contextual interviews, with a semi-structured interview protocol (based primarily on the structure outlined by Krueger and Casey *(2009),* Appendix Q. Focus Group, Facilitator's Guide). The Loughborough focus group pilot was held in October 2011, at Loughborough Library, Figure 3-4, *neutral territory*, in others words, not an academic research venue which may inhibit discussion or intimidate participants. The Manchester focus group interview was held in October 2011, at the Old Trafford Community Centre in Manchester, Figure 3-5. As with the focus group pilot, this venue was neutral territory, with the local community centre being a venue that all the participants would have been familiar with and which did not carry academic overtones. The focus groups were recorded using dictaphones, note taking and a video camera.

Figure 3-4 Loughborough Focus Group Interview, with Prototype

Figure 3-5 Manchester Focus Group Interview

The first of the two videos shown and narrated to the participants depicted a typical *scenario* of occupant behaviour captured within the contextual interview and guided tour data previously studied. In this first scenario, the storyboard of which can be found in Appendix R. Focus Group, Scenario Video Storyboard, the individual within their living room experiences thermal and air quality discomfort and seeks to address this. The individual becomes cold and physically touches the radiator to determine the heating systems status. Deciding that the heating system is not active, the individual turns the thermostat up and then monitors the change in radiator temperature over time through physical contact with the radiator, until the radiator becomes too hot to touch. After a long period the individual experiences air quality discomfort and decides to open a window to air out the room, forgetting that the heating system is active. The window is then left open and the energy waste conflict between window and heating system is never considered. The purpose of the video was to introduce to the participant the research study in a relatable and tangible way, as well as to focus discussion towards the required topics and issues *(McClelland and Suri, 2005)*.

Storyboarded in Appendix S. Focus Group, Intervention Video Storyboard, Figure 3-6, the second video introduced the intervention into the established context and played through an expected typical use scenario. Repeating the same scenario as before, the individual becomes thermally uncomfortable and following being informed by the intervention as to the heating systems off status, turns the thermostat up. The effect of this action is then monitored over time by the individual observing the intervention. Again, after a long period the individual decides to air out the room due to unacceptable air quality parameters and so opens a window. This time, the intervention informs the individual as to the conflict between window and heating system use and appropriate action is taken.

Figure 3-6 Capture from the Intervention Video

Finally, the physical prototype was introduced to the participants to capture and provoke any further reactions to features that may not have been possible through the video format *(McClelland and Suri, 2005)*. The question route or sequence used within the interview protocol consisted of five parts:

- the opening questions to get all the participants talking;
- the introductory questions to introduce the subject for discussion;
- the transition questions to link the opening and introductory discussions to the key questions;
- the key questions to drive the discussion towards that which the focus group has been created to discuss;
- and finally the ending questions to bring an end to the discussion *(Krueger and Casey, 2009)*.

It is worth noting that aside from minor changes made to the information sheet (Appendix T. Focus Group, Information Sheet) and questionnaire (Appendix U. Focus Group, Questionnaire) for the main focus group interview, there were no changes made to the facilitators guide or to the two video storyboards. The results of this pilot focus group interview have been incorporated into the findings of the main focus group interview, discussed in detail in Chapter 6.

3.5.2.2 User Trials with Semi-Structured Contextual Interviews

Evaluation methodologies fall into two categories of purpose; *formative* or *summative*. Formative evaluation is used to generate information that can be fed back into the research process, such as with the focus group method previously described. Summative evaluation on the other hand focuses on the effect that the research has upon the user *(Maguire, 2001, Robson, 2002)*. A *user trial*, also known as *user-based testing (British Standards Institution, 2010)* or *controlled user testing (Maguire, 2001)*, involves taking a representation or embodiment of one or all aspects of a research study outcome and allowing a participant to interact with it within an experimental control or real world environment. The purpose of such a trial is to explore physical and cognitive impact, measure performance and to investigate contextual factors *(Maguire, 2001, McClelland and Suri, 2005, Lilley, 2009a, British Standards Institution, 2010)*. As an approach used early in the research process it can be used to *develop* understanding and application within the research study context, a form of *process* assessment (formative); user trials can also be used to assess and understand the *impact* of the research, the researches *outcomes* (summative) *(Robson, 2002)*.

The purpose of this evaluation was to measure the performance of the research outcome (does the design function within requirements and to what extent has the users behaviour changed towards sustainable ends?) and to provide feedback into the research process (why have the user and design requirements not been met, and are there any new insights from the trials so to improve our understanding of the user and design requirements?).

The data from the user trials was gathered through semi-structured contextual interviews, an approach that generates a tremendous amount of qualitative data as previously discussed, as well as being a technique that the participants were comfortable and familiar with. Similar in style to the interviews conducted to understand the initial requirements of the user and context, the aim of these interviews were to provide a comparative evaluation between a pre-intervention baseline state and a post-intervention state.

In brief, information sheets (Appendix W. User Trial, Information Sheet, Appendix X. User Trial, Prototype Information Sheet) and consent forms (Appendix Y. User Trial, Consent Form, Appendix Z. User Trial, Prototype Consent Form) were provided to the participants prior to the installation of the prototypes. A pre-intervention qualitative baseline was established using a semi-structured contextual interview (Appendix AA. User Trial, Facilitator's Guide), which was proceeded by the installation of the intervention prototypes (Appendix AB. User Trial, Installation Guide). The pre-intervention questions focused on updating and re-establishing a baseline of our understanding of the participants' knowledge and normative structures, as well as the context in which they operate.

The intervention prototypes were installed into the living room of CA02, Figure 3-7, and into the kitchen of CA05, Figure 3-8, in December 2011. These locations were chosen for installation as they were self-designated by the participants as their *most comfortable space* in the context study (section 4.2.2.1).

Figure 3-7 CA02 Living Room with Prototype

Figure 3-8 CA05 Kitchen with Prototype

The post-intervention questions were split into: understanding if there had been any change in the participants experience of comfort and how they attain it (has the users behaviour changed as a consequence of the intervention and is this change in behaviour sustainable?); and secondly, questions relating to the product itself (did the produced design solution function for the specified context?). A third and final section concluded the project with them and presented a re-cap of our pre-installation findings to them.

The duration of the user trial used in this study was four months, uninstalled in April 2012. It was envisaged that this timeframe would provide a compromise between the research study duration and the allowing of any change in habitual behaviour to take shape. The appropriateness of this timeframe is borne out by Lally et al. *(2009)*, who found, in their study on habit development, that automaticity, a key component of habitual behaviour, plateaued on average in sixty six days, although the spread was in the order of eighteen to two hundred and fifty four days. Following removal, both CA02 and CA05 participated in a final semi-structured contextual interview (Appendix AC. User Trial, Extraction Guide), in order to provide a qualitative comparison to the pre-installation baseline and the context research study.

Please refer to Chapter 6 for the results of the user trials and focus group interviews.

3.6 Data Analysis Techniques

This section illustrates the techniques that were employed in the analysis of the data generated through the collection techniques in relation to their relevant research objective. This description includes; what the analysis techniques were, their relevant advantages and disadvantages and comparison to other techniques, as well as a brief summary of how they were conducted within this research study.

Creswell *(2007)* states that there are six stages to data analysis and representation within a case study approach. These are; the *management* of data; the *reading* through and *memoing* of the data; the *describing* of the case and its context; the *classification* of codes and themes within context; the *interpreting* of codes and themes within context; and finally, the *representing* or *visualising* of the case in detail. With emphasis upon the *classification* and *interpreting* of data, key aspects of the data analysis are discussed.

The data analysis techniques applied within this thesis are presented in relation to their research objective and the chapter in which their application resides, illustrated in Table 3-3 Data Analysis Techniques. Whilst this chapter discusses the purpose of the techniques and the rationale for their selection, please refer to specific chapters for their detailed use within this research study.

Chapter Title	Research Objective	Data Analysis Techniques
Research Study: Control, Comfort and Energy in Context	• To understand how inhabitants of social housing properties define and control comfort and its associated impact on their domestic energy consumption.	• Thematic analysis
Design Intervention Evaluation	• To evaluate the feedback intervention prototype, using assessment criteria developed from the literature review.	

Table 3-3 Data Analysis Techniques

3.6.1 Data Analysis Techniques for Control, Comfort and Energy in Context and Design Intervention Evaluation

Information gathered through the data collection techniques of semi-structured contextual interviews, semi-structured guided tours and later through semi-structured focus groups and user trials with semi-structured contextual interviews needs to be *classified* and *interpreted (Creswell, 2007)*. Through these analytical processes, the structure and consequences of user behaviour and action within this research context and the impact of the feedback intervention are understood.

As such, this section presents the data analysis technique of *thematic analysis*, a technique intended to develop a detailed description and understanding of the research case study.

3.6.1.1 Thematic Analysis

Thematic analysis is a data analysis technique for *"identifying, analysing and reporting...themes...within data* [which] *minimally organizes and describes your data set in (rich) detail" (Braun and Clarke, 2006, P.79)*. Thematic analysis is a type of *template approach* to data analysis. Codes (and themes) are determined by the researcher, which forms the template for the analysis of the data *(Robson, 2002)*, with supporting text or protocol extracts to provide evidence and texture to the case description and interpretation. The use of thematic analysis within the context of this research project is, therefore, to identify and analyse themes relevant to describe the case and bounded system of domestic energy use and comfort within social housing in Merthyr Tydfil.

Codes are shorthand descriptions of *key* categories based on sections of data, which are *determined* in one of two ways, either *inductively* (data driven coding without a pre-defined coding frame) or *theoretically* (the use of *priori* or *prefigured* codes from a predefined theoretical stand point or interest) *(Robson, 2002, Braun and Clarke, 2006, Creswell, 2007)*. Themes are broad level combinations of codes, which form the start of the analysing process and may be either *semantic* (interpretation by the researcher on an explicit level, not attempting to understand underlying ideas and assumptions that may form the data) or *latent* (a theoretical examination of the underlying structure of the semantic level) *(Braun and Clarke, 2006)*. A *thematic map* helps to understand and refine the relationship between multilevel themes and codes, by visually representing the themes and their connecting threads *(Braun and Clarke, 2006)*. With themes identified and clearly defined, naturalistic generalizations and direct interpretations are made in relation to the research objectives, supported with data extracts that tell the *story (Robson, 2002, Braun and Clarke, 2006).*

It is worth noting that codes and themes do not *emerge* or are *discovered*, as this suggests the process to be passive and does not account for the researchers theoretical or philosophical standpoints, also, code and theme generation is not determined by code counting or quantifying alone, rather it is the *prevalence* and *keyness* of an issue in relation to the research study *(Braun and Clarke, 2006, Creswell, 2007)*.

The disadvantage of thematic analysis compared to *conversation analysis* and *discourse analysis* is twofold. First, within conversation analysis and discourse analysis the emphasis is on the *structural organization of talk* (speech patterns and use of language) and its *sequential* ordering (sequence of verbal action based on contextual events)*;* the psychological *why* and *reality* of language as opposed to just the *what* of thematic analysis *(Silverman, 2001, Braun and Clarke, 2006)*. Second, thematic analysis does not retain a sense of the individual participant, by drawing out themes across data sets. Compounded without the sequential ordering, individual contradictions or self-references may not be analysed *(Silverman, 2001, Braun and Clarke, 2006)*. The advantage of using thematic analysis over these two approaches, however, outweigh the disadvantages. As a method, it is quicker to apply and better suited to the researcher as an active tool working with participants. Furthermore, it can offer a *rich* and *thick description* of a large amount of data and is in a format that makes it easier to compare and contrast data across sets *(Braun and Clarke, 2006)*.

Within the control, comfort and energy in context study, the data sets were split between two researchers for initial analysis; this researcher and a social science researcher from KCL (please refer back to 1.2 Project Context for further details of this relationship). Taking an inductive approach to the data, each researcher independently determined and *classified* semantic codes in relation to the research objective. The data sets were then swapped and the process repeated. The two researchers then discussed and compiled the codes and worked towards the defining of thematic groups. A thematic map was produced to help the refining of thematic groupings. The themes were then further analysed and *interpreted* in relation to the research objective; the process and analysis of which is described in detail within Chapter 3. For the design intervention evaluation study (detailed in Chapter 6) a similar process was followed, with the only change being that the analysis was conducted by this single researcher.

3.7 Sampling Strategy

Sampling, in short, is a selection of individuals from within a group or the *population* in order to form an understanding of the research problem and phenomena at study *(Robson, 2002, Creswell, 2007, Barbour, 2007)*. There is not one type of sampling strategy that can be applied to all qualitative research inquiries, but rather there are several on the table (indeed, Creswell's *(2007)* investigation demonstrates a typology of sixteen different, *non-probability*, sampling strategies for use in qualitative study) to be selected from. The selection of a sampling strategy is but one part of the multifarious decisions made by the researcher in order to determine *how* they want to understand their study. Further considerations include: what or who forms the group or population from which to sample, what is to be the size of sample they wish to study, and furthermore, will this sample by able to provide the data and insights required in line with the research *approach* taken*(Creswell, 2007)*.

The issue of sampling within the context of this research study is primarily split between two phases of investigation, the initial research study and the design intervention evaluation. The research study was formed of a single sample group, and the latter evaluation phase was comprised of three sample groups as detailed below.

The selection of case study participants was managed by the Welsh School of Architecture at Cardiff University as part of the CCC project. Whilst the selection of the sample was *not* under the management of this research study, it is worth discussing the sampling strategy applied as its effects *were* of concern to this research. The selection of a sample (or case) for a case study is not a question of being able to form generalizations of *typicality* and *representativeness* or other forms of *statistical* extrapolation. Case study sample selection is a question of being able to answer the research objectives and *properly describe* the *bounded system* of interest (which contributes to *naturalistic generalizations* or is comparable to other research based on *fit*) *(Hammersley and Gomm, 2000, Yin, 2009)*. The type of sampling employed by Cardiff University was a form of *homogeneous, purposive sampling (Robson, 2002, Creswell, 2007)*, where the focus of the sampling strategy was to purposely select social housing tenants within the Merthyr Tydfil region of

Wales, through the Merthyr Tydfil Housing Authority [MTHA]. As the number and composition of the sample was irrelevant in terms of statistical generalization, the composition and size of the sample was primarily determined though the limitations of the project and the requirements of analysis (in order to understand how inhabitants of these social housing properties define and control comfort and its associated impact on their domestic energy consumption, a smaller sample would allow for a richer and deeper description and breadth of analysis). Project limitations included the three-year project duration, project funding, monitoring technology and number of researchers available. Seven households were selected for this part of the study, distributed across three areas within the county of Merthyr Tydfil with three households distributed across the suburbs of Merthyr Tydfil (CA01, CA03 and CA05), three located in Treharris (CA02, CA04 and CA07), and a further household located between these two regions, in Merthyr Vale (CA06), Figure 3-2. Within the dataset, there were several dimensions of variability between the coded participants, such as household composition, the built form and age of the property, as well as variations in terms of heating system and meter or tariff type, as shown in Table 3-4.

Code	CA01	CA02	CA03	CA04	CA05	CA06	CA07
Date of Visit	March 2010	April 2010	March 2010	March 2010	March 2010	April 2010	April 2010
Location	Dowlais, Merthyr Tydfil	Treharris	Georgetown, Merthyr Tydfil	Treharris	Dowlais, Merthyr Tydfil	Merthyr Vale	Treharris
Household Composition	2 adult (F)	2 adult (F), 1 adult (M), 1 child	1 adult (M)	1 adult (F), 1 adult (M)	1 adult (F), 1 adult (M)	1 adult (F), 1 adult (M)	1 adult (F), 1 baby 1 young child
Relationship of household members	Mother and daughter	Grandmother, daughter, son-in-law, grandson	Elderly male	Wife and husband	Wife and husband	Wife and husband	Single mother with baby and a young child
Main Participant	Mother (CA01F)	Grandmother (CA02F)	Tenant (CA03)	Wife (CA04F)	Wife (CA05F)	Wife (CA05F)	Mother (CA07)
Built Form	Terrace, solid walls	Semi-detached, cavity walls	Flat (sheltered), cavity walls	Semi-detached, cavity walls	Semi-detached, cavity walls	Terrace, solid walls	Semi-detached, cavity walls
Built Age	~100 yrs	<20 yrs	~10 yrs	<20 yrs	<10 yrs	~100 yrs	<20 yrs
Heating System	Gas: back boiler	Gas: combi boiler, Electric: L/Room fire	Electric: storageheaters and immersion	Gas: combi boiler, Electric: L/Room fire	Gas: combi boiler, Electric: L/Room fire	Gas: combi boiler	Gas: combi boiler
Meter / Tariff	Standard (gas & electricity)	Prepay (gas & electricity)	Standard (electricity only)	Prepay (gas & electricity)	Standard (gas & electricity)	Prepay (gas & electricity)	Prepay (gas & electricity)

Table 3-4 Summary of the Seven Participating Households

The same case study sample was used throughout the project for interviewing purposes as described elsewhere. However, in order to provide a detailed evaluation of the design interventions during the evaluation phase of the research, a smaller sample group, derived from the original sample (in order to compare the pre-intervention and post-intervention data in detail) was required for user trials. The Project Context (section 1.2) also had an influence on the sample size, as the number of participants available from the original sample had to be distributed amongst the other prototypes generated by Loughborough University through the CCC project (discussed further in section 8.5). The strategy for sample selection in this case was *criterion, purposive sampling (Robson, 2002, Creswell, 2007)*, as each of the two households were purposely selected for a prototype based on their recorded motives, knowledge and actions, which are described in further detail in Chapters 3. The two participant households that formed the cohort for the context research study and the intervention evaluation phase were; CA02 and CA05, (Table 3-5). CA02 and CA05 were selected as in the context study they both exhibited frequent use of windows for the control and circulation of fresh air and controlled the heating on an ad hoc basis, often leading to energy conflicts with their window actions or to a comfort conflict with other tenants. For a list of the five CCC design interventions and their assignment to each household (as part of the larger research project), please refer to Appendix V. User Trial, Sampling Strategy.

Code	CA02	CA05
Date of Installation /	5 December 2011 2 April 2012	7 December 2011 3 April 2012
Location	Treharris, Merthyr Tydfil	Dowlais, Merthyr Tydfil
Household Composition	2 adult (F), 1 adult(M), 1 child	1 adult (F), 1 adult (M)
Relationship of household members	Grandmother, daughter, son-in-law, grandson	Wife and Husband
Main Participant	Grandmother (CA02F)	Wife (CA05F)
Occupation	Retired/housework	Retired/housework
Built Form	Semi-detached, cavity walls	Semi-detached, cavity walls
Built Age	< 20 years	< 10 years
Heating System	Gas: combi boiler, Electric: L/Room fire	Gas: combi boiler, Electric: L/Room fire
Control of System	Room thermostat, TRV	Room thermostat, TRV
Meter / Tariff	Prepay (gas & electricity)	Standard (gas & electricity)

Table 3-5 Summary of Information for the two user trials

For the two focus groups, the sampling strategy and size were different to the main case study sample. The aim of a focus group, in a similar way to the case study, was to provide an understanding of the problem and phenomena that is the focus of the research study. Again, the aim was not to provide a statistical representation, rather to determine the *range* of the issues, and *provide insights* concerning the research of interest *(Krueger and Casey, 2009, Macnaghten and Myers, 2010)*. A form of *snowball, purposive sampling (Robson, 2002, Creswell, 2007)* was used to recruit the participants to the focus groups. This was achieved by approaching known gatekeepers who had knowledge and access to the groups of individuals of research interest, which were not available through other methods, and providing them with broad recruitment criteria (i.e. social housing tenants only). In the Loughborough focus group, the gatekeeper was one of the local social housing tenants highly active in his community. Recruitment for the Loughborough pilot focus group interview was initiated through a flyer campaign. Five hundred invitation flyers (Appendix M. Focus Group Pilot, Invitation Flyer) were distributed to socially housed tenants within Loughborough following which contact was made with FG01 who provided details of a local community association meeting in which he was actively involved. Information packs consisting of an information sheet (Appendix N. Focus Group Pilot, Information Sheet), consent form (Appendix O. Focus Group, Consent Form) and questionnaire (Appendix P. Focus Group Pilot, Questionnaire) were distributed at this meeting following a brief presentation on the project. The questionnaire was devised to capture specific information such as heating system type to form basic comparisons to the Merthyr Tydfil participants.

In the Manchester focus group, the gatekeeper was the community centre liaison to local social housing tenants, Harvest Housing Group's Neighbourhood Regeneration Officer Kate Eastwood. The tenants and the properties of Harvest Housing Group constitute a form of social housing (i.e. low rent properties provided to those with a housing need by a governmental or not-for-profit organisation *(Department for Communities and Local Government, 2011)*), therefore the tenants are comparable to some degree to the participants under study in Merthyr Tydfil. Miss Eastwood contacted several tenants in the Manchester region of the UK, providing each with the information contained within the Information Sheet (Appendix T. Focus Group, Information Sheet).

The Loughborough focus group was conducted with four social housing tenants (including the original gatekeeper), with the Manchester focus group being held with six social housing tenants (excluding the original gatekeeper). Whilst it may be traditionally argued that the sample size for a focus group should be between ten to twelve participants (a marketing research perspective), in reality smaller focus groups of four or six tend to be easier to facilitate and are generally more comfortable for the participants *(Krueger and Casey, 2009)*. The negative side of having smaller focus groups is that you may have a smaller *range of experiences* from which to generate insights, rather than any irrelevant statistical generalization issue *(Krueger and Casey, 2009)*. Both of these focus groups are discussed in detail in section 6.3. Participants designated as FG01 - FG10 pertain to these focus group interview studies (Table 3-6).

Code	**FG01**	**FG02**	**FG03**	**FG04**	**FG05**	**FG06**	**FG07**	**FG08**	**FG09**	**FG10**
Date of FG	Oct 2011	Oct 2011	Oct 2011	Oct 2011	Oct 2011	Oct 2011	Oct 2011	Oct 2011	Oct 2011	Oct 2011
Location	Loughb', England	Loughb', England	Loughb, England	Loughb, England	Manch', England	Manch', England	Manch' England	Manch', England	Manch', England	Manch', England
Household Composition	1 adult (M) 1 adult (F)	1 adult (M) 1 adult (F)	1 adult (M)	1 adult (F) 1 adult (M)	1 adult (F) 1 adult 3 children	1 adult (F) 2 children	1 adult (F) 1 adult	1 adult (M) 1 adult 1 child	1 adult (F)	1 adult (M)
Household members	Couple (01&04)	Mother & Son	-	Couple (04&01)	Mother & 4 children	Mother & 2 children	Friends	Friends	-	-
Main Participant	Husband	Mother	Male	Wife	Mother	Mother	Female	Male	Female	Male
Occupation	Retired	Housework / Watch TV	Socialwork / Reading	Housework	Housework	Housework	Employed	Employed	Retired	Un-employed
Built Form	Terraced	Flat	Flat	Terraced	Terraced	Terraced	Flat	Ground floor flat	Semi detached	Ground floor flat
Built Age	<100 years?	< 50 years	< 50 years	<100 years?	100 > years?	?	New build	New build	?	New build
Heating System	Gas fires (not central heating)	Gas: combi boiler	Gas (central heating)	Gas fires (not central heating)	Gas: combi boiler	Gas: combi boiler	Electric storage heaters	Electric heaters (not storage)	Gas boiler	Electric storage heaters
Control of System	Turn on/off	Room thermostat	Room thermostat	Turn on/off	Room thermostat	Room thermostat	Turn on/off & thermostat	Turn on/off	Room thermostat	Heater settings
Meter / Tariff	Direct Debit (gas & Electricity)	Prepay (gas & Electricity)	Quarterly bills	Direct Debit (gas & Electricity)	Prepay (gas & electricity)	Prepay (gas & electricity)	Monthly	Monthly	Direct Debit	Monthly Direct Debit

Table 3-6 Summary of Information for the Focus Group Interview Participants

3.8 Validity of Research

Unsurprisingly, literature defining *validity* in qualitative inquiry terms does not give a unified standpoint, with as many variations in perspectives and terminology as there are qualitative research approaches and techniques (Creswell *(2007)* this time points to eight different studies with differing perspectives and terms). One perspective is to use a set of four evaluation terms such as *internal validity*, *external validity*, *reliability* and *objectivity*, or to use a similar perspective that renames these terms with language that is more from a qualitative tradition; *credibility, transferability, dependability* and *confirmability (Robson, 2002, Creswell, 2007)*. These terms, however, revolve around the viewpoint that qualitative research needs to have parallels to quantitative research, and follow the same rigid definitions of scientific rigour.

The perspective of validity taken in this body of work echoes that as stated by Creswell *(2007, P.249-250)*:

- *"...“validation” in qualitative research* is *an attempt to assess the “accuracy” of the findings, as best described by the researcher and the participants*.
- *...validation* is *a distinct strength of qualitative research in that the account made through extensive time spent in the field, the detailed thick description, and the closeness of the researcher to participants in the study all add to the value or accuracy of a study.*
- *...the term “validation”* emphasizes *a process, rather than “verification” (which has quantitative overtones)...*
- *...researchers* should *employ accepted strategies to document the “accuracy” of their studies."*

Methods to document this *accuracy* of research, also known as *validation strategies (Creswell, 2007)*, were applied throughout this research study, and are briefly described below.

The duration of the research study allowed the researcher to visit the Merthyr Tydfil site five times over two years, providing *prolonged engagement* or *involvement* with the participants in context. Although contact from this researcher was not on a daily basis, the advantage of such prolonged exposure between the researcher and the participant is that of building trust, as well providing opportunity to further understand the culture. This and the on-going interviews also allowed for *member checking*, presenting the insights from the preceding guided tour and interviews to the participant in order for their reflection on its accuracy *(Robson, 2002, Creswell, 2007)*.

Triangulation involves the use of multiple methods, researchers and theories in order to substantiate and confirm findings (or to discover inconsistencies). *Data triangulation,* which involves the use of multiple data collection techniques was employed during the initial research study. Data was triangulated through the guided tour by using the observational information and combining it with parallel contextual interviewing in order to triangulate the participants' definitions and descriptions as analysed from the earlier, initial contextual interviewing stage. *Observer triangulation* concerns the use of multiple observers or researchers during the collection and analysis of data, and was enacted throughout the research study, from the initial contextual interviews and guided tours, through to the user trial installation and interviews, and focus groups (although the Manchester focus group was carried out by a single researcher). This primarily involved this researcher working alongside another researcher from Loughborough University, or in conjunction with another researcher from the CCC project (KCL) *(Robson, 2002, Creswell, 2007)*.

Peer review or debriefing involves the use of research peers to question the work of the researcher, including methods and interpretations, in order to reduce researcher bias. Such groups can also provide *support*, and a sympathetic ear. This function was provided through supervision and bi-weekly meetings at Loughborough University [Lilley and Bhamra providing supervision over PhD studies, with Bhamra and Haines providing supervision over the research project], as well as further peer review and support provided through quarterly CCC project meetings *(Robson, 2002, Creswell, 2007)*.

The final two validation strategies applied throughout this research study, involved the use of *rich* and *thick* descriptions *(Creswell, 2007)*, and a fully accountable *audit trail (Robson, 2002)*. By ensuring that all records of the research methodology (including rationale for selection) and context are complete and transparent, as well as the insights and findings recorded in rich and thick description, this has allowed those external to the research to be able to assess for themselves whether the methodology presented is appropriate and supports the insights and findings presented. This also allows the external party to understand how the research contributes to naturalistic generalizations and is comparable to other research based on appropriate fit.

3.9 Research Ethics

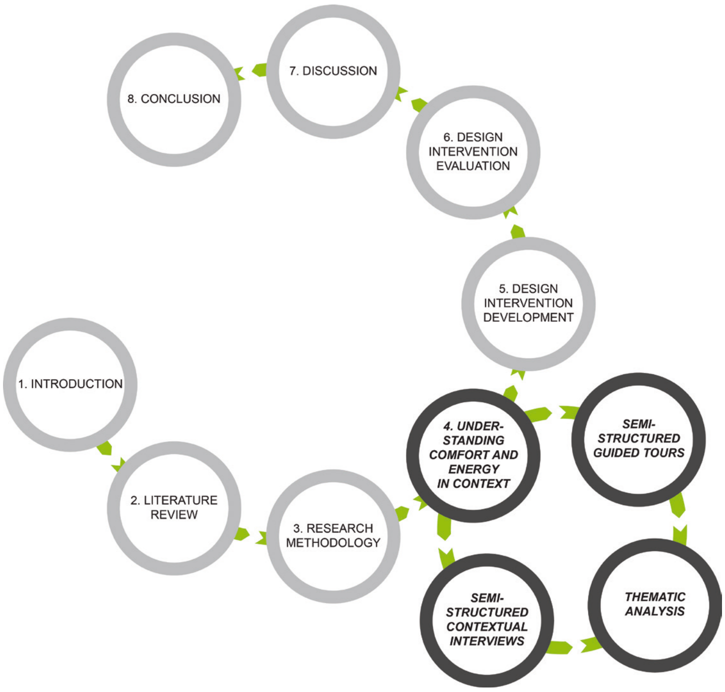
The aim of this short section is to provide a summary of the ethical procedures executed within this research study. Ethics as a part of DfSB and the design process are discussed in detail in section 2.7.

To provide ethical integrity to the research, several documents and checkpoints were instated at a managerial level for the project and researchers at Loughborough University to abide by. These documents include an Ethical Clearance Checklist as provided by the Ethical Advisory Committee at Loughborough University to assess the overarching ethics of the project; a project risk assessment to determine potential hazards during research; as well as an Ethical Protocol in relation to the security of research participant's personal information and data storage. Requirements included within this protocol are; the provision of information sheets and the requirement of signed consent by all participants, the guarantee of participant anonymity, the detailed recording of any 'incentives' given, as well as matters relating to the safe storage of data and the limiting of data access.

Furthermore, all researchers had an Enhanced Disclosure check by the Criminal Records Bureau [CRB] due to the potential of dealing with vulnerable participants. Additionally, all researchers carried visible personal and institutional identification when in the field of study.

4 Understanding Control, Comfort and Energy in Context

4.1 Introduction



It has been established through an extensive review of the literature, captured within Chapter 2, that the factors that drive and shape individuals consumptive actions are linked intrinsically to the complex combination of both behavioural cognitive processes and the facilitating conditions in which the individual uniquely operates. In order to design and understand the efficacy of a feedback intervention that seeks to reduce domestic energy consumption, it is imperative, therefore, that both the individual and the operating context are investigated and understood, thereby completing the second objective of this doctoral research:

> *To understand how inhabitants of social housing properties define and control comfort and its associated impact on their domestic energy consumption.*

This chapter presents the findings of this investigation, with discussions positioned in relation to relevant conclusions drawn from the literature review (Chapter 2).

4.2 Main Study Findings

Themes drawn by the researchers from the data collected through the interviews and guided tours centred on the main theme of *comfort* ,as depicted in the thematic map produced, Appendix F. Main Study Thematic Map, and can be disaggregated into the following (along with sub groups):

- Type (thermal, safety, aesthetic, activity based, light, aural, physical, freshness)
- Place (micro/meso/macro placement)
- Social (people, community, negotiation/conflicts)
- Regulation (knowledge, controls, money, meter)

The findings presented below are an abridged version of the 25,000 word thematic analysis report produced for the CCC project by the investigating researchers, with this section focussing only on the themes relevant to this doctoral research *(Hinton and Wilson, 2010)*.

4.2.1 Type

This first section concerns how participants understand and define comfort in their homes. Comfort was described in relation to multiple dimensions including thermal (in relation to the built environment, physical artefacts and systems), light (artificial and natural), aural, physical (pleasure/relaxation and health) and concerns for freshness.

4.2.1.1 Thermal

Thermal comfort is regulated through the occupants' use and knowledge of the built environment, heating systems and physical artefacts.

The sub-theme of built environment concerns the use of windows, vents, doors and insulation (including wall insulation, loft insulation, sealing around windows and general draught proofing).

Unwanted draughts seemed to be a major contributing factor to thermal discomfort described by the participants. In many of the households, participants reported that unwanted vents in addition to draughty doors, windows or otherwise inexplicable draughts all lowered comfort levels. Relatively modern double-glazing was attributed as a source of draughts by some participants, whilst others attributed coldness to draughts arising from ill-fitting external doors and vents. One participant describes how the removal of draughts greatly increased the comfort of her home:

> CA02F ...I find it a very comfortable cosy house. I mean, at one time I was having terrible draughts through the windows, but they came and done them for me and repaired them, and I find it really comfortable here.

CA05F responded to an ill-fitting, draughty window in their living room by completely sealing around it such that the window could no longer be opened:

> CA05F Well, like with the window there, there's no purpose to it at all. You [CA05M] were getting a stiff neck so I sealed it…you couldn't really get out of that to get out so I put seal all around it. It is freezing.

Several participants reported using various kinds of physical artefacts to regulate their experience of thermal comfort, including the use of fans, blankets, and hot water bottles. Clothing was used to regulate thermal comfort by many participants. In household CA02, CA02F's daughter would use clothing to balance out the different thermal comfort preferences between household members.

> CA02F's D ...I'll have my jacket on and my coat. Everybody else is walking around in T-shirts and I'm freezing all the time.

Several participants referred to the routine use of particular items of clothing such as dressing gowns as part of other everyday activities. Throws and blankets were used by some participants for both thermal and aesthetic comfort. Additional quilts were also used by one participant (CA03M) in particularly cold weather in his bedroom, one room that he never used heating in.

Thermal discomfort may arise when participants are too hot, as well as when they are too cold. Some participants reported using electric fans to keep cool when feeling too hot; CA02F installed a combined ceiling light and fan in her living room and had fans elsewhere in her home, whereas CA05F only used fans in particular rooms.

CA02F I've always liked the winter. I don't like the summer; I don't like the heat. I can't go out because I burn so much…I've got the fan by there look.

One participant reported relying on hot water bottles to improve her personal physical comfort regularly using hot water bottles to provide localised heat to the pain in her back throughout the year.

For some participants, the control and use of the heating system related to their perception of the fuel type concerned. Some participants with combi boilers perceived that they were relatively cost effective, providing a good thermal output at a high speed throughout the house:

CA02F We just put it on in the morning on the thing in the wall out there and in five minutes the radiator's boiling. It's good. It's very efficient.

-

CA05F I just put it on as and when I need it and it does come, you know, it warms up pretty quick.

The perception of electricity and its associated costs and values affected the use of several appliances by the participants, with many believing the cost of certain appliances to be too high to use.

CA01F I always think electric water would be expensive so I'd rather not use it…[Referring to the gas fire] But I would never use that because it would cost a lot of money, I would have thought…I think, monster, I'm scared that it's going to eat all the gas!

-

CA03M They've got the fan heater on the wall there but I don't put it on because they are expensive to run, those types of things. I think they are one of the most expensive things to run.

-

EDH So have you ever used the fire?

CA02F No. It's not even earthed because I don't want to use it because it's electric and it costs a bomb. So it's never been used…electric fires are very expensive, aren't they?

Whereas many participants demonstrated an awareness as to the cost of energy associated with using gas boilers or electric storage heaters or an electric fire, during the guided tours it was observed that many households left electrical appliances such as TVs, satellite and digital TV receiver boxes, video and DVD players and video gaming equipment on standby.

EDH	So in your grandson's room we saw there were various kinds of things…left on standby, would they normally be left on….?
CA02F	Yes. Do they use a lot of electric them?

4.2.1.2 Light

Many participants reported that light – both artificial and natural – influenced their evaluations and experiences of comfort within their domestic environment.

Households in this sample used a number of types of artificial light fittings, including ceiling lights, supplemental lights (including freestanding and table lamps) and lights associated with electric fires; these, in turn, used a range of types of bulb including CFLs, tungsten filament and halogen. CA02, CA04 and CA05 only used their electric fires to provide incidental lighting, never using the fires for the production of heat or delivery of thermal comfort.

CA02F	Yes, that's just a flickering light, that is…yes its lovely, reminds me of an open fire even though it's not like…
-	
CA04F	No, I don't use the fire. I just use it just for the lights. You know, it has the effect that it's on, like, it's cosier.
-	
CA05F	…I just put it like that, see, so I think it makes it look warmer just by looking at that…I shut the blinds, put the lamp on and the fire and then I sit down and read the paper.

Sidelights, lamps, and candles were found to be preferred by many of the participants when trying to relax, as opposed to the ceiling lights that were perceived to be a harsher type of light (preferred by some when completing tasks).

The use of natural light was found to be regulated by participants using windows, blinds, doors, and curtains. Natural light was also mentioned by a few of the participants as providing additional thermal comfort.

CA01F I think so, a yellow warmth, a light, you know. I love the sun, I get very depressed in the winter because then there's no sun, so I think it does help a lot the warmth in the sun.

4.2.1.3 Physical

The physical aspects of comfort may be addressed through engaging in leisure or relaxation activities, or through engaging in particular comfort practices necessitated by health conditions.

Participants reported relaxing in a number of different ways, including watching TV or DVDs, playing games, using the computer, drinking, and reading; the settee or chair in the living room, or bed in the bedroom played host to the majority of these activities. However, improving one's health or the restrictions imposed by an ailment have been shown to affect the comfort of the participant. Many of the participants found that certain ailments ruled out certain activities or interactions. CA01F found that her ailment prevented her from being physically able to access her boiler; for CA03M and CA04F, certain areas of the home were in effect off-limits or restricted access; for CA02F, particular pets were no longer tenable; and some ailments required special care or management.

EDH So I suppose this is your downstairs loo?

CA02F Yes…very handy when you can't climb stairs like me.

-

CA04F Well, in the heat, my feet... my legs just... my ankles just swell all up. If I stay too much... I can't stay too much outside. And in the cold then, in the winter, it's really painful on the joints.

-

CA03M …and you can actually feel it if you sit in there, if you've got these doors open in the evenings, not so much during the day unless it's very cold, but even in the evenings if you sit in there you can feel it on your legs; you can feel your legs are quite cold, you know. It does cause me a problem because of the arthritis; it tends to aggravate it a little bit.

Because of ill health, several routines appeared to have developed.

CA02F	I put it on every morning before the baby gets up, because he's got asthma so I need to make sure it's nice and warm for him.
-	
CA04F	Because I'm on the menopause…so I've got the [bedroom] window open and it's like that all night.
-	
CA07	…I like her [daughter] bedroom to be one specific heat like and if they're sick, one night it can be warm and then it's cold breezes and I wouldn't, I don't like it for her chest, because it closes. I might turn the radiators down to the lowest and see how that is.

4.2.1.4 Freshness

Several of the participants made observations about the air quality both indoors and outside. The attainment of 'fresh' air has led to several self-reported actions:

CA02F	Always in the morning I open the windows to let some air in…we open the doors just to get some air in and then shut them later on then.
EDH	So when you've got the windows open even in the winter, would you have the heating on at the same time?
CA02F	Yes, but I don't open them for long in the winter but I mean bedrooms got to have a bit of air haven't they…say in the winter about half an hour and then shut them then.
-	
CA04F	It has been cold. First thing in the morning and obviously it's really cold. [Unclear]...once I open the window the heating's on so when…once I've had the air in the house, then I shall close all the windows then.
-	

CA03M During the day you've got to have the windows open, particularly if you are cooking, because if you don't you will end up with condensation and black mould…

-

CA05F And if it's a nice day when we're going out I leave the bedroom window open for the fresh air and I walk in and run straight up the stairs because it's like an icebox then. You know, it's nice to have fresh air in.

4.2.2 Places

The location of an occupant within the home can have a significant effect on their perception and comfort requirements, as well as their performed activities. Within the home, during the guided tour participants were explicitly asked to decide upon which spaces were the most comfortable and which were the least. The results are presented in Table 4-1 below.

Code	**'Most Comfortable Space'**	**'Least Comfortable Space'**
CA01	Main Bedroom	Bathroom
CA02	Living Room	Kitchen
CA03	Living Room	Bathroom
CA04	Living Room	Kitchen
CA05	Kitchen	Living Room
CA06	Living Room	Upstairs
CA07	Living Room	Kitchen

Table 4-1 Most and Least Comfortable Spaces, Reported During the Guided Tour

4.2.2.1 Most Comfortable Space

When asked why their most comfortable space was, in fact, the most comfortable, a number of reasons were offered, not all of which involved privileging thermal definitions of comfort – although thermal comfort was cited as part of the reason a space was comfortable by some participants. For example, CA01F's most comfortable room was also considered a cold room:

CA01F … when you're in bed it don't matter, and I go and I watch some telly and my DVDs and I'm cosy, it's got to be my favourite room...but as I said, I still love this room because you can get in there and you're warm, and there's my hot water bottle.

For CA05F, the most comfortable room – the kitchen – was considered so because it was both bright and warm; it was also where she carried out most of her daily activities:

CA05F This is the room...because, you know, I'm cooking all the time and it's just…and it's brighter and it's – it's nicer, more pleasant.

Furnishings were referred to by some participants in their descriptions of why a space was considered comfortable, at times in relation to the types of activity that they facilitated:

CA02F Well because you've got comfortable seating and it's...I fancy it's warmest here.

Activity was referred to by some participants in their articulations as to why a space was comfortable:

CA06F Because I can relax down here more than anything and be with this lot [gestures to animals]. I normally have at least one vodka and coke in front of me while these all like a bottle of Blue. Oh yes, I've got alcoholic cats.

4.2.2.2 Least Comfortable Space

Interestingly, thermal comfort appeared to be an important factor in participants' articulations of why particular spaces were particularly uncomfortable.

CA02F That's my kitchen; it's cold…well, it is darker in here. The living room is not as dark as this.

-

CA05F It's comfortable in the way of the furniture that I've got in there, but for the warmth and that... Feel how cold it is here now…compared to the kitchen. You know, I was in here the other day and I had the heating on, but I haven't had it on today and you can feel how cold it is, can't you?

Not all participants had a least comfortable room; CA04F attempted to identify the least comfortable room as the one in which she spent the least time. In contrast to all other participants, CA06F referred to an entire zone of the house – the upstairs rooms – as being the least comfortable, instead of settling on just one room. She reported that these rooms were the least comfortable because of their current decor in addition to the objects stored in some of them, making the entire area feel 'messy'.

4.2.2.3 Factors Affecting Use of Space

Limitations due to health issues may restrict or increase access to certain parts of the home:

CA02F	I haven't got dressed yet...I only go up there once a day…to bath and go to bed…
-	
CA04F	I'm disabled, so I'm limited in what I can do, so it all depends. Every day differs. Like, sometimes I'm just up in bed and other days I may potter around.

Activities by visitors may dictate room usage:

CA02F	… my friends come and they're smokers, because I don't allow smoking in the living room because our baby's got asthma. So they come in here [kitchen] and have a cigarette like.
-	
CA04F	…because I'm a smoker and my family and friends are, and so obviously I open the window and the back door, because the only place we smoke is here [kitchen]…

Several homes with multiple occupancy based on age (such as mother and daughter, rather than husband and wife), tended to show that although there may be communal areas within the home, each 'group' tended to have their own specific room to engage in comfort activities.

CA02F	… they're only a young couple [daughter and son-in-law] so I like them to have privacy so they've got a big TV up in their bedroom and they watch their thing up there.
EDH	So, do you find you end up being in different rooms because they are too cold?
CA02F's D	Yes.
CA02F	She couldn't sit down here in the evening with me.

CA02F's D No.

EDH Oh, so you physically just move to a warmer room when you're too cold?

CA02F's D Yes. And she likes to watch her programmes down here, so I go and watch whatever I want upstairs. But I stay in bed all day.

4.2.2.4 Micro Placement

The location of a participant within the environment may be determined by proximity to a point of comfort.

EDH So when we were here last, your daughter was sitting by the radiator. Would that be normally where she would sit?

CA02F Yes, on top of it if she can.

EDH So when you're here you always make sure you get a seat by the radiator?

CA02F Yes.

-

EDH Well, just kind of how do you feel comfortable? What do you do?

CA05F Well, that's my chair over there next to the radiator because there's no fire here. There's just an electric fire here I like to put on with the red light on.

Furthermore, micro placement may also be in relation to a 'comfort activity': the combination of thermal comfort and the ability to undertake particular activities recurred throughout the dataset. CA05F spent most of her time undertaking room-specific activities in her most comfortable room, the kitchen; others reported positioning furniture and furnishings in particular ways in order to undertake particular activities.

4.2.3 Social

Social factors influenced actions and experiences of comfort for many participants. Members of the community may pass in and out of participants' homes; friends and family members may visit for short or long periods, irregularly or frequently; and many participants kept animals as pets.

4.2.3.1 Negotiating Comfort

Different members of the household may have different perceptions of comfort within the home; the presence of visitors may also require a negotiation in practicing comfort. In some households, different members of the household had notably different thermal comfort requirements. In CA02, CA02F prefers cooler conditions whilst her daughter prefers the warm and refers to herself as 'a freezer'; in CA04, CA04F prefers cooler conditions whereas her husband, CA04M is 'a freezer' and prefers it to be warmer; in CA05, CA05F describes herself as 'a freezer' whereas CA05M normally doesn't feel the cold. This can result in different members of the household regularly altering thermostats of different kinds to attempt to manage their own comfort:

CA02F	I change it. Like tonight now I will put the heating on when it goes a bit chilly in the evening. I will just put it [thermostat] on to 15. But in the winter I will turn it up for the rest of them, the freezers.
CA02F's D	I turn it all the way up anyway.
EDH	So, what kind of temperature do you turn it up to?
CA02F's D	30.
EDH	30? And you keep it at 15?
CA02F	Yes!
EDH	So do you find there is a little bit of… you notice someone has changed it and you go and quickly change it back?
CA02F	She goes behind me. She turns the radiators up.
CA02F's D	When I go into the toilet in the morning, she turns the radiator off in the little toilet, but I go…
CA02F	It's a waste of money, isn't it?
CA02F's D	I turn it up to five, and then you can't breathe in it. But then I like it when I go back. Then I go in oh, she's turned it back off. And I turn all these up to five. She went out last night so all these went up to five. And now they're on two again.

-

CA04F	Oh, he'd be happy to have it on 30 all the time, he [husband] would…yes, he's a freezer, he is.
EDH	Okay. So does he do that? Does he turn the heating up quite a lot?
CA04F	Yes.
EDH	Okay. So... but him being here doesn't change how you use the heating, necessarily? You still keep it normally on 20?
CA04F	I normally keep it on 20.
EDH	So what happens when he changes it? Do you, kind of, let it...?
CA04F	No, I shout at him then, turn it back down. That's what it's like all the time. I'm more of a warm person and he's really a freezer.

Health issues may also create comfort preferences in conflict with those of other household members.

CA02F	I've got a fan on the ceiling and a big stand up fan, because I've got emphysema and I've got to have… And she'll [daughter] come in and go oh, it's freezing; I'm like it's lovely. I don't like a warm bedroom; I like to walk into a freezing bedroom, and then it's so nice when you get under the quilt.

Particular visitors, and their particular requirement, may influence how participants regulate comfort in the home:

CA05F	I usually put it on when my daughter's coming because she's got a heart problem and she feels the cold terrible. So If I know she's coming I've usually got the heating on and she sits in the kitchen right by the radiator, doesn't she?
-	
CA07	…well, the other night, my neighbour was complaining it was cold in the house, but it was, to us, it was warm, so I just put the heating on higher than what it normally is because she was cold, so it was on for her really.

4.2.4 Regulation

This theme concerns the ways that participants regulated their heating systems, and the particular forms of knowledge that they draw from to do so, including the use of controls (including routines of turning heating on and off and the use of various kinds of thermostats), knowledge (spanning direct and indirect experience), the use of meters and the role of money.

4.2.4.1 Controls

Participants interacted with a series of controls to regulate their heating systems ability to produce conditions of thermal comfort. For those with gas central heating systems, these included the use of multiple thermostats and programmer/timers; for our participant with electric heating, this involved interactions with storage heaters.

Turning the heating on and off was achieved in a number of ways: through use of the thermometer; use of the programmer/timer; or directly on the boiler. One participant (CA07F) reported using the thermostat to turn the heating on and off; she said that the thermostat is an easy way to control the heating, and that using the thermostat to control the heating reduces her consumption of gas compared to if she did not have a thermostat.

> CA07F …I'd always set it [the thermostat] to a certain temperature, so if it goes below, it will knock on automatically, so I don't use as much gas as what I'd normally do.

The rapidity of the heat provided with the new boilers installed, suggested by one participant, made the use of a timer an unnecessary practice.

> CA02F Well, I just prefer to control it. Because with a combi boiler it is practically instant heat anyway. You know what I mean? If I get up at seven and put the heating on, by five past seven they're boiling, you know; whereas some of the old boilers they take ages to work. But it is practically instant heat anyway, so it's not worth the bother.

Participant CA01F found the use of timers 'restricting', preferring to turn the hot water and central heating on and off when required. No participants admitted to regular use of the programmer/timers for their gas central heating. The programmer/timers were never used for CA05 and CA06, although CA05F did previously use it when she was working, but no longer feels she needs to.

> CA05F No, I know how to use the timer, I used to…When I moved in here first I was living on my own and I was working…but I don't work now so I'm

here in the day, so I just put it on as and when I need it and it does come, you know, it warms up pretty quick.

CA05F also believed that using the programmer/timer was wasteful because it would result in the provision of space heating when it was not necessarily required.

CA05F I used to use it when I first moved in but it seemed a waste because, say now, you know, like as it's starting to get warmer, you'd have the timer to come on, but there wouldn't be any need, really. You know, say I always get up and go straight in the shower, well, if I wanted to I could run down and put the heating on for it, you know, for it to be warm down here anyway. But I think it's a waste using it.

Only one participant, CA07F, reported currently using the programmer/timer; she uses it only when she plans to be away from home, in order to keep the house warm and to prevent the pipes from freezing.

For most households with room thermostats, these were located in the hallway (with the exception of CA01's, which was located in the kitchen); CA06's heating system was the only gas central heating system that did not have a room thermostat. Many participants reported setting their thermostats at somewhere between 15^{o}C and 20^{o}C normally, although when they were cold and wanted the house to warm up quickly, some participants (CA05F and CA07F) reported turning the thermostat up either higher than normal, or to the maximum setting, for a time until the house heats up and then setting the thermostat back to what they would normally have it set to. CA04F reported that she does not undertake this practice because she believes it to be wasteful:

CA04F Well, what I do do... A lot of people, they just put it on high and then turn it down. I fancy that's wasting too much money. I'd rather leave it on number 20, constant, like that. I find it cheaper to run it on number 20.

Two participants (CA05F and CA07F) referred to the thermostat turning the heating on when the temperature dropped below a certain level. CA05F said she knows that this is happening because she can hear the sound of the thermostat clicking on and off, and seemed to consider this in a positive light.

CA05F If it's really cold I turn it right up for, say an hour, until I can feel the heat coming out and then I like to have it on that. Or sometimes what I do then, I turn it even lower so, you know, if it comes quite warm, it warms up and then it goes off and then you can hear it clicking on and then it goes… it warms the radiator up to a certain temperature and then it goes off. And then in about 20 minutes it'll warm up again so you don't need it on constantly.

Most houses with gas central heating had TRVs on most, if not all, of their radiators (bar CA01F who had no TRVs on any radiators). Most participants (CA02, CA05, CA07) had the TRVs on different settings in different rooms, depending on: how cold the room normally gets (the TRV in CA07's kitchen, and CA07's and CA05's lounge, are normally set to maximum because these rooms are normally cold); how warm or cold that the room feels at any given time (e.g. CA07F adjusts TRVs in rooms depending on how warm the room feels); the activity that was planned for that space (CA05F reduces the TRV setting in the kitchen when she is cooking to compensate for the heat from the cooker, whilst CA07 turns up the TRV in the bathroom when she plans to bathe her children); to reflect particular preferences for particular rooms (both CA05F and CA07 keep the TRV in their bedrooms set relatively low because they prefers a cooler bedroom).

CA05F I'd turn the one off in the kitchen because it's warm in there, obviously, with the cooker and everything on so that the rest of the house is warm. Upstairs I've only got them on low. This one's on full.

Two participants (CA04 and CA06) reported never altering the TRVs, where these were all set on the maximum setting; CA06 also does not have a room thermostat.

4.2.4.2 Knowledge

Participant knowledge can be grouped into themes pertaining to direct and indirect experiences, theories of how things work or how they believe they should work and the use of energy and payment meters and the methods through which energy consumption is paid for.

Participants reported perceiving and evaluating the functionality or comfort performance of their house and heating systems in many different direct ways.

Several senses were involved in signalling such performance: touch (e.g. knowing that the heating is on because the radiators feel hot, or feeling draughts), sight (e.g. the presence of condensation, mould growth or dust around CA05's Dry Master), sound (e.g. the sound of the Dry Master working, the thermostat clicking on and off, or the sound of the pump on the heating system working in CA05's house) and smell (CA01's kitchen cupboard smelt damp and so she did not use it).

CA05F	I mean, if you touch that radiator it is very hot and I've got it on 20, I think. You know. It's halfway, say. But it does warm up. You could feel… you know, switch it on and within five minutes you can feel it coming through the radiators. It's very good and the hot water's marvellous.

-

CA01F	Well because you know it's on, I mean, like I know it's on now because I pushed the switch down.
GTW	Okay.
CA01F	Sometimes you don't – you're right, when you suddenly go brr, not in here but downstairs and I think, what? And I touch it and…oh it's like now, it's cold.

Responses were made on the basis of the sensory stimuli already listed, in addition to evaluations of temperature (of spaces and radiators), speed (the speed with which hot water is available through the taps or in the radiators) and quantity (relating to the quantity of radiators to heat a space). For example, CA05F and CA05M believe that there are an inadequate number of radiators to heat their hallway and landing area. Some participants compared their current houses to those in which they had previously lived, and on this basis evaluated the comfort performance of their current property. CA05M, for instance, reported that their current, relatively modern house is not as warm as his previous, older home.

Some participants described why they do and don't do particular things with reference to personally held theories as to how systems work. These theories concerned the energy intensity of different actions, how heat and moisture behave in the home, how different devices and systems work and the health benefits of particular actions.. CA05F reported turning some radiators either down or off in order to prevent their 'taking' heat from elsewhere in the house.

CA05F	The [radiator in the] passage is on three because there's… You know, I think, if that's on full there's no heat in the rest of the house, it takes it all.

Theories of how things *ought to* work may at times be based on comparisons to a historically used system. CA02F believes that gas central heating is inherently less healthy than a house heated by a coal fire:

CA02F	… my father was a miner and we always had the coal fire. There was a fireplace in each room so if you were ill in the winter my mother would light the fires in the bedrooms. It was lovely. I think this is a lot of causes of bad chest: gas, central heating, it's dry isn't it, and coal fire was so much nicer.

Judgements and evaluations as to the comfort performance of the house, how to run it efficiently and judgements of the acceptability or otherwise of energy consumption, were often made based on indirect experiences - comparing with what they had heard from friends, neighbours or family members (which we can think of as 'hear say'). For example, CA05F and CA05M referred to how one of their friends uses their heating system, but they reasoned that this approach is not right for them:

CA05F	Because some people reckon to leave the heating on all the time, put it on, you know, say 15 and just leave it to run the whole time because you're not wasting energy then warming up from scratch. But I could never, we could never have it on in the night to go to bed…they reckon it's cheaper to just leave it to run on a bit lower than warm it up each time you know, but. It goes against the grain, that, to just leave it. You think, no, no…
CA05M	I don't see the point of it, personally. If you're out and I'm out, well, I'm always out all day, why run it, like, you know? Why use the gas when there's no-one in? Doesn't it take… I mean, as [CA05F] said, once it's on, within ten minutes, quarter of an hour, the house warms up, doesn't it?

The presence of the physical monitoring researchers, and their equipment, imparted a further element of expert knowledge to participants. CA01F explained during the guided tour where the problematic areas of her bedroom were, with reference to knowledge that the physical monitoring researchers had imparted to her during the course of producing a thermal image of her property several weeks previously:

> CA01F …and apparently the damp – the area they filmed was there really…but it doesn't show, doesn't look – well not damp but cold spots, sorry cold spots.

Participants did not always agree with the expert knowledge; in several cases this caused conflict against the participant's knowledge or opinion.

> CA01F Yes, so and the man surveyor said, oh, no, that's fine, it's because you've had furniture there, it's a blind… not blind spot, some other – what did he call it? And I thought that's baloney, and it's been empty that space for a long time now and it's, ughh, you can see all the whitish stuff growing. Ughh.

The majority of participants' houses had prepayment (or credit) meters installed for both gas and electricity. These households were required to interact regularly with their meters to add credit to their energy accounts with the monitoring of energy consumption in terms of how much money was left on the meter rather than how many kilowatt-hours or cubic metres of gas they had consumed. Topping up of these meters was also found to be ritualistic, with many participants indicating a regular routine of checking, going to a regular purchase point, and topping up on certain days of the week.

> CA07F I have to check, I check it some days just in case I think, oh, I might be running low, but other times, I, sometimes the £15 will last me the entire week.
>
> -
>
> CA02F I don't know. Every Monday I automatically get £10 on each. And then I go up the road on a Thursday, I have a look then to see if I need more…I never leave myself without.

The use of meters also allowed participants to be aware of the consequences of using more energy intensive appliances.

CA04F Yes, [unclear]. As I say, there's only me and my husband so we really don't need a lot of electric, to be honest, like. I can get away with putting £5 a week in mine, except…the drying and the washing. That's different. So I usually put about £10.

Households CA01, CA03, CA04 (gas only) and CA05 had debit meters installed, but paid for these in different ways. CA01 used the internet to pay by bank card, CA03 paid in full on receipt of the bill, whereas CA04 and CA05 paid by direct debit. None of these households read their own meter; CA03's was locked away in a room to which he was not permitted routine access, whereas CA05 and CA01 relied upon external meter readers to routinely read their meters and provide them with accurate bills.

GTW [Do] you regularly check your meter, your electricity meters, I mean?

CA01F Oh, God, no. I don't do things like that…Well, a man still comes out to read them…and then I usually get him to tell me what they are, and I write them down and then when the bill comes, I check that they correspond online what he said they were when he came round. So that they're not ripping me off by thousands.

Typically, participants reported being happy with their energy bills, with many receiving a tax free £100-£300 payment for fuel from the UK government due to the cold winter (the Winter Fuel Payment is eligible to those born on or before 5th July 1951 and claim State Pension or social security benefits *(UK Government, 2013)*). One participant, CA05F, reported consciously trying to use less energy for fear of a high energy bill over the recent cold winter period:

CA05F I've started putting a cardigan on, which I never used to before…well, I started thinking, you know, before we had the bill I was thinking, oh, my God, what's this bill going to be like? And if, like if I wouldn't be too warm then I think, oh, I'll try a cardigan. You know, with the bills. I don't like to waste it, mind, I've got to be honest. I do knock it off quite a lot.

CA01F reported that waiting for a bill could be stressful, and affected her use of energy in the home:

CA01F …when it came, I couldn't open it, I felt my stomach go, ugh. Oh no, it was an email, that's what it was. It was… I know you'd want to know that energy bills are ready to view. I thought, no, I don't want to… But I had to. But before… because I smoke I had to have a cigarette, I really felt that nervous, I thought, oh, I can't bear it…

In contrast, CA02F believed that the cost of energy is irrelevant as it is a necessity; she therefore does not worry about the cost.

CA02F I don't really care what I spend on gas and electric because to me that is as essential as food, isn't it, heating. So, I never make a bother about that really, do I?

4.3 Discussion

From the findings presented above, it is clear that the attainment of domestic comfort is intrinsically linked to perceptions of energy and the myriad of mechanisms through which its consumption is controlled. In order to further this discussion, the above findings have been framed with reference to the body of literature reviewed in Chapter 2, with specific attention given to the antecedent structure of behaviour as posited through the augmented Theory of Interpersonal Behaviour (as defined in section 2.2).

4.3.1 The Intention to Consume - Attitude, Social Factors and Affect

Attitudes towards energy and comfort have been shown to have an impact on the intention of the individual to consume. Several participants had a perception of the monetary cost of energy, in particular electricity used for space or water heating, which directly influenced their use of comfort providing devices. Phrases yielded by participants, such as '*electric water would be expensive*', and '*electric fires are very expensive*', not only highlight heuristics associated with cost expectations, but also illustrate the emphatic association between the product and consumption (as opposed to describing the product by its output, such as the term *hot water* instead of *electric water*). Interestingly, however, this association does not seem to extend to smaller consumer products, such as TVs, where the energy consumed on standby is often not even considered, supporting the perception of energy as being generally of low interest *(Burgess and Nye, 2008, Fischer, 2008)*. The attitude of one participant towards the use of gas-powered space heating considered it *essential*, on a par with the necessity of food and therefore did not consider the cost or mitigating its use. Perceptions of the size of the device have also been shown to affect the perception of energy use, '*I think, monster, I'm scared that it's going to eat all the gas'*. Perceptions are also to an extent steered by historic associations, such as the use of coal fires being perceived as being healthier than gas central heating.

Direct and indirect experience of using energy-consuming products to provide comfort has also had an impact on the ways in which the participants interact with these devices. The perceived output and efficiency of gas central heating is generally considered a substantial benefit, with the expectation that when the heating is *put on* that the home will warm rapidly. Such expectations are evaluated through multiple physiological senses, such as the touching of a radiator to determine its temperature and the *clicking* sound of a boiler to confirm its activation. One tenant illustrated that although she believed the heating system to be on, upon touching the radiator she found it to be turned off by the thermostat settings. Although the intention to act was initiated and the behaviour complete (turning on the central heating system), the outcome from the system was unexpected and invisible to the participant. The use of programmers and heating strategies (such as leaving the house at a lower temperature constantly) are considered redundant due to this perceived rapidity of benefit, with automated products and the heating system active when it is not perceived to be required going '*against the grain*'.

Social factors have also been shown to influence the consumption of energy towards the attaining of comfort. There is clear evidence that many of the participants have knowledge in how neighbours and friends manage their comfort and energy systems with considered opinions framing their own consumption as being more or less in comparison. The effect of friends and family to an extent also dictates room usage, and by extension energy usage and comfort, with a consensus amongst those that smoked (or had guests that did so) that the kitchen with the back door or window open was acceptable. The primary influence of social factors within this sample was noted within those households with multiple occupancy. Members of the same household generally had competing comfort expectations, leading to the frequent use of terms like '*he's a freezer*' to denote those that preferred hotter thermal conditions. This often led to conflict, with ad hoc changes to the heating system often carried out without informing other tenants, although this has been shown in some cases to be avoidable with different layers of clothing. Social factors were also embodied through the role of the primary participant (who was also in all cases the tenant that spent the most amount of time at home and the one in primary control of the heating systems; a form of *heating guardian*). The primary participant often fulfilled the role as carer or maternal figure for the household, adjusting and controlling the temperature to suit the health requirements of other household members or visitors, sometimes in detriment to their own preferences.

The role of emotions was noted as one of the primary factors in determining the most and least comfortable spaces alongside thermal and furnishing preferences. The abundance or lack of light has been found to make spaces more '*pleasant*' or '*depressing*' respectively. The extent to which light has been used to generate comfortable environments is evident in the proliferation of electric fires that generate an artificial light reproduction of a coal fire but the heating function of which is never used. Statements such as '*I think it makes it look warmer*' and '*reminds of an open fire*' have emotional attachment, recalling past family members and previous households that had and operated coal fires. What this also represents is a disaggregation of the heating mechanism and the natural feedback it provides. Coal fires are explicit in their function as the heat is synonymous with the light it produces. The modern systems found in many of the homes here have a gas powered central heating system with no natural feedback mechanism. The focal point of the living room is still the *fireplace*, however, it is no longer part of the *actual* heating system and offers nothing in terms of understanding the consumption of gas for space heating.

Emotions attached to the paying of energy bills, or more specifically, to the *unknown* amount that bills *may* be, include nervousness and fear. To an extent, the unknown parameter of consumption quantity drove participants to become uncomfortable and/or start to explore alternatives such as the use of extra layers of clothing.

4.3.2 The Automaticity of Consumption – Habits

The self-reported nature of interviews and the guided tour makes habits, discernible through frequency of behaviour and automaticity of cognitive function, difficult to evaluate. Having said that, certain self-reported routines were clearly stated, revolving around the use of heating systems during winter, the year round attainment of fresh air and the payment of energy consumption.

Ill health, in itself a facilitating condition, has prompted several routines such as putting the heat on first thing in the morning or leaving the window open at night to alleviate the symptoms of medical conditions. As the majority of the participants in this case study have underlying medical issues, it is important to consider that requirements for physiological comfort may differ from what may be considered to be *average* or *normal*, propagating quite unique habits within the household. The use of prepayment meters has also created routinized behaviour, with the checking of meters and purchasing of 'credit' becoming a regular event, whether necessary or not. With the regular pre-purchase of a set quantity of energy, one can foresee a secondary effect, indirect rebound whereby the amount saved through feedback or other behaviour change mechanisms focussed on heating or otherwise may be transposed onto another energy consuming act, thereby maintaining the amount of energy consumed *(Sorrell, 2007)*.

The prevalent self-reported habit here was the pursuit of *fresh air*. Several participants stated that even in the height of winter they opened windows and doors to their home daily, even in some cases with the heating on, to '*get some fresh air in*'. Although the participants displayed awareness as to when they perform this action, the action itself clearly displays aspects of habitual behaviour. Exhibited were a history of frequent past behaviour, efficiency (always performed at the same time in the same way), difficulty in controlling the behaviour (still performed despite the hostile external weather conditions) and a sense of identity linked to cleanliness and the protection of other household members. Although the impact of opening the windows and doors in parallel to having the heating system active is a contradictory use of comfort management systems, the consumptive effect on the heating system is not considered relevant by many of the participants, even in homes where they were concerned with energy consumption. This may be due to the lack of information portraying the consequences of this dichotomy or the lack of individual's knowledge as to what this effect may be. In addition, the perceived convenience of having a rapid and efficient boiler may outweigh the cost in terms of effort for turning the boiler off during this period or the time it takes to heat the home back up to a comfortable level. Interestingly, draughts were not considered in the same vein as controlled air management, with tenants finding unwanted draughts to be an undesired nuisance.

4.3.3 The Enabling and Constraining of Consumption - Facilitating Conditions

Several facilitating conditions are clearly linked to the built environment and the provision of comfort controls. The rapidity in the provision of central heating, as previously stated, allowed participants to use the heating system on an ad hoc basis, heating and cooling the home as and when it was deemed necessary. The use of TRVs, room thermostats and boiler controls reflected this desire for contextual control based on the participant's perception of comfort at a given time. In some cases the thermostat is used to ensure that the heating system will turn itself off at a desired temperature, but at other times, it is dependent on the perceptive ability of the participant, sometimes waiting for a comfort extreme, such as being '*boiling*' or too cold, before acting to adjust the system. There was also a lack of knowledge noted when relying on the thermostat, which, on occasion after having been set, may turn the heating system off or on without the tenants awareness. Lack of knowledge and excessive energy consumption through extreme use can both contribute to a wasteful consumption of energy and prevent the fostering of optimised use through a developed understanding of the consequences of their action.

Aside from placement within a space, such as the living room, which was often determined by proximity to heat and light sources or influenced by physical activity, such as watching the TV, it is apparent that the health of the participants in this case study was a major facilitating condition to their action. The health of several participants prevented them from accessing certain parts of their own home and introduced habitual behaviour in the form of coping mechanisms, such as remaining bed ridden for large stretches at a time or leaving windows open at night. It is evident from the findings presented that the management of comfort for health benefits, in terms of physical disabilities or thermal and air quality, takes priority over the monetary cost and consumption of energy.

4.4 Conclusions

Recognising though the literature review, presented in Chapter 2, that the consumptive acts of the individual may be formed and perpetuated through a complex intertwining of cognitive process and context, the aim of this chapter was to provide resolution to the second objective of this research study:

> *To understand how inhabitants of social housing properties define and control comfort and its associated impact on their domestic energy consumption.*

The findings and ensuing discussion, presented thematically and then discussed in relation to the augmented behaviour model the Theory of Interpersonal Behaviour (as defined in section 2.2), provides this understanding.

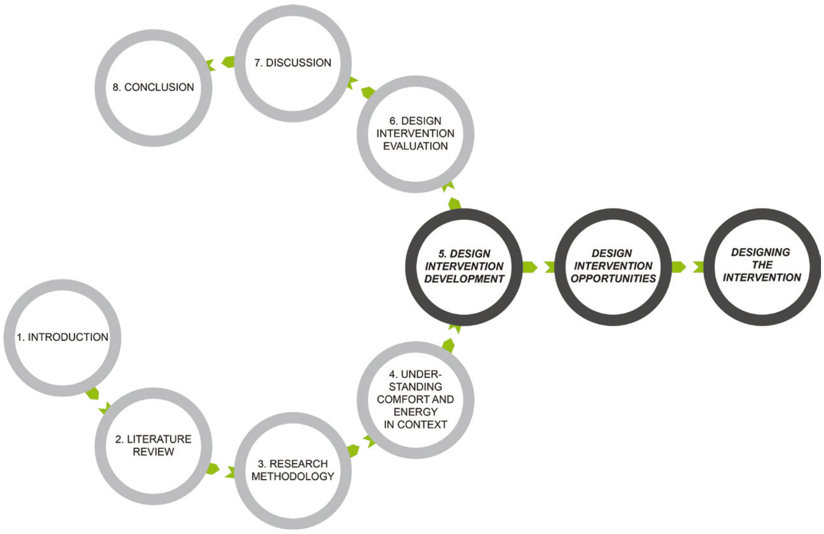
Comfort has been thematically illustrated to encapsulate not only thermal aspects, but also dimensions related to light, sound quality, physicality and the desire for freshness. Expanding upon this, the effect and perception of space has been shown to be relevant to this defining of comfort and its impact on energy consumption, as has been the effect of social influences, such as friends and family and the level of knowledge that the participant has garnered through both direct and indirect experiences. The built environment has also helped to influence this knowledge, as well as to provide the necessary controls in which to attain this definition of comfort.

From a psychological perspective, it has been shown that whilst the factors that form intention, namely attitude, social factors and affect, do have a direct and profound influence on behavioural action and domestic energy consumption, they may be mitigated by habitual action, such as the pursuit of fresh air. In turn, this is checked through facilitating conditions including participant health and control technology.

The next step for this doctoral thesis is to position these findings within a design process, exploring the process by which this information can be used to generate insights and opportunities which in turn can be used towards the design and evaluation of feedback intervention concepts and prototypes.

5 Design Intervention Development

5.1 Introduction



With the intervention context understood, the process through which this knowledge and understanding is managed and translated towards the *solving* of the *problem* must be considered if the following research objective is to be realised:

> *To design and produce a feedback intervention prototype that intends to reduce domestic energy consumption whilst maintaining inhabitant defined comfort levels.*

This chapter discusses the design process and the positioning of DfSB strategies within these models, moving on to explore methods through which the qualitative understanding and themes established in the previous chapter can be worked and transparently managed towards the generation of tenable design opportunities. The later sections of this chapter consider the generation of solutions within this design process, culminating in an intervention prototype.

5.2 The Design Process

A design process is a sequence of standardised activities that moves the designer from an input to an output, or from a problem to a solution *(Dubberly, 2004, McClelland and Suri, 2005, Cross, 2007, Cross, 2010)*. Defining the process through which this transition takes place has led to a proliferation of models, with each proposing a different collection of methods and approaches towards reaching a design goal. Dubberly *(2004)* presents an extensive, but by no means exhaustive, catalogue of over one-hundred design and development processes, highlighting the breadth, diversity and the apparent need for both academic authors *(Pugh, 1990, French, 1998, Pahl et al., 2007, Cross, 2010)* and the design industry *(IDEO, 1999, Dubberly, 2004)* to create formalised and structured processes. Adhering to a structured process, it is suggested *(Cross, 2007)*, can lead a designer efficiently, logically and repeatedly to multiple *good* solutions. Design practice, however, is not always carried out in a systematic way, with designers often reaching good solutions through *opportunistic*, non-structured routes *(Cross, 2007)*. Whilst each strategy has its positives and its negatives, the key point to emphasise is that an unstructured or ad hoc approach to the design process is not repeatable *(Dubberly, 2004)*. If we consider the design process required for this research sitting within a case study approach it is essential that the process followed can be made repeatable. Repeatability is important in order to reflect upon and improve the process for subsequent reimplementation and furthermore that the results and process can be generalised against extant theories and case studies.

DfSB is already moving towards systematic implementation within the design process, with several authors *(Selvefors et al., 2011, Tang and Bhamra, 2011, Zachrisson et al., 2011)* tentatively producing new models that account for DfSB at each stage of the design process. Each prescriptive model follows a similar linear trajectory, moving from an exploration and identification of the problem or target behaviour towards identifying and implementing an appropriate intervention strategy. These models, however, are embryonic and still open for debate with a lack of supporting case studies. Therefore, for the purposes of this research it may be more appropriate to implement an already established design process, specifically one that revolves around the techniques that have so far been implicit in DfSB anchored design schemes; the User-Centred Design [UCD] process.

UCD (otherwise known as Human-Centred Design *(British Standards Institution, 2010)*), is focussed on understanding the user, their tasks and context, accounting for their needs and requirements as opposed to commercial or technical issues *(IDEO, 1999, British Standards Institution, 2010, McClelland and Suri, 2005)*. The rationale for employing a UCD process in this research is primarily that the principles of UCD are synonymous with the principles and requirements that are being established and developed through DfSB research. These UCD principles, as stated by the ISO standard for Human-centred design for interactive systems *(British Standards Institution, 2010)*, include:

- the design is based upon the explicit understanding of users, tasks and environments;
- users are involved throughout design and development;
- the design is driven and refined by user-centred evaluation;
- the process is iterative;
- the design addresses the whole user experience;
- the design team includes multidisciplinary skills and perspectives.

These principles clearly resonate with the key features of DfSB, as discussed in section 2.6, concerning the need for the forming of an on-going understanding and dialogue between the user and a multidisciplinary team, which establishes the knowledge base and interactions through which to specify, design, iterate and evaluate behaviour change interventions. Furthermore, involving the user throughout the UCD process ensures that the ethical rights of the user and other stakeholders have been accounted for and multistable effects considered. These UCD principles have been codified into a design process or series of *activities* within this BS EN ISO 9241-210:2010 standard, as illustrated in Figure 5-1.

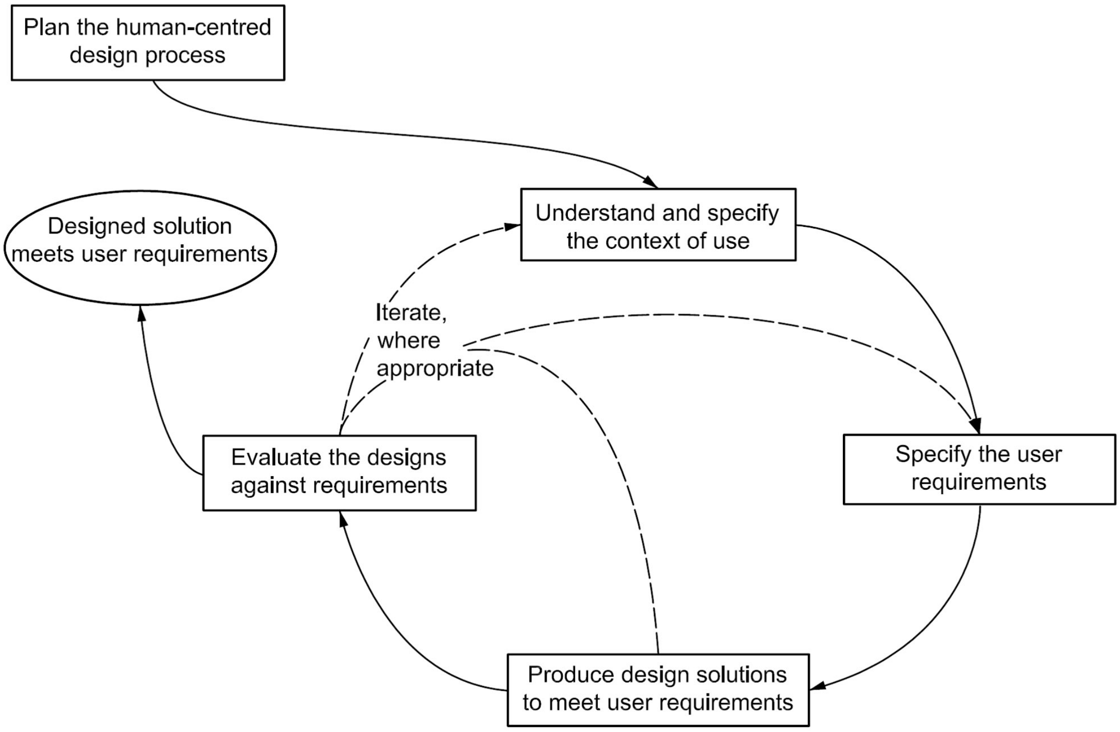


Figure 5-1 HCD Activities (British Standards Institution, 2010)

A UCD process typically follows a cyclical, iterative structure, beginning with the exploration, understanding and specifying of the context of use and the users' needs and requirements. Although presented as disparate phases within the ISO standard to emphasise their relative importance, in reality, the user and the context are inextricably linked and this understanding and specifying of their features and criteria may be established concurrently *(IDEO, 1999, McClelland and Suri, 2005)*. If the aim of DfSB is to change the behaviour of a user, composed of intention, habits and facilitating conditions, then clearly this stage is vital to developing an understanding on which to base, inform, and evaluate future design decisions to reach this goal. A second phase discussed in UCD literature *(IDEO, 1999, McClelland and Suri, 2005)* but not explicit in the ISO model concerns the identifying of design opportunities, a point of synthesis, turning the qualitative data gathered in the preceding phase into forward facing statements of design direction. Opportunities from a DfSB perspective could be related to identifying specific behaviours and actions to target or strategies to implement. Returning to the ISO standard, the next phase concerns the production of design solutions, a formalising of design knowledge (function, aesthetics etc.) into concepts that address the opportunities identified and that are in line with the understanding and expectations of the user and context *(British Standards Institution, 2010)*. DfSB solutions that respond to the ill-defined problems and opportunities identified can be explored and iterated from a large number of initial concepts to an eventual convergence on a single concept *(Pugh, 1990, Cross, 2007)*. The next phase, but not necessarily the final phase, is a user-centred evaluation, an evaluation of the concept (and assumptions made) with real world users *(McClelland and Suri, 2005, British Standards Institution, 2010)*. A DfSB evaluation specifically concerns the evaluation of the design, sustainability and behavioural aspects (as discussed further in Chapter 6) benchmarked against the user and context as identified in the initial understand and specify phase as developed through the course of the design process. This phase may not be the last as the evaluation may uncover or illuminate a need for further information or redefinition of the user, context or opportunity (an iteration back to the understanding and specifying or intervention opportunities phases), or may also illustrate design weaknesses that require improvement (an iteration back to the intervention design phase). For the purposes of this thesis, the definition of the UCD process as described above can be visualised as the following diagram, Figure 5-2.

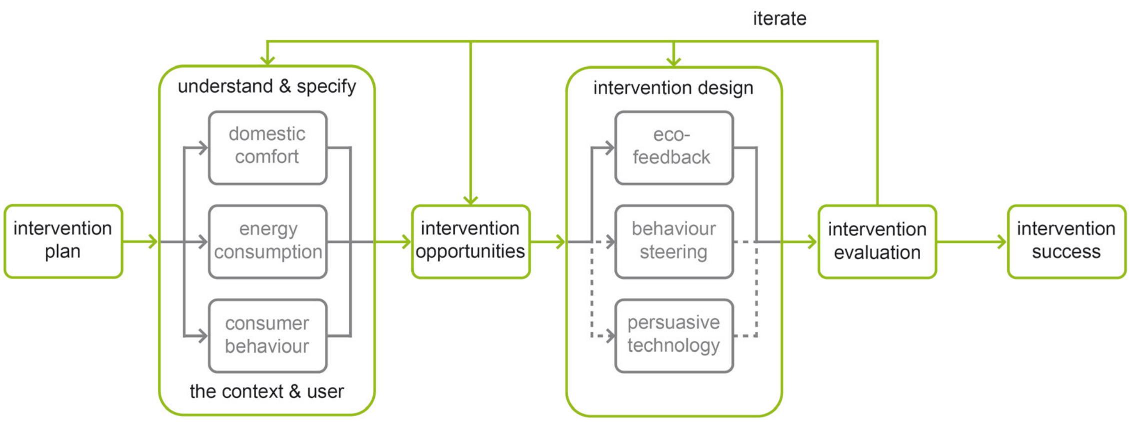


Figure 5-2 The Design Intervention Process

The *understand & specify the context & user* phase maps to Chapter 3 of this thesis, with Chapter 6 concerning the *intervention evaluation* phase. This chapter relates to the *intervention opportunities* and *intervention design* phases, as discussed in the following sections.

5.3 Design Intervention Opportunities

Drawing from the IDEO Human Centered [sic] Design Toolkit *(IDEO, 1999)*, this section concerns the method for generating *areas of opportunity*; the reframing of a theme or insight based on empathic qualitative research, into future facing opportunities for design investigation. Once *areas of opportunity* have been determined, they are then used to direct the ensuing design effort or to refocus the original design brief.

5.3.1 Insights

In order to develop the qualitative research into *opportunities*, insights based on the data needed to be uncovered. Through the process of uncovering insights, the hidden meaning of the observation was made visible, as opposed to a loose collection of individual stories or actions. This process helped this researcher to engage with the data to uncover unexpected behaviours as well as to perceive the research and project challenge from a different perspective *(IDEO, 1999)*. The themes in this project, as mentioned previously, were inductively generated (an inductive analysis is data-driven, attempting to generate themes from the data, and not fit the data into a predetermined framework), with semantic themes drawn (semantic themes involve interpretation by the researcher on an explicit level, not attempting to understand the underlying ideas and assumptions that may form the data) *(Braun and Clarke, 2006)*. The process of converting the themes into insights, was an attempt where possible, to understand the underlying cause of the observed themes and actions.

The following insights were generated by this researcher working as a designer and team leader within a small interdisciplinary team, including a second designer and an ergonomist. All members of the team were familiar with the transcripts and thematic analysis generated as described in Chapter 3. Table 5-1 is a short extract pertaining to the insights generated concerning primary heating systems and controls. Please refer to Appendix G. Insights for the full table of developed insights.

Theme	Code	Insight
Primary Heating Systems and Controls	M01	Timers and programmers were not used by any tenants, finding them restrictive, redundant, and wasteful. Tenants preferred to turn on/off the heating when required, often with a stay at home occupant in control. Timers were only used to prevent pipes from freezing during extended away periods.
	M02	The heating was physically turned on/off with either the switch directly on the boiler, or by setting the thermostat. A desire for physical control.
	M03	Control and use of the heating system related to perception of the fuel type and associated costs, as well as (often incorrect) heuristic perceptions of the appliance.
	M04	Despite strong heuristics regards heating systems, there was a general lack of awareness as to the cost of electric appliances left on standby.
	M05	Often the heating was set high to compensate for windows having been left open to circulate ‘fresh’ air.
	M06	One tenant regularly adjusted the hot water temperature dependant on the task.
	M07	The lack of control over the primary heating system can lead to frustration and inefficient practices, such as the use of additional heaters, the opening of windows, or the use of kettles to supplement water temperature.

Table 5-1 Primary Heating Systems and Controls Insights

5.3.2 Insights Matrix

Once insights had been identified and coded (to ease the handling of such large quantities of data), it was necessary to determine which of those insights uncovered were of use in the context of this project. As such, a process was required to broadly rank the insights based upon suitable criteria, which in this project, is driven by domestic energy consumption. The *Insights Matrix* provides two axes, frequency of occurrence (self-reported commonality across the case study as reported in Chapter 4) and estimated domestic energy impact (divided into ‘low’ and ‘high’ categories determined by subjective relative comparison, and relates to the insights estimated direct impact upon domestic energy consumption).

Insights from the Merthyr Tydfil site were placed within this matrix, again by the interdisciplinary insights team, with relevant insights regrouped accordingly, as shown in Figure 5-3.

Figure 5-3 Constructing the Insights Matrix

The priorities of the insights were then grouped as thus: a common occurrence with a high estimated domestic energy impact was of a high priority. Common occurrences with a low estimated domestic energy impact were categorised as medium priority, as were uncommon occurrences with a high estimated domestic energy impact; and uncommon occurrences with a low estimated energy impact were categorised as being of low priority. Any additional insights pertaining to issues such as aesthetics, which may not have had a direct impact upon energy consumption but were of relevance to the project, were not included in this matrix, but retained to inform the design process.

In order to supplement the ranking process, various data sets were related to by the team, however this was to provide an idea of relative positioning and prompt discussion rather than absolute values, and furthermore, to negate some of the issues within this study and other quantitative studies in general (discussed further in section 1.2 and section 5.5.1). An example of such a data reference used by the team, the estimated energy impact of leaving an office window open overnight with the heating on from the Carbon Trust, is provided in Table 5-2. Cost calculations were made based on the energy plans available to the Merthyr Tydfil tenants.

"A typical window left open overnight in winter will waste enough energy to drive a small car over 35 miles" Assumes vehicle performance of 10 miles/litre (= 45mpg). Calorific value of petrol = 32MJ/litre = 8.9kWh i.e. 1.12 miles/kWh Assume the effect of the open window is air movement at an average velocity equivalent to 0.1 m/s perpendicular to the facade across its cross sectional area. For a window with an openable area of 1 sq.m this is equivalent to an air change rate of 0.1cu.m/s, = 360 cu.m/hr. density of air = 1kg/cu.m, heat capacity = 1200 J/kg/°C, so for outside air at 0°C displacing internal air at an average temperature of 16°C. Heat loss per hour = 360 X 1 X 1200 X 16 = 6,912,000 J = 1.92 kWh. Assume window remains open for 14 hours, 27kWh Assuming a boiler efficiency of 80% gas fuel requirement is 27/.8 = 33.75 kWh 1.12 * 33.75 = 37.8 miles *(Carbon Trust, 2011)* - After passing the 33.75kWh through a typical energy plan available to the case study participants, the E.ON energy plan with prepayment, 8.573/kWh (first 2680kWh) equates to a total cost of £2.89 per night.

Table 5-2 Carbon Trust Energy Calculations (edited from original) (Carbon Trust, 2011)

The purpose of the insights matrix was not to provide a definite and accurate hierarchical rank of those insights that are most energy consumptive, such as what could be achieved through Elias' *(2011)* Prioritisation Methodology (please refer to section 2.6), but rather to reduce the insights down to a group of *manageable* and *relevant* insights within the parameters of this project (a focus on technological feasibility, energy reduction, comfort and behaviour change, echoing the evaluation criteria later developed in Chapter 6), ready for development into opportunity statements.

The following diagram, Figure 5-4, is the finalised version of the insights matrix. The groupings highlighted in bold represent primary areas of high priority interest, based on relative estimated domestic energy impact and occurrence, and specific to this doctoral research, the provision of an interesting and novel energy and comfort insight and behaviour for further study. The high impact and high occurrence insight M50 (winter fuel payments), for example, was not selected for further consideration within this research as the behaviour was deemed too limited, in other words it lacked the socio-historic depth for an interesting and novel case study. Group M39, M40 and M42 was not selected, as any physical modification of prepayment meter systems would fall outside of the feasibility of this study in terms of development duration required to meet relevant standards. Insights M03, M17, M20 and M22 related to historic and socially created energy perceptions and product heuristics. Whilst an interesting group of insights, they were not anchored to any one specific behaviour or interaction and therefore not taken forwards as a distinct opportunity, however, its analysis has been useful in understanding the overarching behaviour (and potential future behaviours) of the users.

Groupings within a ‘box’ are all of an equal weighting, presenting only four relative options (*high and uncommon*, *low and uncommon*, *high and common*, and finally *low and common*).

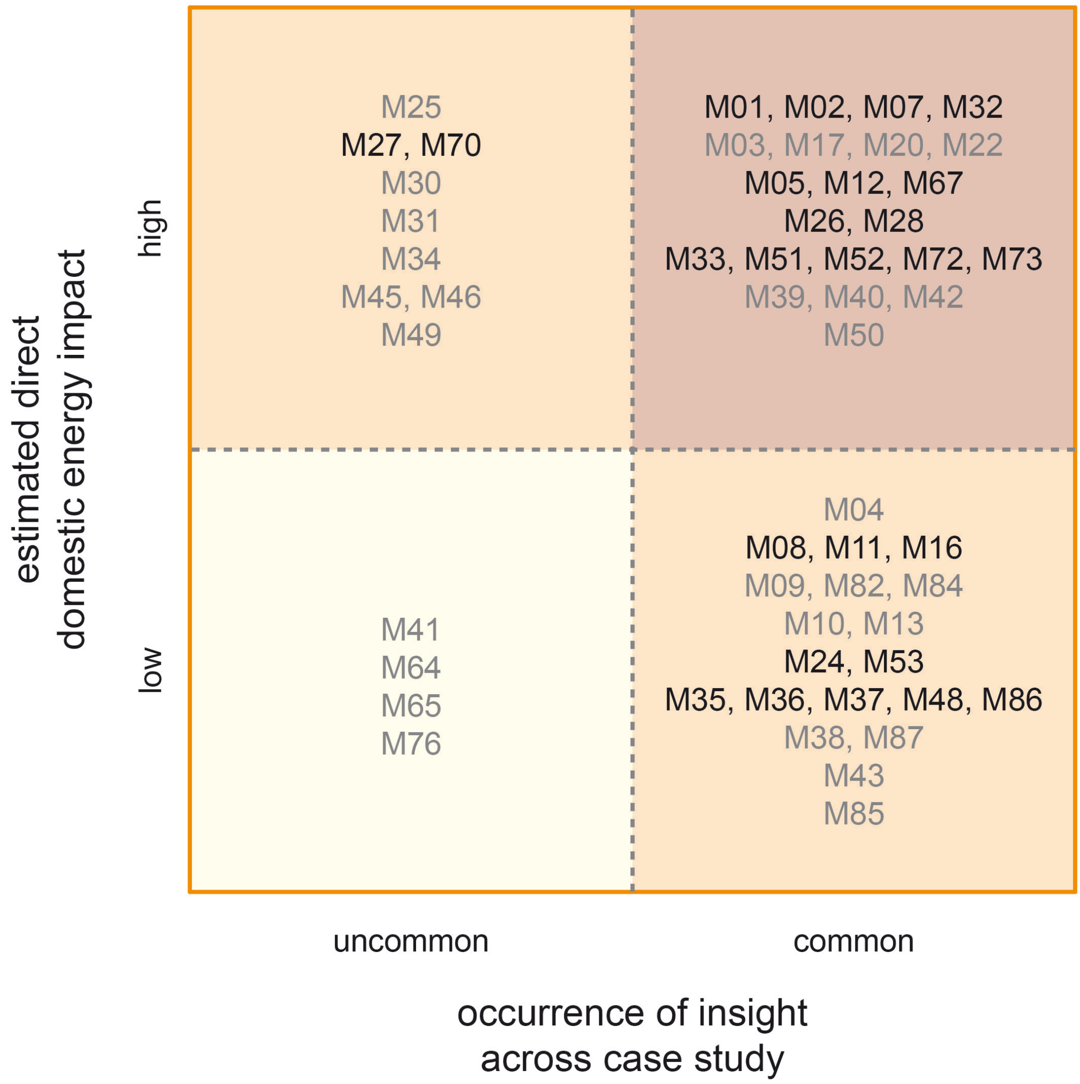


Figure 5-4 Insights Matrix

In brief, the bold categories of interest represent the following groups of insights (please refer to Appendix G. Insights for the full table of developed insights).

High energy impact and of interest (but uncommon):

- the use of electric fans and how smoking dictates room and window usage (M27 and M70),

High energy impact, common and of interest:

- the control (or lack of control) of the tenant over the heating system and its components (M01, M02, M07 and M32),
- methods for regulating fresh air and controlling (M05, M12 and M67),

- the use of clothing to regulate thermal comfort (M26 and M28),
- the difficulties and differences occurring from multiple occupancy and ailments (M33, M51, M52, M72 and M73),

Common and of interest (but low energy impact):

- tenant issues with draughts and attempting their own DIY repairs (M08, M11 and M16),
- the use of comfort artefacts (M24 and M53),
- and the use of lights and in particular, the use of the fireplace for visual comfort (M35, M36, M37, M48 and M86).

5.3.3 Opportunity Statements

Following the distilling of the insights into groups relevant to the projects objectives, these insight groupings formed the basis from which abstract *opportunity statements* were drawn. An opportunity is a redefinition of the need from the observed, into a future facing challenge within the context of the project *(IDEO, 1999)*; the tipping point of the design process from reflective analysis and definition of the *problems*, to the definition and creation of *solutions*.

As an interdisciplinary team, opportunity statements were generated on post-it notes under each insight, as shown in Figure 5-5. Each statement began with ‘How might we...’ [HMW...], with at least fifteen minutes spent on each insight group. Opportunities in this context were constructed based on the overarching project question: *how might we reduce domestic energy consumption with feedback whilst maintaining the occupants comfort levels?* It is also important to consider that at that stage no idea was a bad idea and that the key to this method was quantity not quality. Furthermore, these areas of opportunity statements were not solutions, but provided a step between the insights generated and the brainstorming of new solutions *(IDEO, 1999)*.

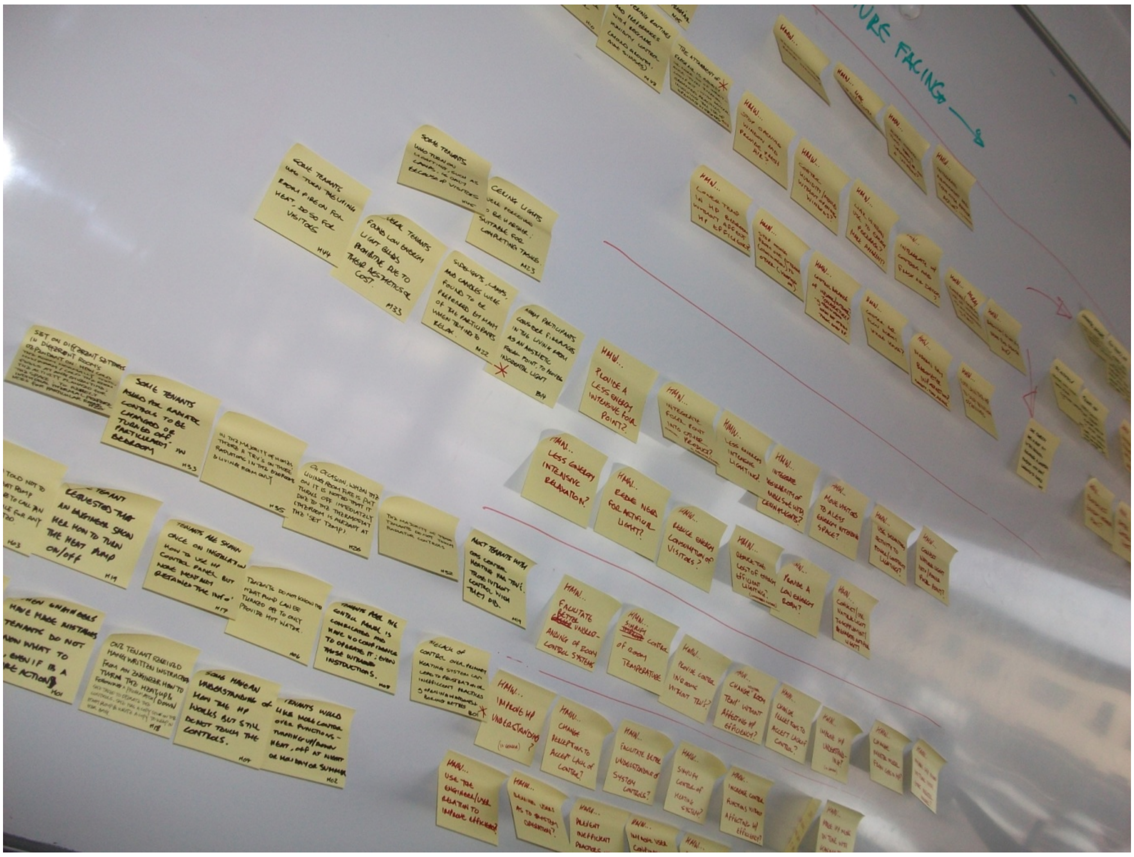


Figure 5-5 Constructing the Opportunity Statements

Following the identification of groupings, assigned with high and medium priorities for research, the insights team constructed opportunity statements, of which Table 5-3 is an extract of the opportunity statements related to the *pursuit of fresh air*. For the full table of generated opportunity statements please refer to Appendix H. Opportunity Statements.

Insight Group	Opportunity Statement(s)
High Priority M05. Often the heating was set high to compensate for windows having been left open to circulate 'fresh' air. M12. The attainment of 'fresh' air is equally or more so of importance than thermal comfort, with several observed practices involving the use of opening windows. M67. Differing routines and preferences with regards humidity control (especially relating to the control of mould growth, and in one case, to aide sinuses).	How might we... ...display/link health to 'open window' action (e.g. health to air quality or temperature)? ...alter expectations of the effects from opening windows? ...integrate air movement and temperature with a physical action (e.g. housework)? ...provide fresh air without opening windows? ...control humidity/mould without opening windows? ...make apparent the link between window use and energy? ...display to the tenant comparisons between the use of windows and alternatives (e.g. fans)? ...reduce or quantify to the tenants the 'actual' need for fresh air? ...stop the tenant from going from one extreme (open windows) to other extreme (heating on)? ...control the balance of indoor and outdoor temperatures? ...control the air flow across the entire house? ...create a modern day barometer?

Table 5-3 Opportunity Statements Related to the Pursuit of Fresh Air

5.3.4 Refocusing the Design Brief

With several opportunities identified for each insight, the opportunities were used to refocus the area of research interest, with multiple opportunities consolidated into succinct developed statements of interest. As a starting point, several statements were created, each consisting of a short paragraph. Once several statements had been identified, and clarity and purpose had been compared against the thematic analysis and the research objectives, it was necessary to reduce the number of statements into an amount suitable for design development within the parameters of this project. Those that could be consolidated into statements that were more substantial were combined, ensuring that the scope of each statement of research interest fitted within the broad scope of the project (again, a focus on technological feasibility, energy reduction, comfort and behaviour change). It is important to consider that these proto-briefs should not constrain innovative design thinking, although they did outline the inflexible parameters and project objectives in which they operated *(Phillips, 2004)*. Figure 5-6 illustrates a section of the results of this method of transforming opportunities, with a consolidation process of amalgamating minor opportunities as far as was deemed feasible, to form several major opportunity statements of interest.

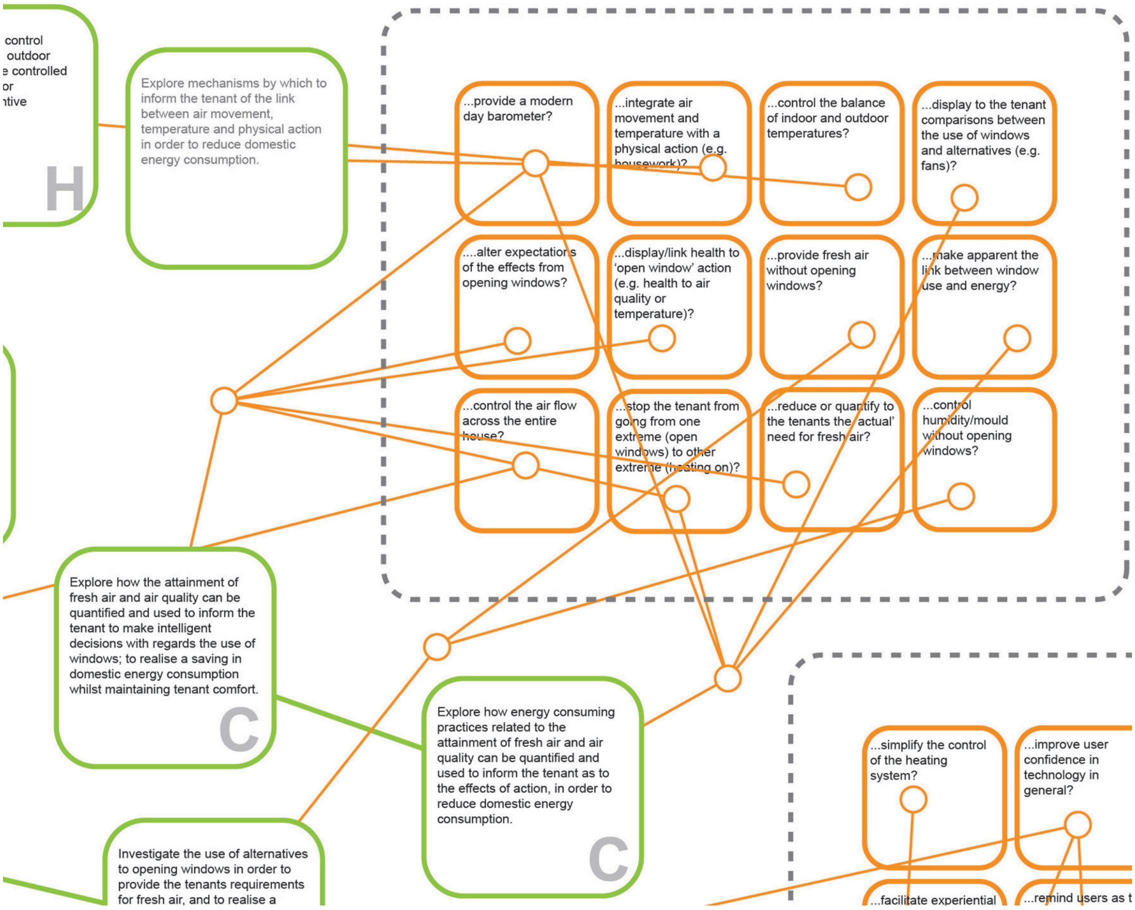


Figure 5-6 A Section of the Opportunity Consolidation Diagram

For the full illustration of the results of this method, please refer to Appendix I. Opportunity Consolidation Diagram. This method was carried out by the interdisciplinary insights team led by this researcher, with the opportunity statement post-it notes, as previously generated, moved around a wall and finally being fixed in position and linked together with lengths of string.

Table 5-4 presents the consolidated statements of research interest, with statement *C* selected by this researcher as the opportunity and direction to pursue:

A. Working within the constraints of the current heating system, develop a means by which to facilitate a greater understanding by the tenant of the technology and its control mechanisms in order to maximise its management for comfort, whilst reducing domestic energy consumption. Opportunities may include: changing the tenants understanding and mental model of the heating system; the facilitation of experiential learning or a mechanism for information retention by the tenant; or through the tenants interface with 'knowledge providers' and technology installers.
B. Working within the constraints of the current heating system, develop a control system that affords to the tenant a better understanding of the technology and its control mechanisms in order to maximise its management for comfort, whilst reducing domestic energy consumption through feedback on consequences of choice. Opportunities may include: changing the tenants understanding and mental model of heating systems, or conversely, changing operation mechanisms in line with current tenant mental models of heating systems; or the facilitation of experiential learning; or the exploration of feedback mechanisms.
C. Recognising that the pursuit of 'fresh air' can have an effect on the efficiency of a heating system, explore mechanisms through which to convey to the tenant the consequences of their fresh air attainment. By feeding back the consequences of choice on the heating system, reduce the tenants' domestic energy consumption whilst allowing for the maintaining of comfort standards.
D. Alter the tenants clothing behaviour through a redefining of the relationships between domestic clothing, heating system energy use, and indoor/outdoor temperatures; to reduce domestic energy consumption whilst maintaining occupant comfort.
E. Using low energy comfort artefacts, generate a new tenant routine that will reduce the tenants overall domestic energy expenditure; whilst also considering gender and health related issues and parameters.

F. Investigate how the current system of venting currently required by housing standards can be redesigned and synergised with behaviours related to the attainment of fresh air. This should be explored in parallel with improving tenants understanding and control of their heating system, so to prevent abuse and unacceptable closures, maintain tenant comfort, and realise an overall decrease in domestic heating system energy consumption.
G. Enable tenants to be able to locate draughts within their domestic environment, and provide appropriate guidance or solutions on how to resolve the draught source issue, so to reduce the burden on the heating system and improve tenant comfort.
H. Consider how the primary heating system controls and efficiency requirements may be synergised with behaviours related to the attainment of fresh air and required ventilation, in order to provide an overall reduction in domestic energy consumption whilst maintaining tenants comfort.
I. Recognising that the living room fire place has become a visual comfort product only and not a thermal output and control device as originally conceived, re-contextualise this focal point as a feedback mechanism to inform the tenant as to the effects of their heating system control decisions; thereby reducing energy consumption, whilst maintaining the tenants expected visual and thermal comfort.
J. Recognising that in multiple occupancy homes there can be disparity in tenant location and activity as well as thermal comfort expectations, investigate how the domestic consumption of these diverse energy interactions can be individually reduced or combined throughout the household in order to reduce overall domestic energy use, whilst maintaining each individual tenants comfort expectation.

Table 5-4 Consolidated Statements of Research Interest

Statement C was selected by this researcher for several reasons. The impact of the behaviour clearly has a detrimental effect on the user's domestic energy consumption, as illustrated previously in Table 5-2. Although it cannot be qualified as the largest in terms of impact, it still represents a significant impact upon user resources that requires further investigation. In addition, the concept of fresh air is extensively and rigorously pursued across the case study sample, and furthermore, appears to be a deeply entrenched habitual action with complex socio-historical antecedents; the selection of fresh air would make for an interesting and novel study, exploring and pushing the limitations of user agentive feedback intervention. Finally, statement C affords potential feasibility in producing feedback interventions to change the behavioural problem within the given project limitations of time period, budget and other project constraints (such as the tenants built environment, heating systems and other technologies).

Statements such as B, F and H for example, would likely require lengthy and costly retro fitting of solutions within the technological systems that are already integrated within the participant's built environment. The installation of concepts would likely require extensive external support, such as by qualified gas equipment installers, and be heavily regulated by British and international standards. This would push the cost and development time required beyond what is feasible within this doctoral study. As a side note, it would have been interesting to tailor the ineffective control mechanisms to the mental models that already exist in order to realise or change cognitive heuristics, although a change in control mechanisms by their very nature would more likely be achieved through antecedent strategies such as persuasive technology than feedback intervention.

Although statements D and E were of interest, the decision was made to focus specifically on feedback intervention through product design, due to the skill set and experience of the researcher, rather than the exploration of comfort artefacts, clothing and textiles. However, it is recognised that design directions may have yielded interesting opportunities for individual, transient feedback devices.

Statement I was also of particular interest, and if it were not for the estimated energy impact of visual comfort behaviours being less than that of opening windows, this would have been a very interesting behaviour to pursue. The very concept of the light of a fire being a natural feedback mechanism that has become disentangled and disassociated from its original function over time, is certainly very interesting, and would have made for a novel case study and feedback intervention.

Finally, components of some of the other statements, such as facilitating 'a greater understanding by the tenant of the technology and its control mechanisms' (statement A), and exploring the impact of 'multiple occupancy' (statement J) although not explicitly pursued individually, were folded into consideration during the conceptual development of solutions for statement C (please refer to section 5.4).

The following table (Table 5-5) expands on the consolidated statement of research interest to provide a concise brief and specification for designing the behaviour change intervention. The brief itself is articulated in terms of targeted behaviour for change and the behaviour change strategy to be employed, followed by the objective of the targeted behaviour change. The specification is presented in reference to the extensive literature review (Chapter 2) and research that formed the control, comfort and energy in context study (within Chapter 3 and Chapter 4).

Behaviour Change Brief:
To change the behaviour of opening windows with the heating system active using feedback, in order to achieve a reduction in domestic energy consumption whilst maintaining comfort.

Specification:
Targeted Behaviour – The targeted behaviour is the opening of windows with the heating system active, a behaviour observed during the 'understand and specify the context and user' phase of the Design Intervention Process. Data on the observed behaviour was collected through contextual interviews and guided tours; analysed in detail through thematic analysis. For supporting information and discussion with regards the self-reported enactment of this behaviour by the user in context, refer to section 4.2 and section 4.3.

Behaviour Change Strategy – The selected behaviour change mechanism (or Design for Sustainable Behaviour strategy) is feedback intervention. Feedback will provide a performance indicator illustrating the impact of the enacted targeted behaviour to the user, in order for the user to cognitively associate the targeted behaviour with its consequences. The rationale for the selection of feedback intervention is discussed in section 1.2. Refer to section 2.5 for an extensive list of feedback design considerations.

Objective of Targeted Behaviour Change – The objective of changing the targeted behaviour is to realise a more sustainable consumption of domestic energy by the defined user within the defined context. This is to be achieved by a user-agentive reduction in the opening of windows with the heating system active, motivated by the users association of the targeted behaviour with its consequences. Comfort levels, as defined by the user (prefer to section 4.2 and section 4.3) should be maintained.

User and Context – The users are social housing tenants, situated within the town of Merthyr Tydfil, Wales. For supporting information concerning the social and geographical context of Merthyr Tydfil, please refer to section 3.4. For an extensive definition of the parameters of the users, including household composition, refer to section 3.7. For an extensive definition of the built environment, including built form, built age, heating system type and metering and tariff schemes, refer to section 3.7. For supporting information and discussion with regards the user's intentions to consume, their habits and facilitating conditions, in reference to comfort and energy, refer to section 4.2 and section 4.3. Further supporting material is available in the form of photographic and schematic layout reference sheets for each users home, found in Appendix E.

Table 5-5 Behaviour Change Brief and Specification

5.4 Designing the Intervention

The design phase is the point in the design process in which the designer creatively frames and explores the *solution space*, rapidly generating and converging a breadth of concepts in response to an ill-defined problem (the brief) *(Cross, 2007, Cross, 2010)*. As the following sections will illustrate, within this doctoral research the design phase of the intervention design process can be presented as four elements*; expanding* the context and user understanding, the *generation* of solutions, the selection and *development* of solutions, and finally the *prototyping* of a solution. Although discussed sequentially, parallel action does occur between these activities, for example, developing the context and user understanding was engaged in concurrently with the generation of solutions.

5.4.1 Expanding Context and User Understanding - Comfort Parameters

With the direction determined, literature pertaining to comfort, and in particular to the pursuit of fresh air, was reviewed; expanding upon the position of comfort as stated in the Research Context (section 1.1) and developing the understanding of underlying causes of the insights generated from the thematic analysis; a process also termed as *problem framing (Cross, 2007)*.

In brief, the pursuit of *thermal neutrality (Fanger, 1970)* in the built environment has positioned domestic comfort on an unsustainable course *(Chappells and Shove, 2005)*, defining comfort through energy intensive comfort conditions *(Shove, 2003)* with inhabitants situated as passive recipients of their environmental context *(Cole et al., 2008)*. However, as Shove *(2008)* and Chappells and Shove *(2004, 2005)* discuss, comfort is not a static and narrowly defined physiological manifestation, rather it is a *dynamic* entity, derived from interplays between the *individual* and their *context*. The following diagram, Figure 5-7, summarises and builds upon this review of pertinent comfort literature, presenting a combination of the principles of adaptive comfort with a systemic approach towards sustainable comfort in the built environment; focussed specifically on the pursuit of fresh air and the control of windows *(Nicol and Humphreys, 2002, Bluyssen, 2009, Hauge, 2010)*.

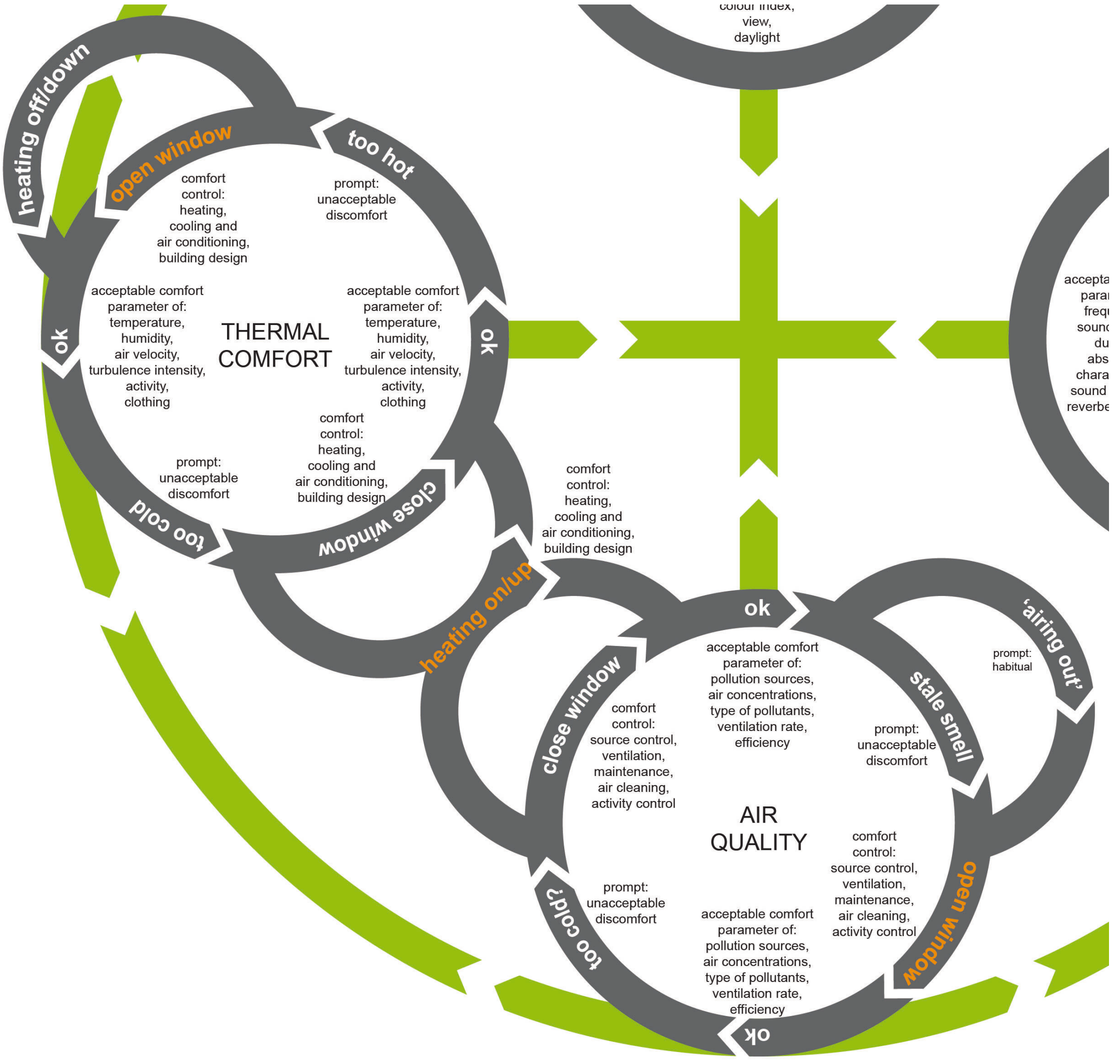


Figure 5-7 Adaptive Comfort as Related to Temperature and Indoor Air Quality (with examples)

A key theoretical component to understanding this diagram is derived from the *adaptive principle,* an approach to thermal comfort and the built environment that posits: *"if a change occurs such as to produce discomfort, people react in ways which tend to restore their comfort" (Nicol and Humphreys, 2002, P.564)*. The level of comfort that an individual experiences is intrinsically linked to their ability to mitigate discomfort experienced within their environment through adaption. This has been represented in Figure 5-7 as a series of *prompts*, points in time in which the level of discomfort has been registered by the individual, motivating action to adapt. Expanding the notion of comfort (and health) beyond thermal quality, Bluyssen *(2009, 2010)* categorises three additional, and inextricably linked, components of indoor environmental quality [IEQ]; namely lighting, acoustical and air quality. Each environmental factor composes a list of parameters and control strategies, with a focus on thermal comfort and air quality (those components most relevant to actions related to controlling the heating system and the pursuit of fresh air) in Figure 5-7. The control strategies follow recognition of the prompt, and provide the facilitating conditions through which comfort (or more precisely, discomfort) can be controlled, thus generating acceptable parameters in IEQ, and by extension, comfort.

Exploring this approach with an example, moving from an acceptable comfort parameter of temperature an individual may become too hot. This may result in the window being opened (possibly with the heating system active) or result in an alternative control action of turning the heating down, returning the individual back to an acceptable parameter of comfort. With the window open or the heating system off, the individual may become too cold, resulting in a control action of turning the heating system on or up, with or without the controlling action of closing the window; the cycle then repeats. A cyclic process of discomfort management clearly has traction, echoing what was discussed in the thematic analysis, *"…tonight now I will put the heating on when it goes a bit chilly in the evening"* (CA02F) and *"…and if it's a nice day when we're going out I leave the bedroom window open for the fresh air and I walk in and run straight up the stairs because it's like an icebox then…"* (CA05F).

Interestingly, prompts may be mitigated through habitual behaviour. Hauge *(2010)* when considering the sensory aspects or fresh air discusses *airing out*, an aspect prevalent in the thematic analysis when pursuing fresh air. Airing out, according to Hauge *(2010)*, may be a socio-culturally determined pursuit, driven by a fear of water damage and poor air quality, or may be taboo and linked to the notion of fresh air in and bad air out (in particular in the bathroom). Airing out may also be physically determined through sensory means, such as the recognition of fragrances, the desire to construct individual comfort zones or the enjoyment of breezes. Finally, airing out may be *habitual* and *ritualised*, frequently repeated and seasonally determined. Again, this habitual element was discussed clearly during the contextual interviews and guided tours, yielding statements such as *"…always in the morning I open the windows to let* *some air in…but I don't open them for long in the winter but I mean bedrooms got to have a bit of air haven't they…"* (CA02F).

The solutions that were generated following this expansion of researcher's knowledge and understanding are presented in the following section.

5.4.2 Generation of Solutions

With the context and user understanding expanded, the next step was to explore concepts that would conclude with a viable solution to the problem; resulting in *a feedback intervention prototype that* would *reduce domestic energy consumption whilst maintaining inhabitant defined comfort levels,* (research objective 3, section 1.4).

The approach used to move from the opportunities identified to the formalising of knowledge towards the production of *design solutions* that *meet user requirements (British Standards Institution, 2010)* can generally be described overall as being *convergent (Pugh, 1990, Jones, 1992, Cross, 2010)*, with interdisciplinary concept selection (*convergence*) at the apex of each generative design activity (*divergence*) working towards a single solution.

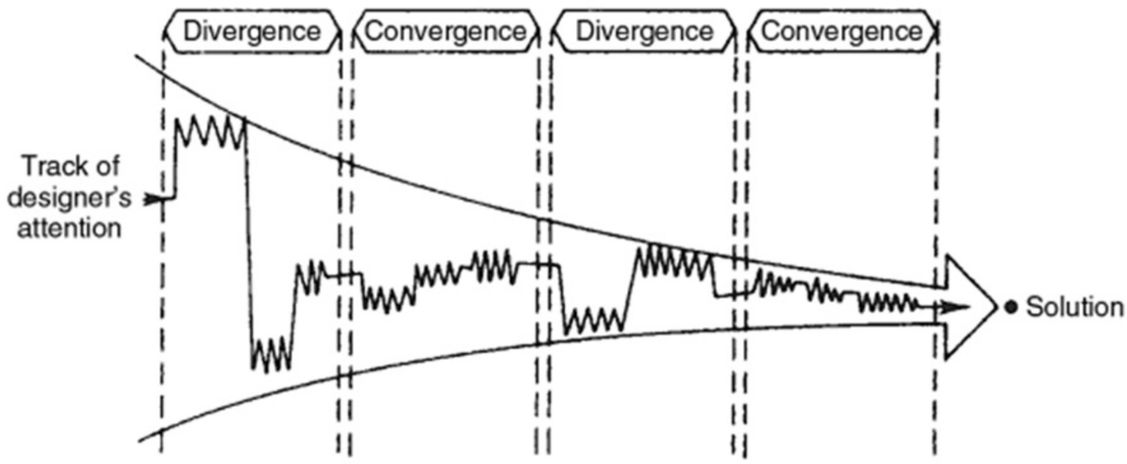


Figure 5-8 The Convergent Design Process as defined by Cross (2010)

The features of divergent activity, as noted by Jones *(1992)*, predominately revolve around the expansion of the solution space, with boundaries made flexible to accommodate the developing of the problem in parallel to the finding of the solution. Crucially, within divergent activity the designer frees themselves of preconceived solutions and evaluation or criticism is prohibited *(Jones, 1992,* *Aspelund, 2010, Cross, 2010)*. Convergent activity is typified through critical reduction, as embodied through evaluation and design detailing activities *(Jones, 1992, Cross, 2010)*.

The starting point for divergent design activity within this intervention design phase was a *brainstorming* of the ways in which the energy consuming effects of the heating system and window use could be represented in terms of sensory impact upon the individual. The initial brainstorming maps can be found in Appendix J. Initial Brainstorming Activity; two illustrative examples of mapped routes include:

- How to convey radiator use? > air quality > "smell" of radiator? > burning dust smell when heating is too high?
- How to convey window use? > physical movement > relate energy use to human body? > too much energy used > out of breath?

Brainstorming as an activity affords a particularly apt platform on which to build the design activity, with several features, such as rapid expansion of the solution space (quantity, not quality), and lack of any form of evaluation, including criticism *(Aspelund, 2010, Cross, 2010)*, resonating with the key features of divergent activity *(Jones, 1992)*. Inspired by a creative mapping of words, feedback considerations were introduced and contemplated in combination with some of the key emerging ideas that offered interesting directions within the solution space. Following this consideration of what feedback criteria would be appropriate to realise words into more developed ideas, the motivation, intent, method and outcomes of each potential direction were reflected on and embodied through explorative thumbnail sketches of intervention solutions. These sketches were amalgamated by this researcher into six core concepts, as presented below.

The motivation behind all six concepts was essentially the same and can be disentangled into three key drivers. The first motivator was legislative and is enshrined within the Climate Change Act 2008 *(UK Parliament of the United Kingdom, 2008)*, which sets the initial target of reducing UK greenhouse gases by up to and including 2020 to 34% lower than the 1990 recorded baseline *(UK Parliament of the United Kingdom, 2009)*. This work aims to contribute towards attaining this set government target. The second key motivator was driven by the CCC project to which this doctoral research is attached. The primary goal of the interdisciplinary project was to reduce domestic energy consumption by 20% through the user-centred design of feedback interventions *(EPSRC, 2010)*. This doctoral research, despite not being obligated towards achieving the CCC projects specific aim and objectives, still was motivated towards contributing to the CCC projects findings. Finally, the third motivator was the design of these concepts, and by extension the completion of this research, for academic reasons; contributing towards this researcher's doctoral thesis in partial fulfilment of the requirements for the award of Doctor of Philosophy of Loughborough University. The intention of the designer, this researcher, was also consistent across the six concepts; to reduce domestic energy consumption whilst maintaining the inhabitants defined levels of comfort. Although the motivation and intent was uniform across the generated concepts, the methods employed through the design decisions taken and the potential outcomes of each intervention were not, despite all the concepts fitting within the category of feedback intervention. The six concepts are described in terms of these two variables; method and potential outcomes.

Concept One (Figure 5-9 and Figure 5-10) was an ambient light that would have been attached to the radiator, fully removable and not connected to the mains electricity supply or central heating system. The light would have indicated to the tenant when their heating system was on or off, as well as roughly how long it would have been on. This would have been supplemented with a sensor on the window that would have changed the ambient light to a warning light should the window have been opened in parallel to the heating being on. A 'click' would have sounded to indicate when a change of state had occurred.

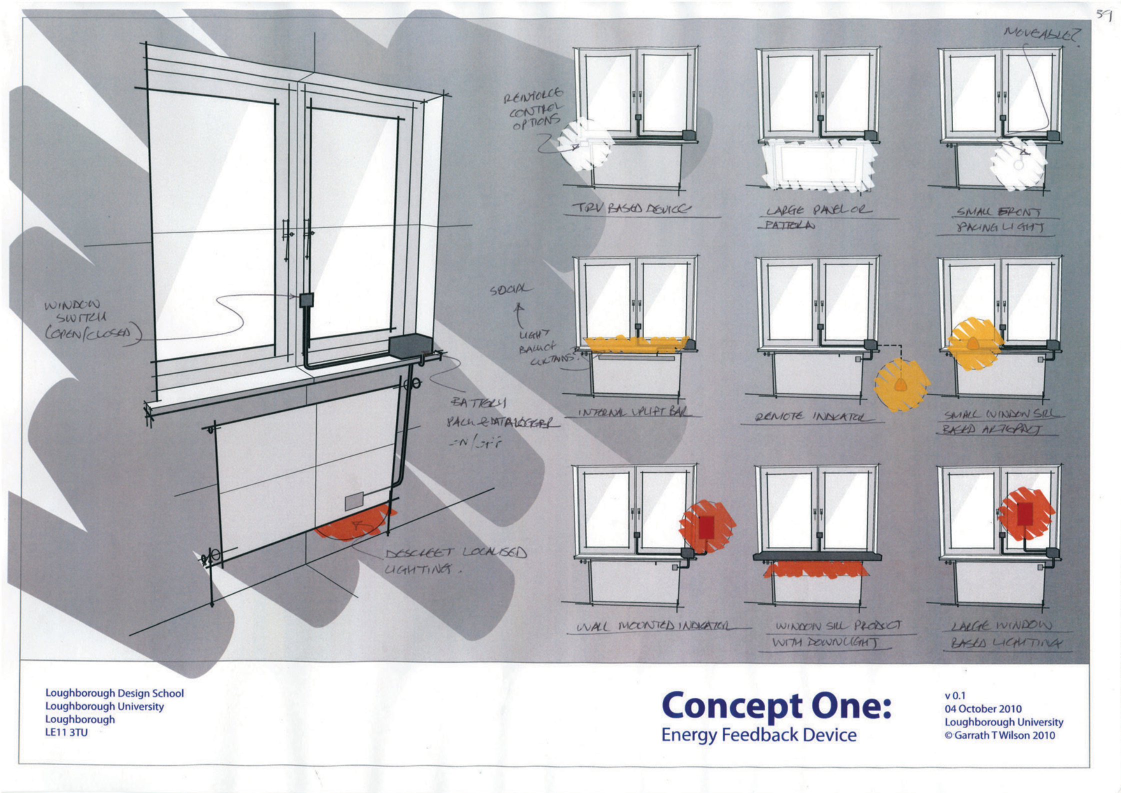


Figure 5-9 Concept One, Board One: Energy Feedback Device

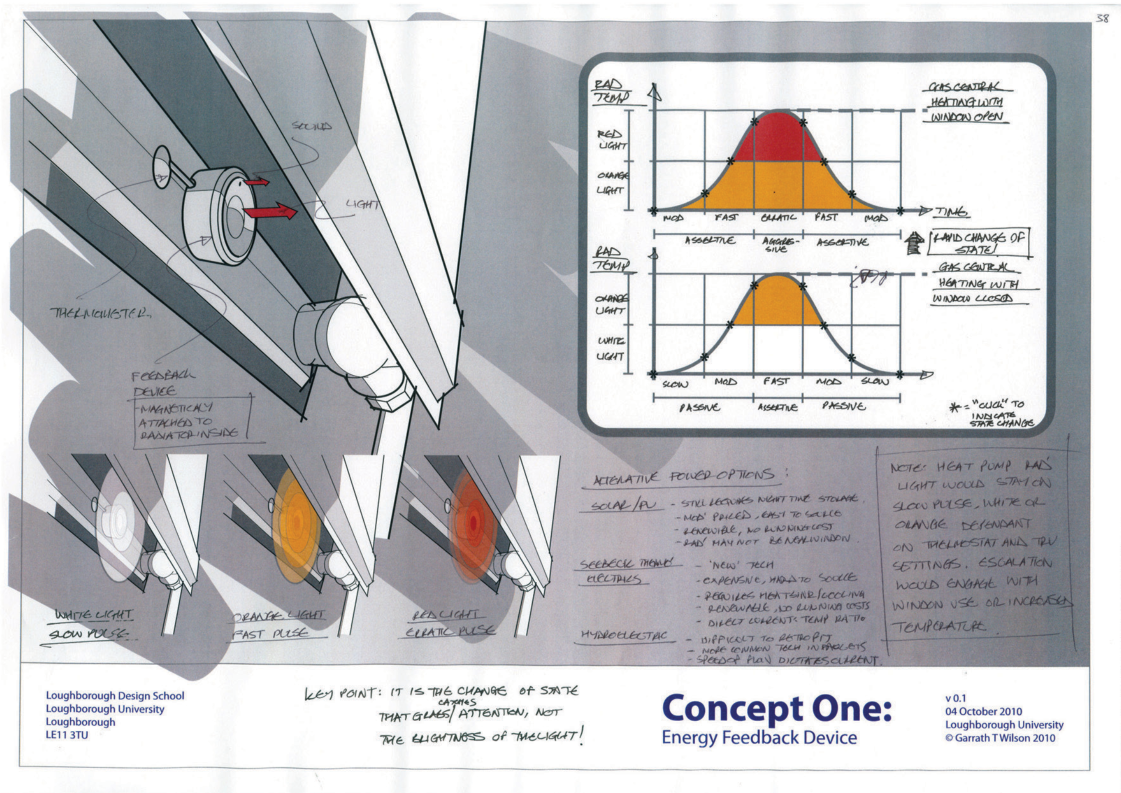


Figure 5-10 Concept One, Board Two: Energy Feedback Device

The aim of Concept Two (Figure 5-11 and Figure 5-12) was to provide a link between the internal and external environments, to better inform the tenants as to the consequences of their heating decisions. Several iterations were explored, including the concept of sharing 'your' data with outside passing society as well as being able to relate the appropriateness of your indoor environment to that of the outdoor environment. The central concept to this intervention was visibility of information to facilitate reflection on social factors (norms, roles and self-concept); displaying energy consumption and environmental conditions to both the tenant and to the wider world.

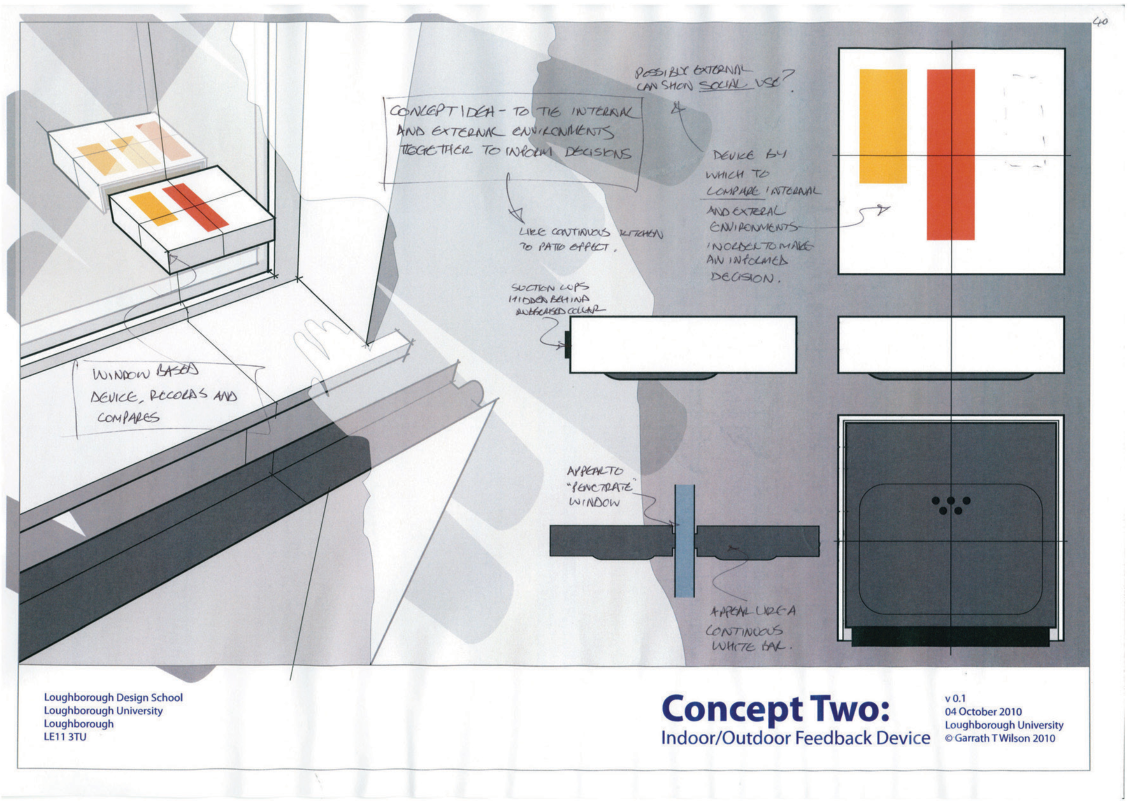


Figure 5-11 Concept Two, Board One: Indoor/Outdoor Feedback Device

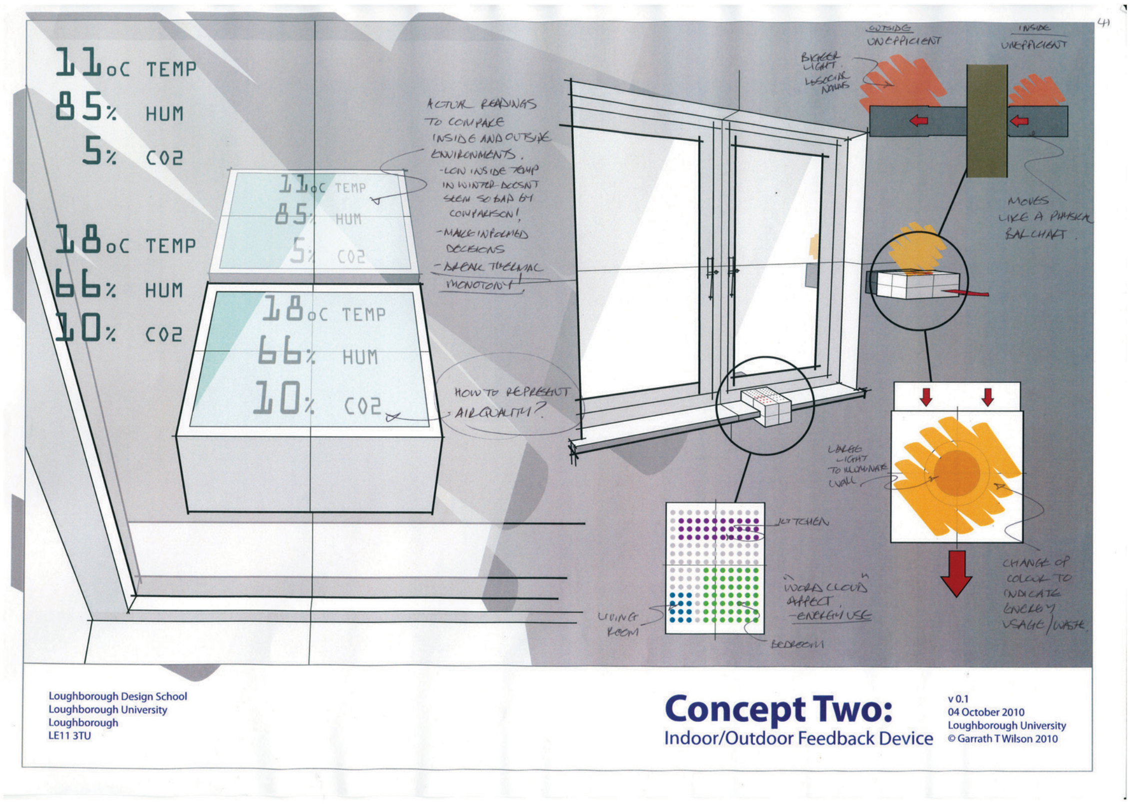


Figure 5-12 Concept Two, Board Two: Indoor/Outdoor Feedback Device

Concept Three (Figure 5-13 and Figure 5-14) was a thermostatic radiator valve [TRV] intervention that changed colour to represent the temperature of the water flowing through the radiator (central heating system activity). In addition, the display of colour would have changed pulse to indicate duration of activity, with a slow pulse indicating a short duration and a quick pulse representing an extended duration (although how 'extended' would be defined was not resolved). The intervention would have automatically turned off the boiler after a set period, unless the top button was pressed to 'accept' the condition, and reset the time cycle. An alternative shutdown concept focused on the pre-use consideration of the duration that the central heating system would have been required. Set as a timer, the device would have counted down to zero and then remotely switched off the boiler. The device would have vibrated to indicate milestone temporal and temperature changes, reinforced with a change in displayed colour.

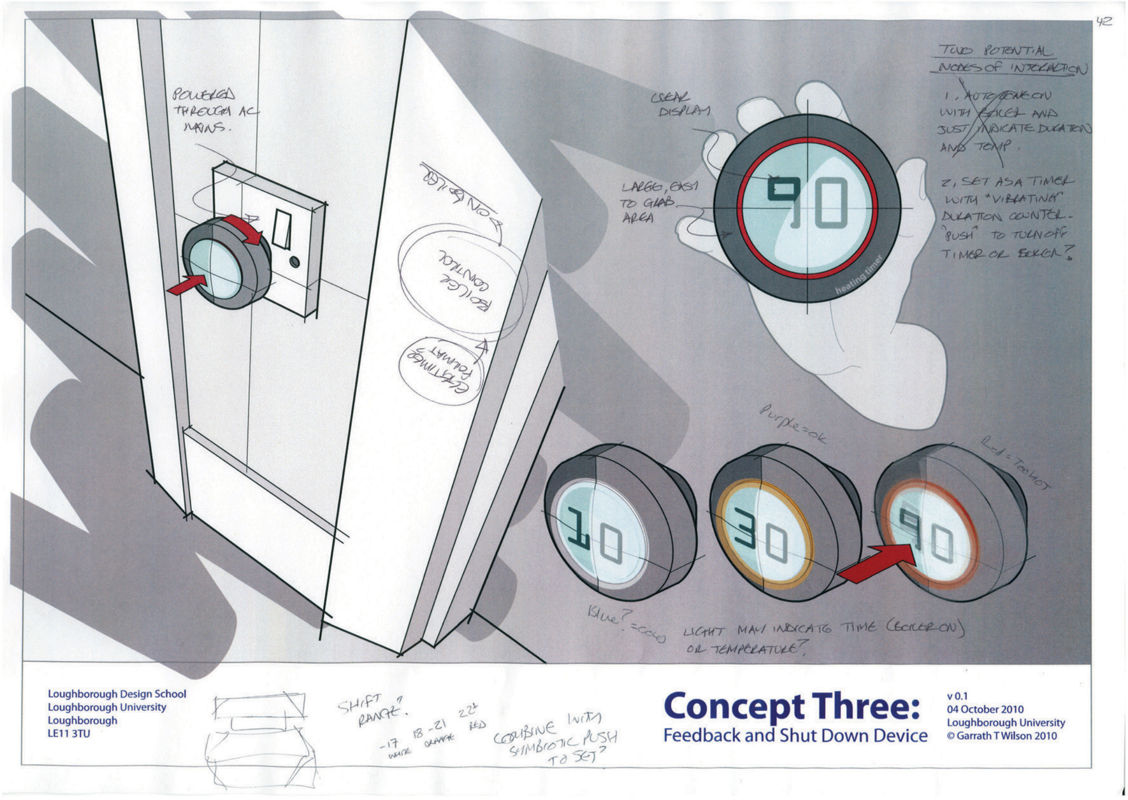


Figure 5-13 Concept Three, Board One: Feedback and Shut Down Device

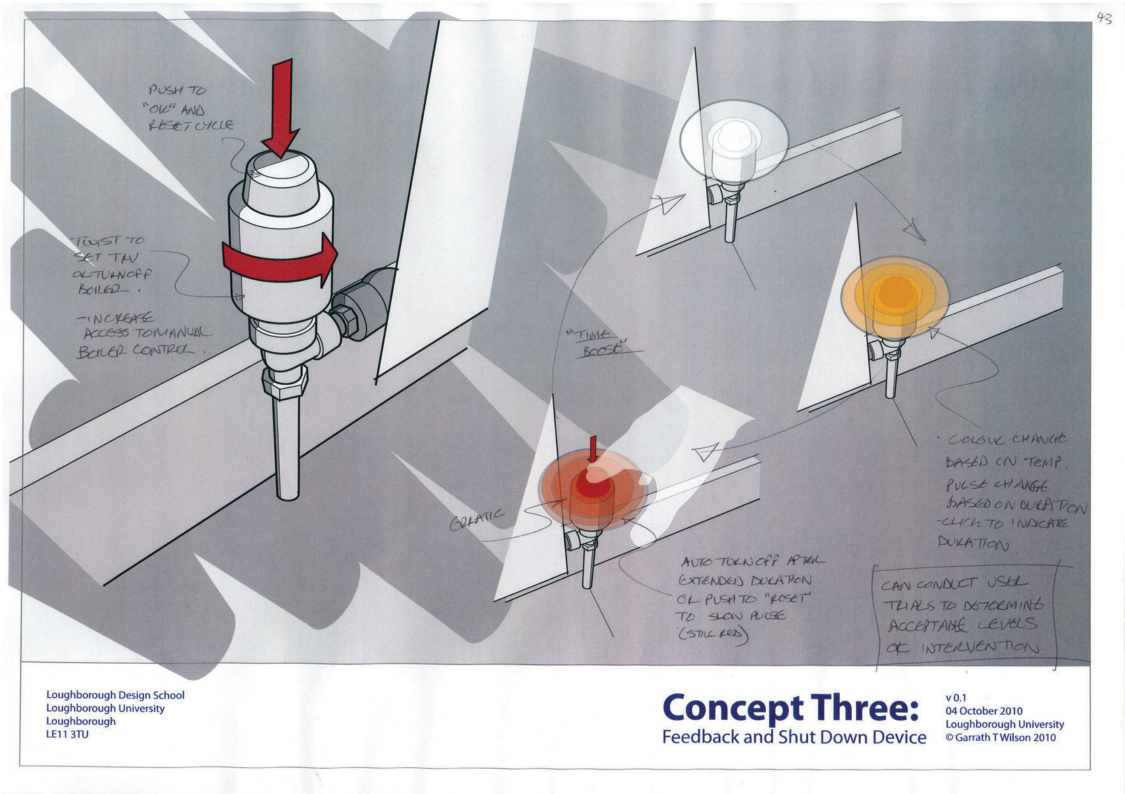


Figure 5-14 Concept Three, Board Two: Feedback and Shut Down Device

Concept Four (Figure 5-15) focused on the delivery mode and medium of the feedback information; an exploration of alternative ways through which data could have been repackaged and presented for delivery beyond the text only LCD display smart meters and home energy monitors. Alternatives included an analogue device akin to barometers and thermometers. Other representations of data explored included comparisons to historical and social baselines, an authoritative scientific styling, and a 'clock' traffic light display to indicate energy use within different rooms. Using such a format, it would be possible to not only display environmental information, such as temperature, humidity and barometric pressure, but could also be used to show external environmental data (to question the need for the heating system to be active or the window opened) or energy consumption, across the household or specific devices.

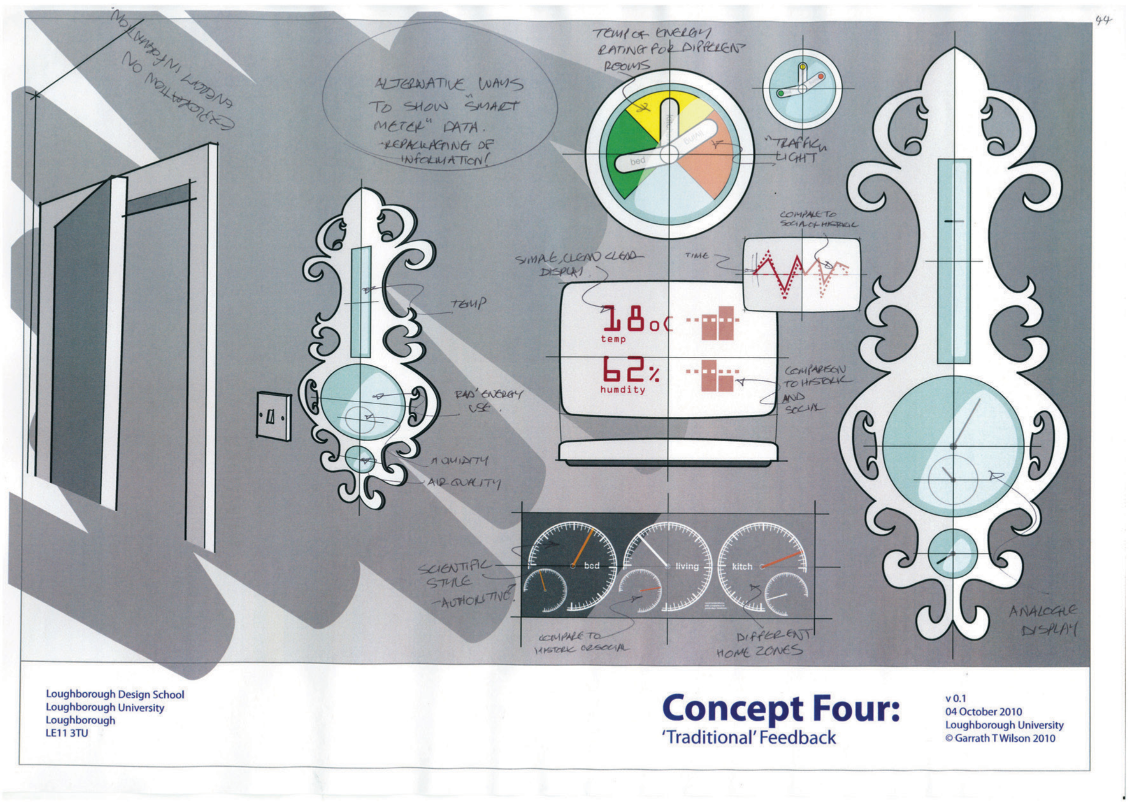


Figure 5-15 Concept Four: 'Traditional' Feedback

Concept Five (Figure 5-16) was a device that replicated the effects of temperature, humidity, and air quality in a biosymbiotic package. Building upon the mechanical media as presented in Concept Four, this concept pushed the solution space to explore how information could be transmitted using biomimetic movement to react to benchmarked comfort conditions. The device in effect would be trained by the tenant to benchmark his or her own unique environmental preferences and to illustrate any deviation from that. The feedback medium goes beyond the use of lights to include mechanical feedback, including vibrating and movement to illustrate a change in state.

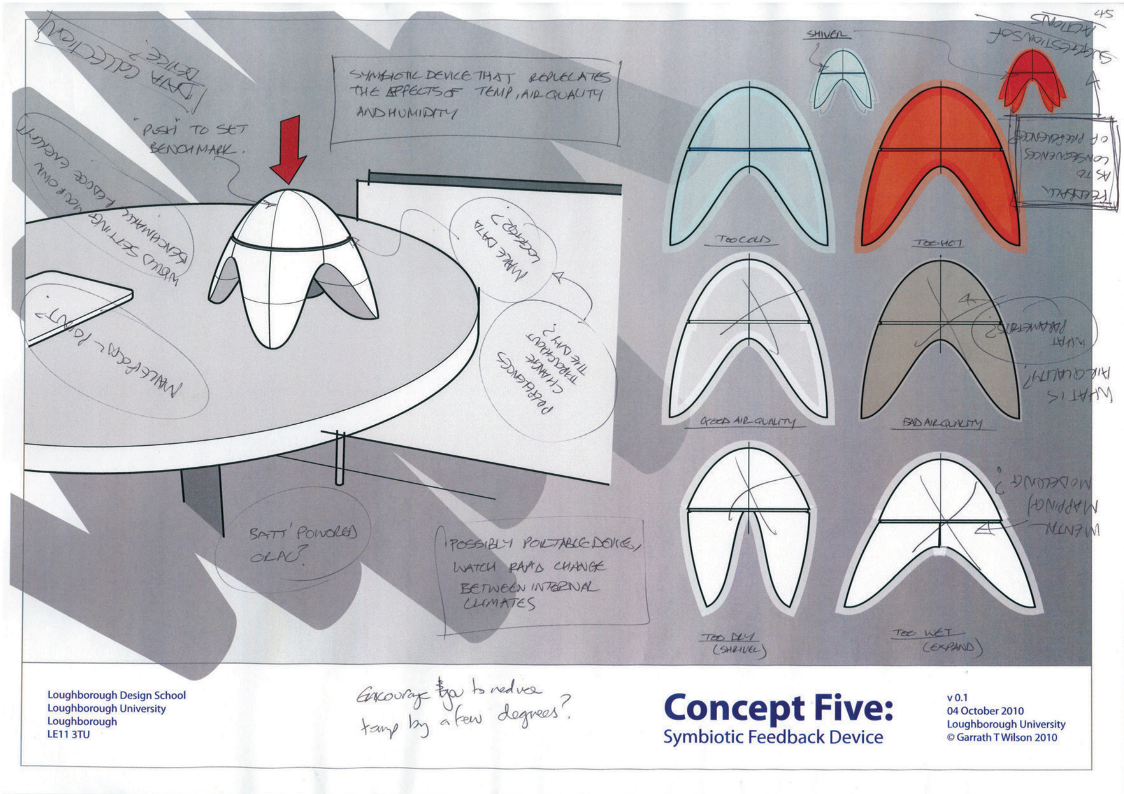


Figure 5-16 Concept Five: Symbiotic Feedback Device

The aim of Concept Six (Figure 5-17) was to provide an ambient light reward for energy efficient balancing of environmental parameters. Attached by sensor to the window and radiator, the *quality* of light would serve as the ambient medium. Rather than just illustrating a change in colour, a common feature of feedback mechanisms, this device would explore other qualities of light such as brightness and projection in order to form cognitive associations between actions and consequences.

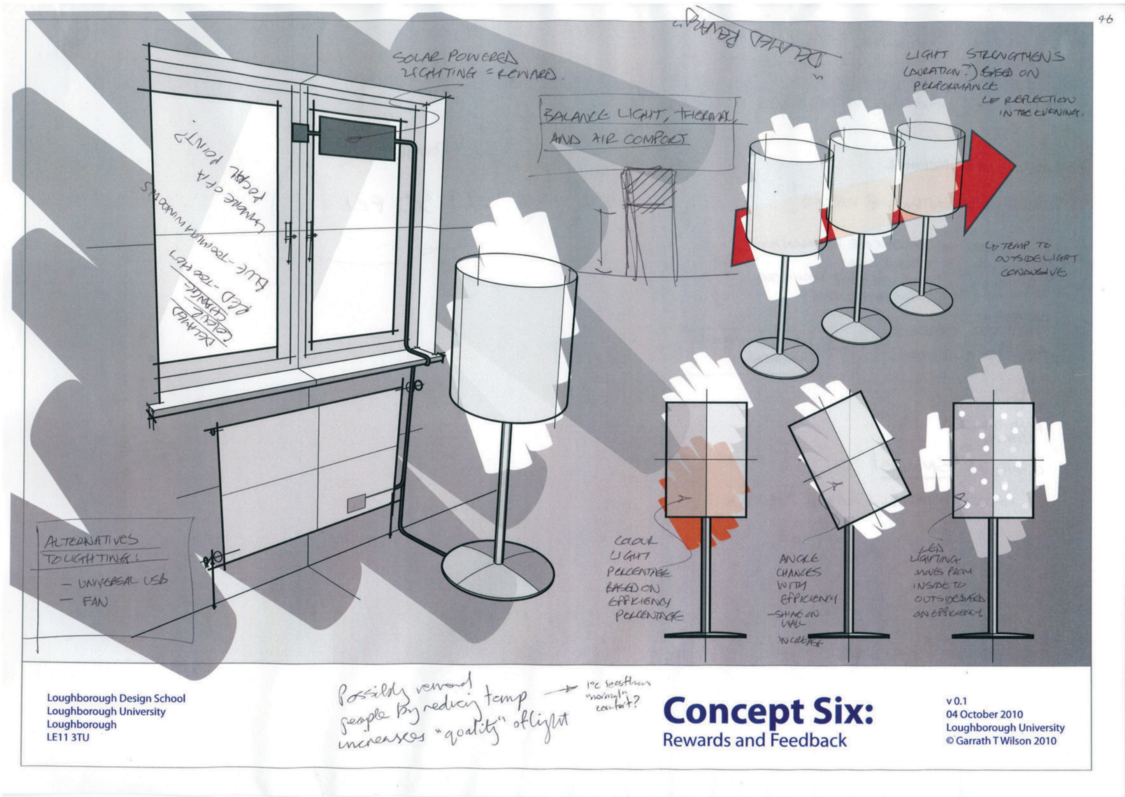


Figure 5-17 Concept Six: Rewards and Feedback

5.4.3 Concept Selection and Prototyping

Following a period of rapid divergence, resulting in the generation of six core concepts, a phase of convergence was required in order to reduce the number of possible design directions in size. This took the form of a critical review and evaluation of the six concepts by the wider interdisciplinary CCC project team (as defined in section 1.2), guided by the design brief and specification (REF). Questions asked, included:

- Is the behaviour change strategy [feedback intervention] adequately designed for the user [social housing tenants] and context [social housing, Merthyr Tydfil]?
- Is the objective of targeted behaviour change [sustainable consumption of domestic energy and maintaining of comfort through a behavioural reduction in the opening of windows with the heating system active] attainable? To what extent can this objective be realised and is it ethical?

The following paragraphs briefly outline the most pertinent points raised from this review of the six feedback intervention concepts, discussed in ranked order of their ability to satisfy the brief and specification (starting with the best).

In brief, the key feedback considerations of Concept One revolved around the ambient nature of the feedback, the location of the intervention and the metric selected. The use of ambient light, it was proposed, would be easy to cognitively process by the tenant and facilitate implicit evaluation, so long as the light could be simply cognitively mapped to afford an 'at a glance' understanding. Both the location of the feedback intervention, on the radiator itself, and the indicated radiator surface temperature, the metric, it was anticipated would help cement the bridge between action and effect. The objective was to provide accessible, relatable and relevant feedback in line with the intentions and facilitating conditions of the tenant; to control their heating system, without waste, to understand and maintain the comfort of their family within the microenvironment (such as from the couch) which this concept achieves. Ambient subliminal or supraliminal feedback was not deemed ethically appropriate due to its covert nature. Anticipated potential outcomes included the tenant being able to understand and relate erroneous energy use prior to excessive discomfort (for example, too high a temperature from prolonged heating system use or the wasting of energy through having the heating system on with the window open). It was also predictable that such a device would help family members to recognise and remember ad hoc decisions concerning heating system control use by the tenant or other household members. A potential negative outcome may have occurred if the tenant perceived the ambient light and associated clicking as annoying or distracting, which due to its pervasive nature may have resulted in the intervention being removed, disabled or having features physically stifled by the tenant. The simplicity of Concept One will make it relatively easy to prototype and to evaluate.

Concept Three combined an automated mechanical intervention with feedback. The key metrics considered were duration of activity and temperature of the heating system, aiming to increase awareness and enable more responsible and considered use to reduce energy consumption. Increasing physical interaction with the heating system in parallel with feedback, it was hoped would help to build the connection between action and effect, removing the level of unconscious on/off automation generated through room thermostats. Increasing association between time and temperature may have enabled the tenant to optimise their comfort within that time period and also consider how their actions (such as leaving windows and doors open, and room thermostat and TRV settings) impacts upon the temperature/time unit. A window open for thirty minutes with the heating on, for example, may foster an expectation of the room to be cooler at the end of the timeframe and to act accordingly. Introducing set prompted times and physical interaction would force the tenant to consider their actions and environment. The location of the TRV device would also help to reinforce this relationship. As a negative outcome, the intervention may not be suitable for those with physical difficulties (both building and human) accessing their TRVs on a regular basis, and may also lead to detrimental comfort conditions should the intervention turn off the heating system when the tenant is unaware. The prototyping of Concept Three is likely to be much more complex than Concept One, due to the integration of the prototype with the heating system.

The variables of Concept Six included brightness, colour (white or red to alert or mimic shame) and the position of light. Inefficient use of the heating system, such as extended use, would result in an indication to be perceived by the tenant as a visual comfort penalty. For example, gradually moving the location of the light source from inside the lampshade, where it would offer shielded light, to the outside, where it would become overt and create a distraction, would signal a scale between appropriate and inappropriate use. The frequency of the change, in response to action and effect on environment would be vital to form the cognitive link required to interpret the ambient features, especially if used *hot* to explore change. Over use of negative features, regardless of connection to action, would likely result in a negative attitude from the tenant towards the intervention and result in disconnection. The aesthetics of such an intervention would also need to be developed in line with domestic interior trends, as the primary function of the device would be as a furnishing accessory. In some respects, this concept is similar to Concept One, in that it uses simple light configurations to indicate a state, however the feedback lighting mechanism in this concept is more emphatic, for ‘pleasure’ or ‘pain’. An obvious flaw with this intervention, which limits its capacity to change behaviour, is that it will only be visible (unless the light features are further emphasised through brightness, colour or fluctuation) during the evening or night and not during the day or morning when the pursuit of fresh air is at its most vigorous.

The symbiotic element of Concept Five was captured through the push button on the top of the device, which served as a *baseline* setting, allowing the tenant to select their own *perfect* parameters, i.e. when the comfort parameters were perfect for them, they would push the button to set the standard. When the intervention would become too hot or cold in comparison to this self-defined standard, it would *shiver*; if the air quality was different to that desired, the body would change in *clarity*; and if the air was too wet or dry, it would have *expanded* or *shrank* correspondingly. Exploring feedback beyond light and sound mediums would have been an interesting development not really discussed in current literature, especially in the exploring of opening windows with the heating on. It also may have been portable, serving as a comparison companion when travelling between rooms. It would have been interesting to explore the potential of two devices, attuned to two different tenant preferences, interacting in the same space. However, although the device would maintain comfort as prescribed by the tenant, the initial standard itself may be excessive in its energy requirements thus perpetuating the consumptive cycle without affecting any meaningful reflection. Although an interesting concept, the feasibility in prototyping within the constraints of this doctoral research effectively means that a full working prototype is unlikely to be realised.

Concept Two explored several metrics and presentation modes, including the use of bar charts, instant numerical readings, a ‘word cloud’ illustrating energy usage by room or a large internal and external ambient light system to project to the outside world the tenants’ energy usage. Through exploring metrics, it was decided that the display would have to be flexible enough to display the metric appropriate to the individual intentions and capabilities of the tenant, however it would be unlikely that any specific metric selected would be relevant to all tenants in a multiple occupancy home or the outsider (society). Possible outcomes could have seen the tenant, for example, in the height of winter reflecting upon a display of lower outdoor temperature and by extension would be more accepting of a lower internal temperature thereby breaking thermal monotony and lowering energy consumption. Alternatively, the device could have been used for those outside of the home to generate an informed understanding of the household's energy or comfort requirements, leading to a reduction in the outsiders own consumption or inducing a form of social pressure upon the tenants to reduce. Whilst the user and context study has illustrated that tenants were aware of their neighbours actions, such a mechanism is unlikely to induce enough pressure to change entrenched habits. Even if the social pressure was high enough, it would likely be undesirable for the tenant and/or may lead to a reduction of energy consumption or comfort to levels detrimental to the tenant. Outsiders may exhibit rebound effects and increase consumption if by comparison their consumption is lower. If the device also displayed information in real time, it may be used by outsiders to determine if the tenants are home, possibly facilitating crime.

Traditionally, devices such as Concept Four would be ornate and indicated predicted weather conditions and environmental metrics on a linear scale through a mechanical medium. Such formats traditionally allowed the individual to benchmark the information against the relevant spectrum (such as between 'fair' and 'rain'). By facilitating such benchmarking, the relativity of actions and its effects could be understood and situated for evaluation against intentions. Using an aesthetically recognised format may have increased the acceptance of the device within the domestic location. However, and as was noted in a guided tour (CA05), these interventions may be considered more ornamental than recognised as a source of useful information, with initial interest eventually subsiding and relegating the device to background aesthetics. Therefore, it is unlikely that such an intervention would realise any change in behaviour and reach the objectives of the brief.

In conclusion of this review, Concept One and Concept Three (specifically the alternative shutdown concept) were selected as most befitting of this criteria and developed further (Appendix K. Advanced Concepts). Subsequently

Concept One, following a brief period of further development, became the single direction determined through which subsequent theory and evaluation methods could be applied and tested towards the completion of this research's aim and objectives (due to project timeframes and limited resources). Following this decision, the level of design detailing and prototype fidelity was established.

In brief, the aim of the developed Concept One was to feedback to the tenant the status of their heating system in tandem with the status of their windows, so to convey to the tenant the energy consequences of their behaviour. This was achieved by the recording of two input variables; the radiators status (radiator surface temperature) as well as windows status (open or closed). Feedback would be provided in the form of two output mechanisms: light (colour) and sound (click). A third variable was discussed, illustrating the duration of radiator surface temperature activity through a biomimetic pulsing of the light, with a more rapid fluctuation depicting a longer period of activity (as if 'out of breath') to raise awareness and prompt action. During prototyping the pulse mechanism was dropped, as it was considered that for the purposes of the evaluation it would be difficult to disentangle and attribute the effects of multiple feedback indicators within a single intervention.

As the initial surface temperature of the radiator increased, the light located within the base of the radiator would activate and change colour depending on the temperature. As the light moves between temperature categories, the feedback device that provides the light, would also click, to indicate a change of state (replicating the sound of a gas central heating boiler turning on). If a window were opened in tandem with a detected increase in radiator surface temperature, the light colour corresponding to temperature would immediately display a warning light, to indicate waste. If the window were closed, the scales would immediately return to the pre-open window state. If the radiators began to cool, the colour change due to temperature would also begin to regress. If a window were opened with no initial surface temperature activation, then no feedback would be required or provided, as there would be no conflict in energy usage.

The temperature indicating the shift from activated temperature range through to warm/hot would be set at 43°C. This temperature is set based on the maximum safe surface temperature recommended for premises where occupants are deemed to be at risk (such as sheltered accommodation) *(NHS Estates, 1998)*. This figure was derived at based on the skins burn time response in relation to temperature exposure, and would seem to be an apt temperature at which to indicate a change in temperature categories (i.e. safe and activating to non-safe and activated).

When considering the colour of the lights, it was important to determine what the light colours were meant to represent. Did they represent a scale of energy use, radiator temperature, a comment on optimal function, or something else? Current research into ambient feedback devices suggests that if the feedback offered is too ambiguous and lacks any distinguishable and interpretable features, the feedback would not be easy to cognitive map by the individual *(Fitzpatrick and Smith, 2009)*. Considering the location of the device as being on a heat source device, it would make sense to frame the feedback content offered in relation to the temperature of the heat provided by this device, with the frequency of update being immediate. The two feedback categories of activating-to-warm, and warm-to-hot, should therefore visually represent the temperature ranges to which they correspond. The feedback category of activated-to-hot in parallel to the opening of windows (or *waste*) is more complicated as it is not a specific heat category, but may be considered a warning. Such feedback should therefore need to be cognitively accepted as being a warning of an inappropriate action by the individual. The intention for the activating-to-warm category was to indicate to the individual that the heating system was on, without presenting any information bias (regards acceptability or unacceptability of use) and fitting in aesthetically with the location to increase acceptance. A neutral hue such as white would likely be acceptable as it was not overtly ‘cold’ or ‘hot’ in appearance. If we further consider the black body scale, a scale that relates the temperature of an object to the level of light emitted, we could use an orange hue to represent the radiators warm-to-hot temperature (a match flame for example equates to 1,700k *(Kodak, 2011)*, has an RGB colour value of 255,121,0 *(Charity, 2001)*), which may cognitively match the users expectations of heat. The historic association of red with danger and negative outcomes has been shown to motivate an individual towards avoidance of an object, event, or possibility. The use of red in an achievement context alters cognitive function towards self-protection and anxiety therefore impairing performance. This occurs without behavioural intention or conscious evaluation *(Elliot et al., 2007, Elliot et al., 2009)*, suitable for a feedback intervention that would require implicit evaluation. The use of red as the warning colour was therefore ideal, as it sub-consciously steers the individual away from this negative state of suboptimal energy use. In the context of opening a window with the heating on (the red light colour activation mode), the anticipated avoidance behaviour motivated would simply be to close the window. Table 5-6 presents the possible permutations in status available to the intervention prototype.

Window Status	**Radiator Surface Temperature (°C)**	**Intervention Prototype Light Status**
Closed	<25	-
Closed	25-43	White*
Closed	43>	Orange*
Open	<25	-
Open	25-43	Red*
Open	43>	Red*
		*A click would denote a change between statuses

Table 5-6 Intervention Prototype Statuses

The prototype itself took the form of a low-fidelity part prototype or experience prototype *(Buchenau and Suri, 2000, McClelland and Suri, 2005)*, forms of prototyping that can be used throughout the design phase to not only explore the specific physical functions of a design but also to explore the non-functional aspects. This definition of experience prototyping includes aspects such as the experiential understanding and impact that the prototype would require or imbue upon the user within context, key components required to explore and evaluate a behaviour changing design intervention as will be discussed further in Chapter 6. The concept of experiential learning and the information it provides back to the designer in parallel with low-fidelity prototyping helps to drive the cyclical design process, providing the mechanisms through which to effectively evaluate and iteratively develop the design of a behaviour changing intervention.

The prototype accurately registered the temperature of the radiator using a self-adhesive thermocouple and the status of the window with a magnetic reed switch (the magnet to make and break the circuit was attached the window, with the sensor attached to the window frame). The information was fed back via three LEDs attached to the lower front of the radiator and through a piezo buzzer located within the main body of the prototype. Aside from these specified functional aspects, the prototype itself was literally a black box device on rubber feet with a removable lid, designed to run on three AA batteries (for safety and to reduce the burden upon the tenant) and to not require complicated maintenance or retrofitting for easy installation and removal by the researcher. The internal architecture of the prototype was developed so to allow for changes in specification and configuration, allowing extra sensors or ambient feedback modules (light, sound etc.) to be simply plugged in with minimal change required to the hardware and software package , as seen in Figure 5-18 (although this function was never ultimately utilised within this doctoral research).

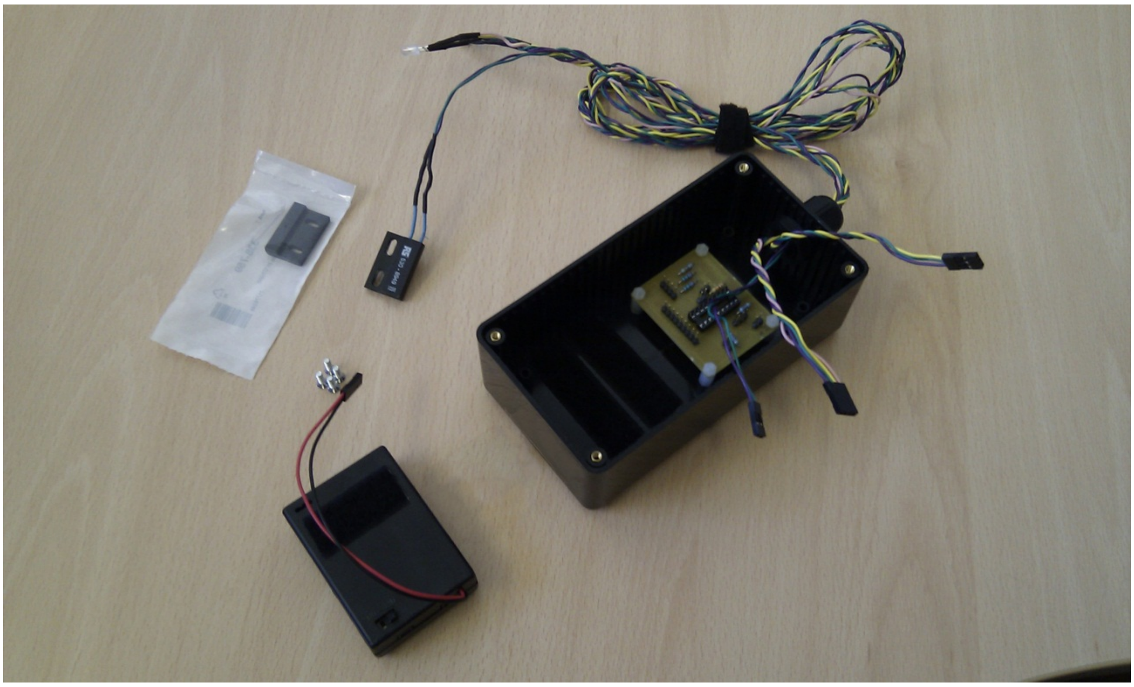


Figure 5-18 Intervention Prototype

A magnet was also produced as part of the prototype, designed to be affixed to the radiator near the LEDs to remind the tenant of their meaning, with a simple one-word description (Figure 5-19). Once the association between the light and its meaning had been established, the instructive magnets could then be discarded by the tenant or reused around the home. The magnets would be the only instructions that the tenants would receive aside from a verbal description during installation.

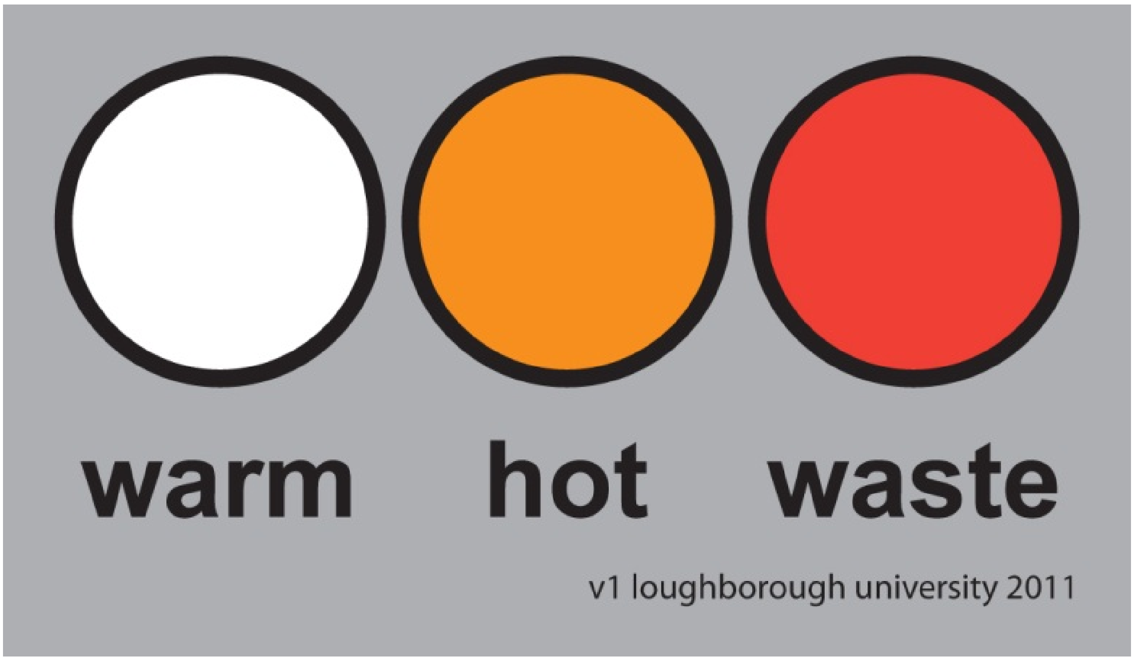


Figure 5-19 Instruction Magnet

5.5 Discussion

This chapter has illustrated part of the intervention design process, from which a backwards facing understanding of behaviour and its corresponding action and effect, the psychological and physical manifestation of *the problem*, can be translated towards the design of future facing behavioural intervention concepts and prototypes - *the solution*. This discussion begins with a reflection on the Intervention Opportunities phase, concluding with a discussion of the Intervention Design phase.

5.5.1 Reflection on the Intervention Opportunities Phase

Insights could be considered the platform on which a UCD design phase is developed, turning the vast amounts of complicated qualitative data gathered in earlier phases towards a simplified design direction *(Jones, 1992, IDEO, 1999, McClelland and Suri, 2005, Aspelund, 2010)*. However, determining which insight or design direction to pursue is not clear. A possible method as stated by Elias *(2008b)*, and discussed elsewhere in this thesis (section 2.6), would be to combine limited qualitative data with quantitative data. Elias proposes that products should be empirically evaluated and *bad behaviour* (or more specifically *bad action*, as the behavioural cause is not investigated) mitigated through redesign. The issue with such a method is that it does not seek to understand or address the underlying causes that drove the action. Changing the product without understanding the cause for action may lead to a negative impact upon both the user and the ways in which the product is used. The insights matrix presented within this chapter offers a valid alternative, emphasising the need to understand the insights *first* and then secondly have an interdisciplinary team broadly categorise them by energy impact. Determining design direction through this method removes the need for lengthy and intrusive quantitative and qualitative monitoring of the actions of the user and allows subjective discussion to take place informed by the less invasive data collection techniques of interviews and guided tours. In addition, this may be the first opportunity for many members of the interdisciplinary team to have access to, and the platform on which to discuss, the qualitative data, as not all team members would have been present or required during different phases of the research process. Discussing the data in such a format helps to unveil additional insights (a human geographers perspective is likely to be different from a designers or a built environment engineer) as well as to foster ownership of the results of this evaluation throughout the team. Although this method may be considered more subjective than monitoring the energy consumption of products (as Elias *(2008b)* proposes), it is also much more feasible and advantageous from three perspectives. Firstly, it does not require all energy-consuming devices to be monitored, which in itself is a complicated and extensive task, especially to monitor transient (such as phone chargers) or alternatively powered (such as battery) devices. Secondly, some effects, such as the use of clothing or venting may not be measured or correlated in such conventional methods as electricity or gas consumption. Finally, this method provides greater flexibility when trying to consider complicated compound actions. Insights into the compound use of windows and heating systems in addition to the effects of multiple occupancy, for example, would be complicated to disentangle through quantitative methods alone.

Following a path of convergence and divergence, reflecting the design phase to come, the reduced number of insights were used to generate several forward facing opportunities that were then consolidated, with a single brief eventually derived at. Multiple opportunities could have been taken forward straight into the design phase, with each explored to generate a myriad of design solutions *(IDEO, 1999, McClelland and Suri, 2005)*, however, given the broad nature of the aim to reduce the tenants domestic energy consumption whilst maintaining their self-defined comfort standards, it was more practical to refocus the opportunities towards a specified direction. This illustrates the complexity and size of the domestic energy consumption problem space, suggesting that projects that have shorter time spans or fewer resources may require a more limited scope or indication of direction prior to commencing the design process in order to reduce the number of front-end convergent/divergent iterations.

If the remit of this thesis was expanded to include the selection of DfSB processes, it is likely that selection process would be contained within this section of the Intervention Opportunities phase, in order to provide direction to the ensuing Intervention Design phase. Although it could be argued that the selection of DfSB processes is a design phase activity, in reality this selection process is more closely linked to the framing of the solution space rather than the designing activity within it and therefore would benefit from an interdisciplinary approach to offer selection guidance from a multitude of perspectives prior to design.

To end this reflection on the Intervention Opportunities phase, it is worth discussing whether it was of value to augment the UCD process as stated by the British Standards Institution *(2010)* in section 5.2. The value of the Intervention Opportunity phase can be seen in the quality and definition of the tenable opportunities generated at the end of this phase, which can all be transparently traced back through the data to the original data. Without this, what could in total be considered a convergent phase, the forward facing solution space would likely have been too large and too ill-defined for the designer to effectively explore without direction.

5.5.2 Reflection on the Intervention Design Phase

Moving on to discussing the Intervention Design phase, it is worth briefly discussing the value of expanding the context. By expanding the understanding of the user and their context, the insights and underlying assumptions that formed the opportunity became clearer and to an extent, although this was not the principal intention, even became theoretically anchored and therefore relatable to other theories and cases studies. Positioning this theoretical understanding in such a format also opened avenues through which to explore and generate appropriate solutions. For example, interventions could have been developed to offer feedback on the control mechanisms themselves, including the use of the heating system or windows, or interventions could have focussed on altering comfort parameters and how the individual defines and expects comfort to be provided. Interventions could also have focussed on illustrating or changing the prompts of discomfort or habitual behaviour, preventing excessive use of heating or cooling that directly or indirectly consume energy. Expanding the insights that formed the chosen opportunity theoretically, the additional clarity helped to define the solution space and steer the direction of further possible opportunities and solutions within this space.

The design of the intervention could be described as being a typically convergent process, prompting discussion on the impact of doctoral research time constraints on this process. Due to time constraints, the development of Concept One became a priority as it was deemed the most feasible direction that promised the biggest impact with regards to the discussed criteria. Concept Three was eventually shelved after discussion with the CCC project team, converging the intervention design phase upon a single concept for user evaluation. Typically, one would expect to evaluate multiple concepts at varying levels of detail and fidelity with the user as part of a UCD chain of divergent and convergent phases before pursuing (or becoming fixated) upon a single direction *(Pugh, 1990, IDEO, 1999, McClelland and Suri, 2005, British Standards Institution, 2010)*. Given, however, that the aim of this research was to understand the processes and methods that generate and evaluate feedback interventions rather than the efficacy of an optimised design intervention per say, a single concept was selected as a truncated, linear direction through the concept design and development phase, for evaluation. In short, understanding the methodological approach to solving the problem was more important than actually solving the problem.

The quality of the concepts relied on this designer having a broad knowledge of both the problem (generated throughout Chapter 4) and of feedback considerations (generated in this doctoral research through the literature review on that very topic, section 2.5). It would be difficult to gauge what the quality of outcome would have been without this knowledge; however, it is plausible that without this bank of case study examples and the knowledge thereby derived from it, that the quality would have been negatively affected. The root of this negative outcome would be attributable to the designer's gap in understanding between the design methods employed and the resulting effect upon the user and their actions. This points towards the need for designers that wish to engage in the effective design of feedback interventions being fully conversant in all the criteria and persuasive methods that they apply, possibly requiring some form of structured guidance or instruction during the design phase.

To conclude the discursive section of this chapter, the subjective nature of the critical reviews (that typified the convergent evaluations) and use of interdisciplinary teamwork is also worth discussing. Although the use of evaluation matrices and charts (as discussed by Pugh *(1990)* for example) were considered it would be difficult to assign any form of plus or minus relationship without subjective debate, especially as the solutions may be so disparate due to the large size of the problem and solution spaces. Although the motivation and intent of the designer may be the same across concepts, it would be difficult to find linear criteria against which to comparably evaluate a concept that relies on biosymbiotic feedback of environmental quality to a concept that interfaces and feeds back duration of heating system activity; hence, the requirement for a more subjective and interdisciplinary review. In addition to these reviews, the transparency of decision processes (such as recording the designers motivation, intent, methods and potential outcomes) and transparency of data manipulation from initial insights through to prototype helps to maintain and monitor the ethical thread that runs throughout the design process and places accountability on those that made key decisions within these phases. Furthermore, such an approach helps to establish and document this research as a structured design process case study for comparison to other research and design processes.

5.6 Conclusions

With the Intervention Opportunities and Intervention Design phases complete and discussed in the preceding sections of this chapter, the question becomes whether this chapter completed the third objective of this doctoral research:

> *To design and produce a feedback intervention prototype that intends to reduce domestic energy consumption whilst maintaining inhabitant defined comfort levels.*

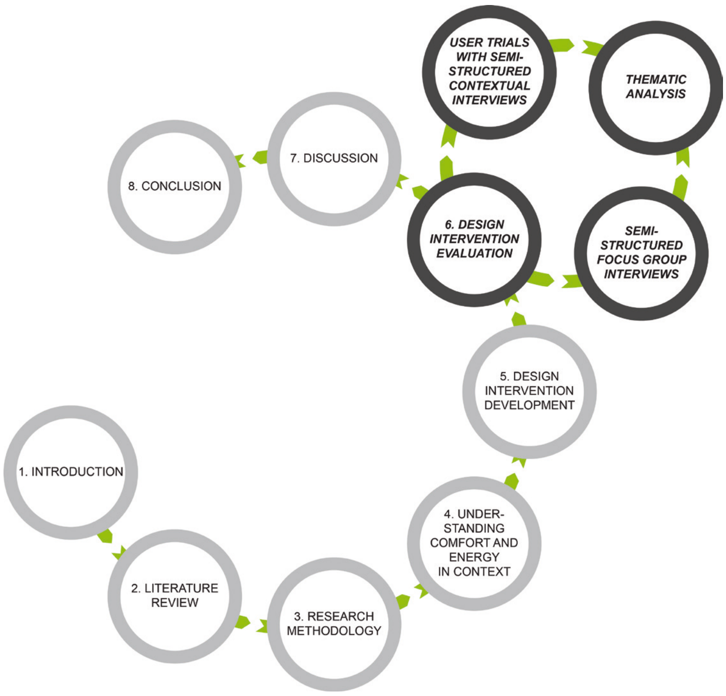
By documenting this process and stating the decisions made, this chapter not only provides a positive conclusion to this objective, but also presents it in a level of detailed resolution so as to allow the structured processes followed to be repeatable, for individual reflection or to be generalised against other theoretical propositions (such as other DfSB models) and case studies.

What this chapter has achieved, is to argue for and document a section of an augmented model of the UCD process (Figure 5-2). Augmenting this model with an interdisciplinary Intervention Opportunities phase, this research has suggested that something is needed between understanding and specifying the context and user (the problem space), and the design of an intervention (the solution space). Without this convergent and divergent *filtering* phase, the problem space is excessively ill defined with multiple disparate issues to consider. For example, although the use of windows for fresh air, decorative living room fireplaces/lighting and hot water bottles all affect comfort and energy consumption, to consider all in one brief would not lead to a single solution that would achieve acceptable resolution to all issues. Likewise, even with a single direction defined, the solution space explored within the design phase would be equally without direction without prior assistance, requiring the need for additional *clarification* of the opportunity or insight, and *guidance* on the methods to use (feedback considerations or on a more macro scale, the selection of the DfSB strategy itself).

In conclusion, the phases of this augmented model have illustrated a process path; taking the themes generated in the proceeding chapter that seek to understand *how* inhabitants define and control comfort, and closing with a structured, well documented and traceable (through the design process) feedback intervention prototype. However, to answer the question specifically as to whether the feedback intervention prototype will *actually* reduce domestic energy consumption whilst maintaining comfort, this will need to be discussed further, and is therefore the subject of the next chapter, Chapter 6.

6 Design Intervention Evaluation

6.1 Introduction



This section details the evaluation phase of the intervention design process (Figure 6-1) towards the completion of the fourth research objective, *to evaluate the feedback intervention prototype, using assessment criteria developed from the literature review*. This section goes on to discuss the methodology employed in the assessment of the feedback intervention as well as the findings of this evaluation.

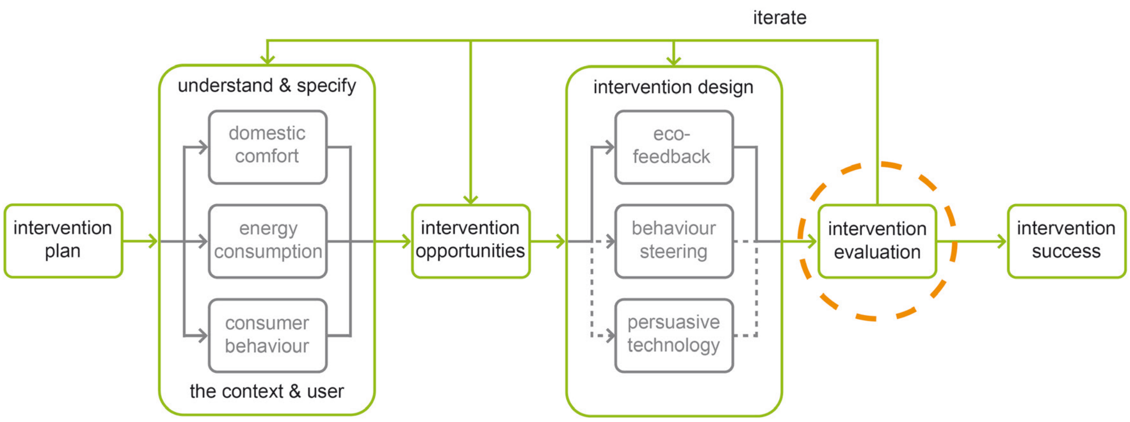


Figure 6-1 The Design Intervention Process – Intervention Evaluation

The purpose of a user-centred evaluation is twofold; to *feed back* positive and negative information into the design process in order to better meet (or understand and redefine) the user's requirements, as well as to understand if the design produced meets those specified user *requirements (Maguire, 2001, British Standards Institution, 2010)*. IDEO succinctly elaborates upon this, stating "*the point...is to change the solutions, not to prove that they are perfect" (IDEO, 1999, P.77)*.

6.2 Evaluation Criteria

The criterion against which a design is evaluated is developed from an understanding of the contextual research study and through a cyclic design process, as formalised within the design brief and specification (presented in section 5.3.4). Although the users' exact requirements will change depending on the aim and function of a design, three fundamental questions arise when faced with the evaluation of a DfSB strategy led intervention (Figure 6-2):

- *Did the produced design solution function for the specified context?*
- *Has the user's behaviour changed as a consequence of the design intervention?*
- *Is the change in user's behaviour sustainable?*

These fundamental questions are a development of those used to direct and reduce the number of insights into tenable opportunities (see section 5.3) and to guide the concept selection process (see section 5.4).

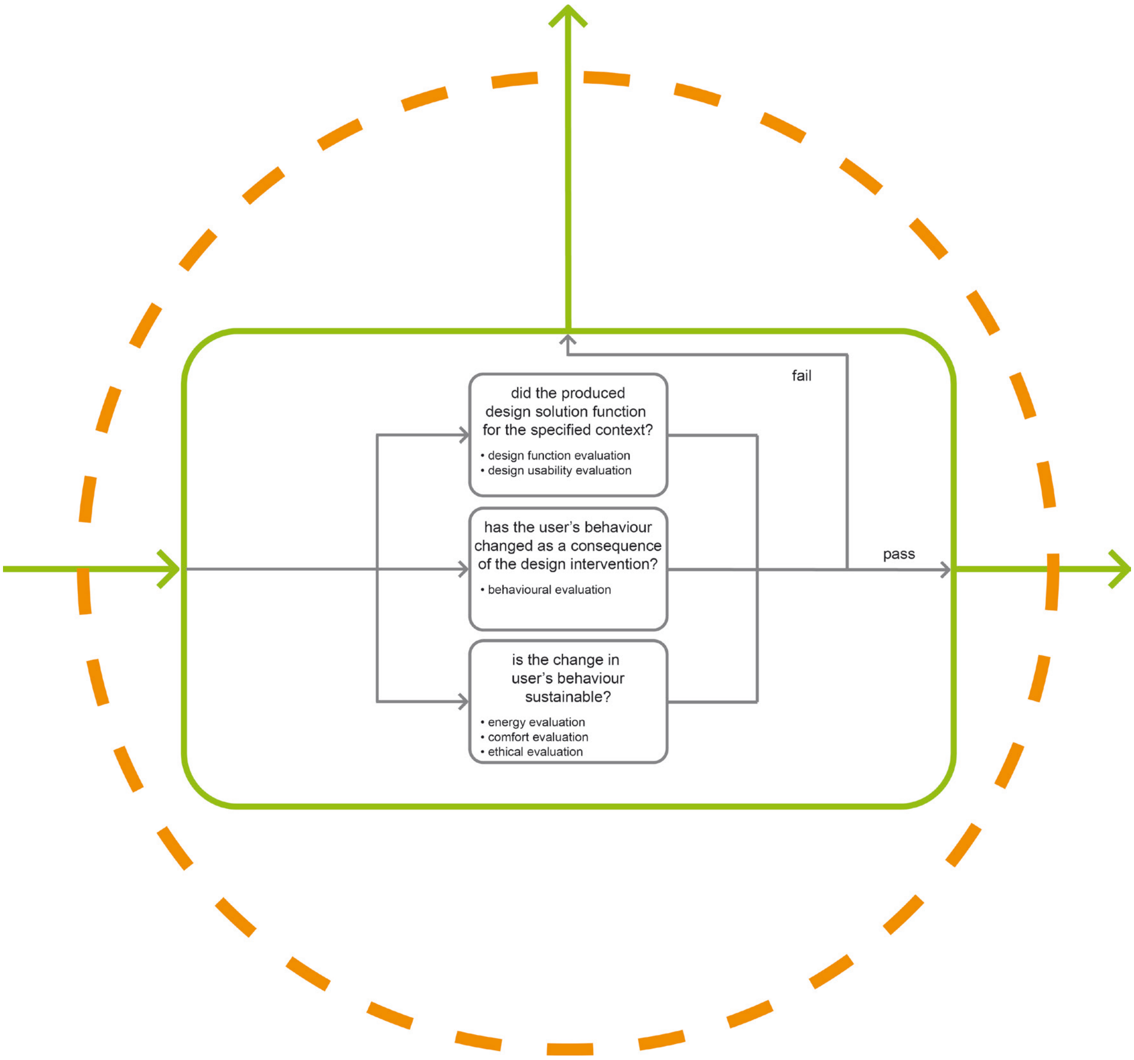


Figure 6-2 Intervention Evaluation Phase of the Design Intervention Process

6.2.1 Did the Produced Design Solution Function for the Specified Context?

This question pertains to an evaluation of the designs *usability* and *function*. Is the usability of the design in line with the user's requirements and expectations, and do the design functions operate as the designer intended? Clearly different designs have different criteria against which to assess usability and function. Taking the three points of Lilley's *(2009b)* strategies as an example, *eco-feedback*, *behaviour steering* and *persuasive technology*, there may be a common target such as reducing resource consumption, for example, but the methods employed vary drastically. Eco-feedback may seek to reduce consumption through the provision of information, which has its own framing questions between itself and the user. Behaviour steering devices may rely on affordances and constraints to encourage a reduction in consumption, and thus semantics and ergonomics may be of focus. Persuasive technologies in negating the user to enforce a change may be assessed against the technical support to install and maintain the technology and to monitor the technology's effects.

As feedback intervention is the primary focus of this research investigation, the question as to whether the produced design solution functions for the specified context should be viewed through a *feedback evaluation lens*. Drawn from the extensive literature review in section 2.5, the following function and usability aspects need to be evaluated to provide a thorough feedback intervention evaluation (Table 6-1).

How frequently and what is the duration of the feedback information that is fed back to the user, and what is the effect this has on the user's cognitive bridging between action and effect?
How accurate is the feedback information presented, and how does this help to associate or dissociate a user with their actions?
How does the selection of the contents and metrics resonate with the user's individual norms and motives?
Is the feedback information presented a granulation from a larger system, and how does it help or hinder a user's understanding of this information within that system?
How does the medium of presentation affect a user's ability to engage with the feedback information?
How does the selection of presentation mode affect the user's comprehension of the feedback information provided?
How does the user interpret ambient features, and to what extent are they cognitively mapped by the user and in line with the designer's intent?
How does the location of the device affect the ways in which the user interacts with the feedback information?
Does the user have any technical expectations of the feedback intervention, and have these been met?
Does the feedback information rely on the use of comparisons to further information groups, and does this inhibit or stimulate consumption?
Has any additional information been provided or goals or reward schemes activated to supplement the feedback information?
Are there any user led challenges that may inhibit or counter the designer's intention for the feedback intervention?

Table 6-1 Function and Usability - Evaluation Questions

Please refer to Appendix L. Feedback Usability and Function Evaluation Questions for an expansion upon the above evaluation questions.

6.2.2 Has the User's Behaviour Changed as a Consequence of the Design Intervention?

One of the primary objectives of a DfSB intervention should be the changing of a user's behaviour towards long-term sustainable ends, not the short term changing of a user's action for immediate ecological/social/economic gratification. Therefore, this second question relates to the DfSB interventions ability to change the behaviour of the user. In order to determine if the user's behaviour has changed due to the design intervention, it is imperative to understand the antecedents of that behaviour targeted for change. Only then can it become possible to recognise and fully evaluate any change in the behaviour attributed to that intervention.

The following questions, also developed from the literature review, aim to determine and understand the changes in context and intentions between the prior and post design intervention installation states (Table 6-2).

What was/is the user's knowledge and perception of environmental matters, morality, resource consumption and comfort, both prior and post to the introduction of the design intervention?
What was/is the user's value weighting of environmental matters, morality, resource consumption and comfort benefit, against expected cost, prior/post to the introduction of the design intervention?
What was/is the user's conceptualisation of social rules and actions relating to environmental matters, morality, resource consumption and comfort both prior and post to the introduction of the design intervention?
What was/is the user's categorisation of social and group roles in terms of environmental matters, morality, resource consumption and comfort, both prior and post to the introduction of the design intervention?
What was/is the user's perception of their self and what do they deem to be appropriate goals and actions in terms of environmental matters, morality, resource consumption and comfort, both prior and post to the introduction of the design intervention?
What are the positive and negative emotional responses associated with actions related to environmental matters, morality, resource consumption and comfort, both prior and post to the introduction of the design intervention?
What was/is the facilitating conditions (capabilities, situational context, public policy, economic variables etc.) that influenced/s the user's action, prior/post to the introduction of the design intervention?
How did/does the facilitating conditions constrain or afford options, prior/post to the introduction of the design intervention?
How did/does the contextual infrastructure moderate or influence between intention and habitual factors, prior/post to the introduction of the design intervention?

Table 6-2 Intentions and Facilitating Conditions - Evaluation Questions

With the contextual aspects and intentions identified in the pre and post design intervention states, the third variable that needs evaluating is the one that governs the user's action, their level of cognitive reasoning, or conversely, their level of cognitive automaticity. In order to determine the habitual strength of behaviour the following questions have been derived from the literature review (Table 6-3).

How frequently was/is the behavioural act enacted, prior/post to the introduction of the design intervention?
Did/Does the user exhibit a lack of awareness of how they act in terms of conscious decision making or delegation of control of the behavioural act to contextual cues, prior/post to the introduction of the design intervention?
Did/Does the user have free mental capacity to do other things, or exhibit efficiency through expectation filters, prior/post to the introduction of the design intervention?
Did/Does the user have difficulty in controlling their behaviour in relation to this act, with trouble in deliberate thinking or planning, prior/post to the introduction of the design intervention?
Did/Does the behavioural action represent a sense of personal identity to the user, prior/post to the introduction of the design intervention?

Table 6-3 Habit – Evaluation Questions

6.2.3 Is the Change in the User's Behaviour Sustainable?

This third category of inquiry relates to the impact of the changed user behaviour, in respect of being ecologically, socially and economically sustainable. Through an understanding and measurement of the change in these sustainability metrics, the success of the DfSB design intervention can be put into perspective against the interventions function and ability to change the user's behaviour. In the context of this research project, the three key sustainability metrics of interest are domestic energy consumption, domestic comfort and ethics. The following items, again developed from the literature review, evaluate the states both pre and post the introduction of the design intervention (Table 6-4).

What was/is the domiciles domestic energy consumption prior/post to the introduction of the design intervention?
What was/is the domestic energy consumption by inhabitant/appliance/room/temporality prior/post to the introduction of the design intervention?
What were/are the inhabitant’s expectations and actual levels of physical (lighting/acoustical/air/thermal) comfort, prior/post to the introduction of the design intervention?
What was/is the domestic comfort level by inhabitant/room/temporality prior/post to the introduction of the design intervention?
Can the effect of contextual infrastructure (such as building fabric, situational context and economic variables such as cost per unit of energy etc.) upon energy use and comfort, both prior and post to the introduction of the design intervention, be quantified?
Does the ecological, economic and social benefit from the change in behaviour outweigh the ecological, economic and social impact of intervention provision?

Table 6-4 Sustainability – Evaluation Questions

As outlined in section 2.7, the ethical measure of an intervention is not only calculated by the behaviour changed, but is also a measure of the design process itself. The following questions, also derived from the literature review, evaluate the ethics of the user’s changed behaviour, as well as the ethics of the process through which the design intervention was created (Table 6-5).

Was the designer’s original intent for designing a behaviour intervention ethical?
Was the designer’s original motivation for designing a behaviour intervention ethical?
Are the intervention methods employed by the designer, in order to change the user’s behaviour, ethical?
Has the designer/user/purchaser taken moral responsibility for the design intervention?
To what extent is the user in control of the design intervention?
Is the level of user control over the design intervention acceptably weighted against the intent and motivation of the designer?
Have the democratic decision making rights of all stakeholders been accounted for in the design process?
Have the values and morals of all stakeholders been accounted for in the design process?
Have the values of the stakeholder been evaluated against a robust ethical framework?
Are the intended outcomes of the design intervention ethical?
Have unintended interactions between the user and the design intervention been predicted and are ethical?
Have unintended use contexts involving the user and the design intervention been predicted and are ethical?

Table 6-5 Ethics – Evaluation Questions

6.3 Design Intervention Evaluation Study – Focus Group Interviews

With the need for evaluation discussed, the remainder of this chapter presents the findings of this evaluation. This section presents the findings from the two focus group interviews, subdivided into the following themes:

- The Need for Information
- Learning through Action and Consequences
- The Use of Windows and the Need for Feedback
- Ambience and Cognitive Mapping

6.3.1 The Need for Information

Several of the focus group participants could not understand the *need* for information on radiator temperature and window status at all:

FG08	I'm not the cleverest bloke in the world but I know if my radiator is on or off!

Such a statement echoes the sentiment of many of the participants in that they believe that they are *always* aware of the status of their heating system and that information is not necessary. Further questioning, however, uncovered several past situations where this was shown not to be the case, and the provision of information may have informed the participant to make appropriate controlling action prior to the excessive or undesired use of their heating system:

FG09	…because I've been so warm I fell asleep...I've got up, looked at the thermostat, and it's like twenty six, and I've touched the radiator and it's been boiling.
-	
GTW	So how do you know when it's too hot [due to the heating]?
FG05	...when one of my kids starts shaking because they can't breathe because of the air.

The same participant who knows "*if my radiator is on or off*" (FG08) resoundingly believed that no amount of information alone was going to change the way in which he operated his heating system, despite discussing past actions where one would assume that information would have been of use. This suggests that the physical connection between action and consequences is of more educational value than information alone to this participant:

FG08 ...I’ve turned mine on, and thought, I’m going to go out, and forgot to turn it off because you only turn it off by manually doing it, there is no other way, and sometimes I've gone to bed and forgot I’ve left the lounge heating on last winter and it’s like the Sahara desert in the front room because it’s been on all night, and I've thought, that’s cost me, so I turn it off.

This may also indicate that the framing of the information may be incorrect. It was clear from the discussions that information on temperature alone may not be a sufficient motivator to action, and that the information provided may be better suited to providing information on economic concerns:

FG07 …you could apply a monetary saving value...so for example if it’s been on three days red therefore you’ve accumulated two pounds something...then you would turn it down...because with heating you think ‘money’, I’m losing out... because if it tells me it’s hot or cold, well my body tells me that it’s hot or cold...

The statement *“my body tells me that it’s hot or cold”* (FG07) is also interesting in itself. The aim of the intervention is to frame comfort and consumption in order to make an informed evaluation; however, it is clear from this statement that the participant believes the purpose of the intervention is to try to *replace* this cognitive decision process, not supplement it. As the participants believe that this information is already available to them (through physical sensation), they suggest that the intervention should “*do something*” (FG08):

FG07 What’s it for...it’s not stopping a process, you’re still opening windows, you’re still going to touch the radiator, you’re still going to turn the thermostat down, so what does that do?

6.3.2 Learning through Action and Consequences

Several of the focus group participants after viewing the scenario video discussed that touching the radiator to determine its surface temperature, as an indication of heating system activity, was something that resonated with the ways through which they interacted with their own heating systems.

Emphasising the lack of conscious thought when evaluating their own heating system, one participant when asked why they touch their radiator even responded, "*I don't really know*" (FG02). Interestingly, a few of the participants used this as one of only a few mechanisms by which to monitor their entire heating consumption.

FG06	I just leave mine set on twenty all the time, and when it goes below twenty it'll just kick on and take the chill out the air...it comes on and off all day itself all through the day and night...it just keeps the whole house warm.
GTW	Do you find sometimes that because you don't know what the temperature is...you can't tell if it's turned on or off?
FG06	Yeah, you can't tell unless you feel the radiators...
FG05	...unless you walk past it and there is a little light on it [in reference to the thermostat] [FG07 nods in agreement].
GTW	So you could potentially spend the whole week with the heating on and not realise it is actually on?
FG05	Just until your gas goes! [FG05 and FG06 laugh in agreement].

The use of sensory contact with the radiator was discussed further by the participants after being shown the intervention video. The consensus of the main focus group was that even with feedback, the individual is still, or even more so, likely to be driven to confirm the information with physical contact:

FG07	You're still going to touch the radiator...it's just human...you're still going to touch it, still going to check it like that...its human senses...like when you hear the thermostat click, you still touch it to see if it's come on, even though the click has told you that the heating is come on.
FG10	...it's human nature.
FG09	...and you rely on that more than a device because a device can let you down, they are not always accurate or they can give you a wrong reading or whatever.

Whilst this may not be such an issue for able-bodied adults, the use of light indication on a radiator may increase the chances of vulnerable adults or young children burning themselves through physical contact with the hot surface that the light is indicating a change in:

FG08 ...but to me, a flashing light attracts them...a kid sees a flashing light, they are going over to that.

FG09 ...they are more inclined to ignore it if there are no light on it.

A counter-argument discussed was that the information could be used to teach children not to touch the radiator when the light is on:

FG05 ...if you've got toddlers, and explain to them that when the red lights on you do not touch the radiator...I know a few toddlers that's touched radiators and burnt themselves because they get that hot…

In addition, a few of the participants illustrate how prepaying for fuel can have an effect on consumption behaviour:

FG08 ...it's like in a car, isn't it, at the end of the month you drive slower in it than at the start of the month...so at the end of the month...you drive as slow as you can, thinking I need to get to another petrol station, but when you've put a full tank in, the first twenty to fifty miles you're going around like the clappers because you think 'I've got loads of fuel'...but it's the same thing with the heating.

FG05 ...when I put my heating in, every time I get paid...the heating's on full blast, then when it comes to Friday Saturday, it's like, shut that door!

6.3.3 The Use of Windows and the Need for Feedback

Although some of the participants agree that feedback may be a good idea (as an educational tool), they cannot see the point in the window sensor; the idea of opening the windows with the heating on to them *"doesn't make sense*" (FG03). However, following the intervention video and lengthy discussion amongst the participants, several situations where such information may have been useful came to the fore:

FG05 ...you heat up your house and then when you are warm enough you have to open up your windows because they've got condensation on them.

FG09 ...well I'm a smoker so I open the windows first thing in the morning.

FG10 ...you have to at least blow everything through and just hope that the heat retained in the walls and the floor that doesn't dissipate quick enough.

GTW So does anybody actually open the windows with the heating on?

FG10 Because to change the air in the mornings [FG09 nods in agreement].

-

FG02 …when I'm drying my clothes I still have the windows open and yet my radiators are on full, otherwise my room overheats and I get breathless and that.

Many of the situations discussed suggest that the windows may be open for short periods whilst the heating system is active. In most of these situations, this action is driven by a short-term immediate goal that is perceived to be of greater benefit than the long-term control and goal of domestic warmth.

Another statement that is revealing is that the participant's perceptions and use of heating systems and windows is similar to participant FG07's statement "*my body tells me that it's hot or cold*":

FG09 …believe me you'll know that the heating goes because by then it'll go cold and you would of shut it long before that!

Again, this statement suggests that the participant is used to managing their heating and window systems through the physical perception of excessive comfort parameters, such as high or low temperatures and poor or good indoor air quality. The reliance on physical sensation has been used as the feedback information mechanism to manage and control comfort historically, and is unique to each individual. Although the aim of the intervention is to prompt and supplement this decision making process, it appears that the participants would be reticent to use the device as they do not see the connection between the information that it provides and the actions that they historically perform. Knowledge that the heat from the radiator may be escaping out of the window may be considered irrelevant. In order for this intervention to succeed, it is clear that the participant first needs to understand the energy interaction between the heating system and the windows, and furthermore, have a desire to reduce or remove the time between action and the experience of extremes in physical comfort perception and associated consumption.

6.3.4 Ambience and Cognitive Mapping

The *off* status of the lights illustrated that either the heating was off or the radiators surface temperature was below 25°C, with the window either open or closed. When the participants were prompted to state what they believed the off status to mean after watching the intervention video, the consensus across all participants was that the radiator was off or is cold.

> FG02 It's a cold radiator.
>
> FG01 It doesn't indicate that anything is happening at all.

The *white* status of the light indicated that the heating was on and that the surface temperature of the radiator was between 25°C and 43°C with the window closed. All the participants agreed after watching the intervention video that the change from off to white status indicated that the surface temperature of the radiator was starting to rise.

> FG05 It's getting there now, isn't it; it's starting to heat up.
>
> FG09 It's kicked in and it's starting to warm up.

FG01 suggested that it might have been a good idea to tie the colour of the status light into the thermostat, however, the surface temperature of a radiator does not correspond to room temperature due to differences in the size of radiators etc. This suggests that the participant may have a linear and incorrect model of their heating system, believing that the higher the thermostat is turned, the hotter the radiator surface becomes (when in fact it is the duration of maximum surface temperature that is actually increased).

The *orange* status of the light indicated that the heat output of the radiator was within its highest surface temperature range, above 43°C, with the window closed. The definitions offered by the participants vary. FG01 assumed that as the orange light was the middle light (sandwiched physically between the white and red LEDs), that the radiator temperature must be half way between cold and the maximum. FG07 tentatively suggested that this may mean that the radiator is *"hot"*. FG05 confused the temperature of the radiator with the room temperature, reiterating again this incorrect supposed relationship between radiator temperature and air temperature as described by FG01. Whilst the surface temperature of the radiator and its exact relationship to air temperature is not clear amongst all the participants, it is clear that the majority of participants liken the change in colour of the status light in the same way as a rising thermometer, that it signalled a general increase in temperature.

The *red* status of the light indicated that the heating was on and that the surface temperature of the radiator was above 25°C and that the window was open. Although one participant vocalised that this meant that you have *"let the cold air in"*, the majority of the participants agreed that the red status light referred to a hotter radiator surface temperature than the orange status light. Some participants believed that having the red status light to signal waste to be confusing as the red was construed as a warning of a broken radiator, not waste.

> FG07 ...you open a window and a [red] light goes [on]…why are the lights going [on], is there something wrong with my radiator...might think their heating system is broken.

FG01 suggests that all the status light should be based on room temperature and that the light state recedes a colour with the window open as the room temperature drops. An alternative suggested by another participant was that the intervention should employ a red/green/amber system, as it would be easier to relate to. Others suggestions included the use of words instead of lights to indicate status as the meanings may be soon forgotten, or that if lights were to be employed, that they may have to flicker to catch the individuals attention. It was also suggested that the device itself may be soon forgotten, like a burglar alarm light, if not correctly positioned and with an appropriate level of intrusive feedback.

> FG07 It's like when you have a burglar alarm, with the sensor in the corner. I hardly notice it...because I'm so used to it, I disregard it.

With regards to the 'click' sound, none of the participants wanted it to play any sort of music or loud interrupting noise, although a few of participants had difficulty hearing the low level clicking sound.

> FG05 You wouldn't hear that in my house, not with all my kids.

The presented findings of the focus groups interviews can be summarised briefly into the participants' perceived and actual need for information, the self-reported evidence of cognitive learning developed through action and its consequences, the participants' perceptions and logic that drive window use, and finally, the cognitive mapping and understanding of the feedback prototypes ambient features by the participants. The findings of the focus group interviews are discussed in detail with the user trial findings in section 6.5.

6.4 Design Intervention Evaluation Study – User Trials

This section presents the findings from the user trials with semi-structured contextual interviews in Merthyr Tydfil. From the wealth of data collected, the following themes have been identified as being of particular interest and are summarised below:

- Information, Action and Consequences
- Installation Location
- Metrics and Monitoring
- Educational Tool

6.4.1 Information, Action and Consequences

The information provided by the intervention was understood to an extent by both participants, raising their awareness of what the heating system was doing in response to certain actions, such as opening a window, or in response to temporal frames, such as the time it takes for the radiator to heat up or cool down.

> CA02 It was good, I thought. It was, it was letting you know when it was hot…my son-in-law would open the window…and you could see the colour changes straightaway. It does make you more aware of the

temperatures in the room…you could understand how the heat could go out of the room so quick and come back on…you can see the difference when you opened the window how your energy is flying out of the window…in fact you can think well, why put the heating on if I'm going to open the windows, because it's just flying out of the window like, isn't it?

-

CA05 It's to remind you, I think, that obviously the white one comes on when it's just warming up and cooling down…now, sometimes I notice, we'll be sitting here and I think: oh, the white light is on there. And for some reason the radiator was going off. So, it was good because otherwise perhaps you wouldn't notice. And then you think: oh, I don't feel so warm now and the heating's on. But then when you'd look on there you'd see it must have been perhaps the turn for that radiator to cool down while the thermostat comes back in.

To elaborate upon the 'extent' of understanding, it is clear that CA02 perceived the temperature of the radiator to correlate directly to air temperature, believing that the 'waste' status of the red LED indicated a higher, and therefore more wasteful, surface temperature, clearly depicting the incorrect mental model that the participant had concerning their heating system. The intervention helped the participant to associate action with an effect; however, the exact understanding of the effect was not entirely correct. CA05 identified that heating systems did cycle, and that the variations between the white and orange status indicators showed this increase or decrease in radiator surface caused by the settings chosen by the participant on the thermostat and thermostatic radiator valves [TRVs] and the air temperature.

CA02, in response to this information, closed her blinds more often as she believed that this cut down on the number of draughts emanating from the window, thereby allowing the radiator to get hotter. This action would prevent heat from escaping from the room, thus increasing the efficiency of the heating system due in part to the information provided.

CA02 Well, you'd hear it click, and then your radiators were then hotter…It's like opening the window, there your heat is going out of the window; and it must be the same with draughts because it was getting hotter,

> you know. I noticed that…it means you should shut your blinds more often, doesn't it? [Laughter]

CA05 responded to the information in a different way to CA02, being prompted to explore and increase her own understanding of how the heating system worked across the household and the consequences of any changes that she made to the settings of this system. Through the changing of the status indicator on the radiator, the participant was encouraged to reassess their thermal comfort, to investigate the settings of their heating system and to act accordingly in terms of her comfort levels and other intentional concerns.

> CA05 The benefit for me was when it was…the radiator was obviously knocking itself off and I didn't realise, you know; so I was wondering why it was. So, it make me then move about to see; I was going in the living room and feeling that one and that would be on, the hall one would be on, and I'd think: oh right, why has that gone off. So, I'd have a fiddle with that. Then I'd see it come back on. And then I'd turn it back down. And I'd be like this then, trying to read the paper and I'd be checking it then; looking at it all the time.

Both participants found that the clicking noise that accompanied the change in status was the first thing that they noticed, drawing their attention to the status light indicator. Over time, how both the participants responded to this information changed. CA02 initially responded to the information by touching the radiators surface, as a form of experiential learning as predicated by the focus group interviews. Towards the end of the installation period, the participant no longer felt the need to touch the radiator, as the cognitive connection between the visual and audible status indicator and the physical radiator surface temperature had been established. CA05 responded over time by paying less attention to the intervention, with it 'blending' into the background. During the initial period of installation, the information provided by the device was considered and acted upon to optimise the use of their heating system. Towards the end of the installation period the device was used less for exploration as the initial desire for experimenting was over, with a stable level of understanding accrued. In addition, the audio-visual feedback itself became more 'familiar' to the participant, with the once invasive feedback becoming part of daily fabric and routine.

CA02	Well, when you got up in the morning of course you put the heating on, and then all of a sudden that would start clicking then. Oh, the radiators getting warm now; and it would click when the radiator was getting warm…if you're just watching telly then the click would be the first thing you notice. But like I said, it wasn't annoying in any way…in the beginning I used to [touch the radiator]; you just get used to it then. Oh, that's getting hotter; or that's not so hot now…
-	
CA05	The lights would come on; it gives a little click doesn't it when it comes on, so I'd notice the click first; then I'd be checking it, you know. But then it just blends in like all the other stuff that's around...I think I got into such a routine with the heating, you know, I forgot it was there really…but you just don't notice them; they're just familiar; they just blend in.

When reflecting upon the intervention, the participants believed that certain actions that control their comfort and energy use are unchangeable, regardless of any information that the feedback intervention may provide. CA05 demonstrates that whilst she is aware that opening the windows with the heating on is something that she would never do, she would still open the window afterwards, despite the radiator still being warm, if she believed the consequences of her actions to have a net positive benefit.

CA05	If I got too warm in here if the heating was on I'd knock the heating off first; and then if I still didn't cool down enough then I'd open the window.
GTW	Would you wait until the light goes before you open the window?
CA05	No, because that white light stays for quite a long time. So, it's depending how I'm feeling, you know.
-	
CA02	…if you're hungry you eat; if you're cold you put the heating on…I don't think anything would change you. It can't actually, can it? Unless you're willing to say right I'm not going to put that up so high; I'm going to put an extra cardigan on…if that's the way you want to live of course...That's the way I suppose a lot of people live; or they put a blanket over themselves or something.

6.4.2 Installation Location

The location in which the intervention was installed also had a noticeable effect on the way in which the information was acted upon by the participant. In both installed locations the intervention was positioned in the room that the participant had previously described as being the room that they are most active in during the day. For CA02, this room was the living room, with the intervention installed on the radiator and window between the participants TV and regular seating position. Prior to the intervention prototype being installed the baseline found for CA02's home that living in a multiple occupancy dwelling, with tenants in different rooms with different comfort expectations, resulted in frequent ad hoc use and changing of the heating system. Without any means of mechanical notification to other tenants, it would not be until the physical sensation of detecting the change in air temperature was noticed that any corrective or optimising changes could be made, such as lowering the thermostat or TRVs altered by other tenants. With the intervention, CA02 was able to detect the change in the radiators surface temperature before physically detecting a change in the air temperature, allowing the participant to alter her radiator accordingly and optimise the system by minimising waste.

> CA02 …if it was a day like today now and [daughter] wanted that heating on, and I certainly don't see no reason for it to be on...I'd put it on for them but I wouldn't have it on myself...I knew she'd been down then and she'd put the heating on…if I didn't want it on I'd turn it off on the radiator.

CA05 asked for the intervention to be installed in the kitchen, on the radiator and window abutting the dining table. It is clear from the following statement that in order for the information to be acted upon, it needed to be in the same location as the participant. This quote also illustrates the difficulties in effectively controlling heating systems such as central gas, where the current information, feedback and control mechanisms available are usually located in a central location that is not necessarily a suitable position for the tenant to effectively engage, immediately reflect and action any changes rapidly.

> CA05 ...In the living room I think I spend perhaps two or maybe three hours a night in there at the most; longer on the weekends because both of us

are here and then we'll go in there, you know. But this [kitchen] is where I am mostly; and this is the room that…I decide whether I'm putting the heating on or not.

GTW …you said earlier that sometimes you forget that the heating's on and you fall asleep…Did this ever remind you?

CA05 No, because if that happens we're usually in the living room then comfortable, you know; you're more relaxed in there then.

The interviews also confirmed the participant's perception of costs and perceived benefits, such as the priority of fresh air circulation and leaving certain windows open permanently over the cost of heating with the windows open. Windows not in close proximity to radiators or within different rooms to those being heated may also have been open, therefore, the full benefit of the information provided by the feedback device may not have been realised (an upstairs window may have been un/intentionally left open by this/another tenant with the heating on).

CA02 As soon as I get up I'd open the window to allow a bit of air in; unless it's extremely cold – in that case I don't…If it's nice for a few hours; but if it's not very nice just for a half hour or something just to let some fresh air in…My daughter opens her bedroom window as soon as she wakes up in the morning…and the bathroom window's open now; the toilet window – just a little bit…

EDH So, if the heating was on and you were airing out how long would the windows be open for?

CA02 If it's cold only about 20 minutes perhaps…

-

CA05 …I open the window automatically. When I get out of bed I open the window always. I leave the blind shut because I go back up for a shower then later. And I just leave the windows open until I feel chilly. It's surprising; if the window's open upstairs you will feel a draught down here around your feet…So, if I feel, I think I feel a bit draughty, and then my husband will come in and he'll say: all right, put the heating on, I'm cold – so I'll say: let me run up and shut the windows.

EDH	Do you still leave the bathroom and the bedroom window open when you go out?
CA05	Yeah…If it's really, really cold I'll have the shower first and get dressed. But I'll usually come down, and if I'm going out I'll come back up and clean my teeth before I go; and then I would shut them then if it's really cold.
EDH	So, is that just for fresh air?
CA05	Yeah…just fresh air.

6.4.3 Metrics and Monitoring

The selection of temperature as the metric represented by the intervention was debated by the participants. Whilst the participants, as previously discussed, could understand the representation of radiator temperature, it did not always motivate them to any form of action. Discussing economic concerns and monitoring, CA05 stated that she would be interested if the intervention could display a *"running total"*, allowing her to monitor and manage her direct debit expenditure. Displaying historic information concerning the cost of the energy that CA05 is consuming, she states, may make her consider alternative options more so before putting the heating on.

CA05	…I mean you put it on, you don't know what you're using until the bill comes…and you could have a really nasty shock. If there was something that would say like a running total, you know, how much your bill is now, perhaps before your bill comes in you'd think: oh, I'll leave it off a bit longer – if you could see how much you are actually using; or how much that radiator is costing when it's on.

Conversely, CA02 believes that monitoring energy use or being made aware of the cost is irrelevant, as she perceives the use of the heating system as being a necessity.

CA02	But I don't believe in people being cold just for money like. I hear people say: well, I turned the heating off so much a day; it's too expensive. But you can't tell people you've got to go cold because I can't afford it…When you're cold it's got to go on…if I thought I could find a way of keeping ourselves comfortable cheaper I would…

In addition to the discussion of economic metrics, CA05 also voiced an opinion on environmental metrics. CA05 was very sceptical over the merits of environmental metrics, believing the negative affect of energy consumption on the environment to be a fallacy.

CA05 …I'm quite sceptical about it all, all this planet thing. I think all this green stuff is just a way of them adding money onto your holidays…I don't think we're doing much harm to the planet myself; but some experts think you are…Some say that the ice is melting and all this; I don't know. I don't believe everything I read.

6.4.4 Educational Tool

As an educational tool, both participants gave examples in which children got involved with the intervention. Echoing some of the discussions held during the focus group interviews, in both households children had the intervention explained to them by the participant with the children seeming to both understand and enjoy applying the knowledge that they learnt from the information provided. In one event, the heating system had turned itself off as the prepaid sum of gas, used to power the boiler, had all been consumed. The grandson of the household had noticed that the light on the radiator had changed before any other tenant had noticed a physical drop in air temperature, indicating that the heating system had turned itself off. On recognising that this was an unexpected event, he informed the adults of the household who then also recognised this to be a display of unexpected information, to which they then responded accordingly. Although it could be argued that this information *increased* their consumption of energy, it did also help the household to maintain their desired comfort level and to *re-evaluate* their consumption.

CA02 Yeah. I thought it was quite good, I've got to be honest, just those little things by there so it was working, that ability like. I really thought it was good. As I said, the littl'un [grandson] was most fascinated; he'd sit by it watching it…Waiting. He was amazed by it…and our [grandson] would get up and say: the radiators have gone off. Well, we'd sit here and we didn't know the gas had gone; we'd run out of gas. So, [grandson] knew by that; the gas has gone, he said, because that's off…Because we didn't really know it had gone off like.

The second participant household also found children to be interested in the intervention. Visiting grandchildren understood how the intervention operated and the information presented, actively explaining the device to other visitors to the household. In addition, CA05 believes that when the children returned home may have applied the concept of energy 'waste' out of windows without the need for the intervention.

> CA05 …the children would tell her [daughter] what it was, you know, because they like to show that they know what these things are. They knew exactly what it was then, and they knew how it worked: now, when it's warming up and cooling down that white light comes on; then when it gets hot you know; and you're not allowed to open the window then when you've got the heating on because that red light will come on. They knew; they understood it completely…if their mother was cooking and opening the window with the heating on...she probably would say: 'mummy, you know, you've got the window open and you've got the heating on, you're wasting'.

6.5 Discussion

Through a combination of formative testing involving focus group interviews and summative testing, consisting of user trials, the design intervention has been evaluated with social housing tenants and the findings presented in the proceeding sections of this chapter. In order to determine if the design intervention has fulfilled its requirements, in other words, to determine if the intervention was a success, these findings need to be put into context against the three fundamental questions posed. Furthermore, it is also important to consider and discuss the suitability of the evaluation methods employed, to determine if these methods are the most appropriate for evaluating a DfSB strategy led intervention.

6.5.1 Did the Produced Design Solution Function for the Specified Context?

A focus group interview is not an ideal mechanism through which to validate and quantify design decisions, due to the discursive and dynamic nature of the method. A focus group interview, rather, is an ideal platform through which the produced design, a culmination of contextual research into an issue or 'problem', can be discussed with users in order to ascertain whether the designers understanding of the issues of concern are correct, and furthermore, that this technological manifestation of the 'solution' is what the user actually wanted *(Nielsen, 1997, Bruseberg and McDonagh-Philp, 2002, McClelland and Suri, 2005)*. The findings from the focus group interviews support this use of the methodology, illustrating multiple discussion points concerning the need for feedback and information, and issues with how the feedback is generally interpreted and may be upon acted, as opposed to any quantitative evaluation.

The findings indicate that whilst the use of scenario videos helped in aiding discussion and framing the context and issues of interest, the participants generally did not understand or see the need for information concerning how they manage their home energy heating systems. The discussions concluded that feedback on window opening in particular would be of little benefit to them but that feedback may be of educational value to children. The majority of the participants relied on the physical sensation of comfort as a feedback mechanism that arises from the use of these heating systems. Examples given of such feedback included feeling too hot with the central heating system left on for extended periods eventually driving a desire to turn it down; the touching of radiators to determine if the heating system is active after altering the thermostat; and windows for fresh air left open too long eventually creating a discomforting cooling effect, finally driving window closure. Such mechanisms, however, are not ideal as they rely on discomfort to indicate a change of state or excessive consumption. Without this information or prompt, the participants provide evidence that such systems may be left unaltered, potentially at great financial cost to the tenant. Whilst this focus group interview has clearly illustrated the need for an intervention mechanism, it is suggested by these findings that the use of feedback information alone, especially regarding temperature data and window use, may not be enough to motivate change.

Concerning the design of the feedback intervention itself, the use of ambience was generally well understood and accepted by the focus group interview participants, demonstrating in part the success of using scenario videos and the physical prototype as part of the methodology. The concept of having a red light for ‘waste’, however, was an issue as the majority of participants believed it to represent a hotter radiator temperature, indicating that the majority of participants did not fully understand how their heating systems actually worked.

The advantage of using user trials over focus group interviews is that it is possible to understand how the user engages and interacts with an intervention in a real use context over time. Changes in perception and interaction can be mapped over the installation period in situ, rather than a static first impression of the device out of its use context. What the findings of the user trials illustrated, is that the frequency, duration and accuracy of the information fed back to the participant had the desired consequence in effectively helping the participant to understand both how the action of opening a window with the heating on and how the heating system actually worked. Through the provision of rapid and accurate information, the participants could see any instantaneous effect that their actions would have on the heating system, either intentional or unintentional such as opening a window, changing the thermostat or TRV, or running out of prepaid gas. This encouraged a period of investigation and optimisation, particularly during the initial period of installation, although towards the end of the four month installation period the participant’s receptiveness to the information seemed to decrease. This may be attributed to either the participants actions becoming optimised as far as they believed possible and therefore no longer required the information, or that they did not perceive any benefit to actions based upon the initial information and so therefore eventually chose to ignore it.

The location in which the prototype was installed had a clear effect on the level of information received, as it allowed for the real-time monitoring of the status of the heating system from a position of localised comfort, indicating whether the heating system was active (if an activating/deactivating temperature had been determined by the thermostat or TRV). In terms of the use of ambient features, the use of the ‘click’ mechanism also proved to be of particular use as a localised prompt, as this tended to initiate the opening investigation of the status lights on which subsequent actions were placed. The issue with such a localised information point was twofold. Windows not included within the intervention were not monitored, allowing a window to be open in one room and the heating to be on in another without a 'waste' warning, and furthermore, additional tenants in these multiple occupancy dwellings did not necessarily have access to this information, and so therefore could not act upon it. Further issues include the misunderstanding of what the 'waste' light indicated and similar discussions around the use of monetary expenditure as a metric, the need for physical feedback on comfort parameters to benchmark the information. These issues could have been designed out or built upon through iterative redesign.

6.5.2 Has the User's Behaviour Changed as a Consequence of the Design Intervention?

The findings of the focus group interview do not illustrate any real changes in behaviour, as the intervention and any *potential* change in behaviour that may arise from its use are *discussed*, not actually *enacted* over time within the use context. In addition, the changing of habitual behaviour is also unlikely to be demonstrated from a single focus group interview, as one of the constituent parts of habitual behaviour is a frequency of past behaviour *(Jackson, 2005, Polites, 2005, Lally et al., 2009, Steg and Vlek, 2009)* a change which cannot be established from a single point in time without self-reporting (which brings its own set of problems *(Sniehotta and Presseau, 2012)*). What a focus group interview does offer, however, is the same opportunity that it does when evaluating the designs functions; it allows the researcher to understand if the 'problem' and intervention context has been understood and appropriately translated into a 'solution'. In terms of understanding behaviour and potential behaviour change, this manifests itself as an understanding of the antecedents of behaviour and the effects that the intervention may have upon them, primarily the intentions of the individual.

From these focus group interviews, it is clear that the benefit of comfort provided through such actions as opening windows and using the heating system is weighted as being of greater value than any economic or environmental cost. Some participants leave the heating system active throughout the year, preferring the year-round thermal balance regardless of cost; something that was especially apparent when discussing the short term use of windows for fresh air and managing the effects of cooking, drying clothes or smoking, where the windows are opened irrespective of whether the heating system is active or not. These short-term benefits were perceived as being of greater value than the economic cost of leaving a window open or the cost of effort required to modify the heating system. The findings also provide evidence that the participants have a distrust in technological devices and information in general, preferring to defer to their own perception and senses, relying on experiential learning and experience to determine future courses of action. Another interesting finding supports the position that those who use a prepayment system or shorter billing term for paying for energy may have a different model of understanding and associated consumption than those who pay by direct debit over longer periods such as by yearly quarter. A few participants analogised the use of home energy to being like that of a car, whereby you are only concerned with its consumption towards the end of the week or month (or tank of petrol to use the analogy), when the cost of its use is again put into the users frame of awareness.

In terms of habitual behaviour, as previously discussed, it is impossible for any such change to be effectively noted or its antecedents understood from a single focus group interview. It is possible, however, to attempt to understand and theorise any *potential* use contexts with the participants, based on the participant's intentions and experiences.

Several participants discussed their heating system use patterns, including leaving the heating on year round, the need for airing out the home and their compulsion to touch the radiator in order to determine whether the heating system is active. Although these issues relate to the intentions of the user, they also point to their habitual actions. Awareness as to when the heating system is put on or turned up, and opening a window was generally high, although after this engagement their awareness of the consequences of this action dropped, with the individual preferring to allow the system to run unabated until extreme discomfort was experienced.

The user trials provided the opportunity to detect a change in behaviour by comparing a baseline taken of the individuals behavioural antecedents prior to the installation of the design intervention, and then comparing that baseline to a point taken after the design intervention had been installed. The advantage of such a methodology is that it allows the researcher to determine how the individual's intentions, habits and resulting action may have changed over time, providing, in this study, fixed points in time for qualitative comparison (pre and post installation). In addition to understanding the change in action, changes in the facilitating conditions can also be revealed that will influence behaviour, such as any change in the built form of their home, their heating system, economic concerns or the other tenants with whom they reside.

Comparing the baseline data to the uninstallation data, it is apparent that the majority of intentions, facilitating conditions and habits have stayed the same. From the qualitative data, it is clear that the built form and heating technologies are still the same within these participating properties, with the same tenants occupying the same rooms, performing similar daily tasks and window opening and heating activation routines as recorded in the baseline. Perceptions of the role of one's self as well as perceptions and the value weighting of resource consumption and comfort had not changed between these two recorded states. What had changed, however, was the knowledge and awareness that the participant had concerning how the heating system works and when it is active. This change in knowledge and awareness manifested itself with both participants having a deeper understanding of how, when and why their heating system is active or inactive, leading to the exploration and optimisation of its control (primarily through the thermostat or radiator TRVs) for both resource consumption and comfort management. Importantly, this awareness occurred prior to extreme discomfort, the mechanism noted in the baseline as being the primary notification of undesired heating system activation or running, therefore, essentially reducing the time that the heating system was running in its inefficient state, saving energy.

6.5.3 Is the Change in the User's Behaviour Sustainable?

In order to determine the sustainable impact of the change in user's behaviour, sustainability metrics need to be quantified. This research has been limited in its capacity to evaluate the sustainability impact of the intervention, primarily due to the lack of quantitative data (as discussed in section 1.2). Questions such as *what was/is the domestic energy consumption by inhabitant prior/post to the introduction of the design intervention?*; and, *does the ecological benefit from the change in behaviour outweigh the ecological impact of the intervention provision?* cannot be addressed without a quantitative baseline prior to intervention compared to a quantitative post intervention evaluation of energy consumed (with its relevant environmental proxies). Environmental assessment tools such as Life Cycle Analysis (Bhamra and Lofthouse, 2007) are severely limited without such necessary information.

The use of a focus group interview was limited as a method in investigating the sustainable effects of the design intervention. Whilst a focus group interview may provide an insight into the intentions of the participant, it can only offer a small amount of predication to its actual impact on comfort and resource consumption. What the focus group interview provided was a discursive opportunity for the researcher and the participants to discuss values, moral and expectations.

During the focus group interview, an example of such discussion arose around the use of windows with the heating system active. From a resource conservation perspective, it would be ideal for the participants to turn their heating off when opening the window. The majority of the participants, however, did not anticipate doing so even when provided with information from the intervention, potentially choosing to ignore the values inscribed by the designer in order to pursue their own perception of values and benefits. The device potentially allowed the user to choose the action appropriate to them, being afforded *democracy* in decision-making. In addition, the platform allowed the potential users to discuss any issues they thought might have been of concern arising from the scenario video and envisaged potential use of the device, facilitating the discussion of intentional and unintentional potential outcomes. One particular issue of concern was that the flashing multicolour LEDs of the intervention might unintentionally draw young children to the device increasing the chances of them being burned by the radiator. It was decided following the focus group interview that until the exact effect of the LEDs could be established, that the intervention would not be installed in any homes for the user trials with young children, highlighting the necessity for such evaluative work early in the design process. Furthermore, the focus group interview also provided evidence as to why an intervention was an ethical necessity, with the findings stating that leaving the heating system active for an unintentionally long period may be detrimental to the health of some children, resulting in a lack of breath and "*shaking*".

Although limited by a lack of quantitative data, the user trials, however, did allow for an evaluation of the ethics surrounding the intervention and the design decisions made. Rather than being a prediction as to the uses of the intervention, the evaluation could be made based on the participants experiences of interacting with the intervention over time. An intentional ethically responsible effect of the device was that it eventually removed the need for the participant to touch the radiator in order to determine the temperature of the radiator. Once the participant had cognitively associated the temperature of the radiator with the status indicator LED, the need for the participant to touch the radiator was removed, reducing the chance of the participant burning herself because of this desire for information. An unintentional effect of the intervention was that it allowed the participant to realise when they had run out of prepaid gas and the heating system had shut itself off, allowing the participant to hastily reinstate the gas supply without too great a loss in comfort. Whilst this may have in effect increased consumption, the value priority for the participant at this point was comfort, and this intervention helped to facilitate that management.

6.6 Conclusions

Whilst the proceeding chapters sought to understand and apply insights from the intervention context towards the development of a feedback intervention, the purpose of this chapter was to investigate whether criteria garnered from the literature review could be drawn together and applied for assessment of a DfSB intervention, evaluating both the intervention and the data collection methodologies used. This purpose is enshrined within the fourth objective of this doctoral study:

> *To evaluate the feedback intervention prototype, using assessment criteria developed from the literature review.*

One conclusion drawn from the findings and discussions is that the assessment criteria drawn from the literature review can in effect be placed into three distinct groups, resonating with the design, sustainability and behaviour aspects of the eponymous strategy used, DfSB. Split into three lines of questioning, the design group of questions focused on the function and usability of the intervention, noting that each intervention strategy would require its own set of guidelines. The behavioural line of questioning was subsectioned into the antecedents of behaviour change, focussing on detecting and understanding changes in the intentions and habits of the individual, as well changes in the facilitating conditions that surrounded them. The third and final line of questioning focussed on sustainability aspects, including in this particular study the consumption of energy, the regulation of comfort and the balancing of ethics.

In attempting to answer these questions, several data collection methodologies were applied. Table 6-6 summarises how appropriate each methodology was in providing answers to the three groups of questioning. Conclusions drawn from this table are that a focus group interview is ideal when attempting to uncover and gain further discursive insights concerning the individuals' intentions, and how these values and beliefs reside within an ethical framework. In addition, the functionality of the design can be discussed, not to provide a quantitative assessment but rather to explore if the researcher's original interpretation of the individual's values and intentions was correct, and that the designed intervention was appropriate to the 'problem' and to further discuss any potential ethical issues that may arise from its uses. A focus group interview, whilst not ideal for summative evaluation, is good for the early formative stages of designing a DfSB strategy led intervention. User trials are well suited to both formative evaluations, to help with the cyclic process of understanding and iterating the design, as well as summative, to draw conclusions as to the change in behaviour and sustainability impact over time. The application of energy consumption and environmental monitoring would have, it is predicted, provided both physical and quantitative evidence for any measurable change in comfort (through environmental proxies) as well as determine if the intervention had actually reduced or increased energy consumption, filling in the evaluative gap left from the user trials.

	Design	**Behavioural Antecedents**			**Sustainability**		
	Function	**Intention**	**Facilitating Conditions**	**Habits**	**Energy**	**Comfort**	**Ethics**
Focus Group Interview							
User Trials with Contextual Interviews							

Table 6-6 Data Collection Methods Used and the DfSB Data it is Suited to Collect

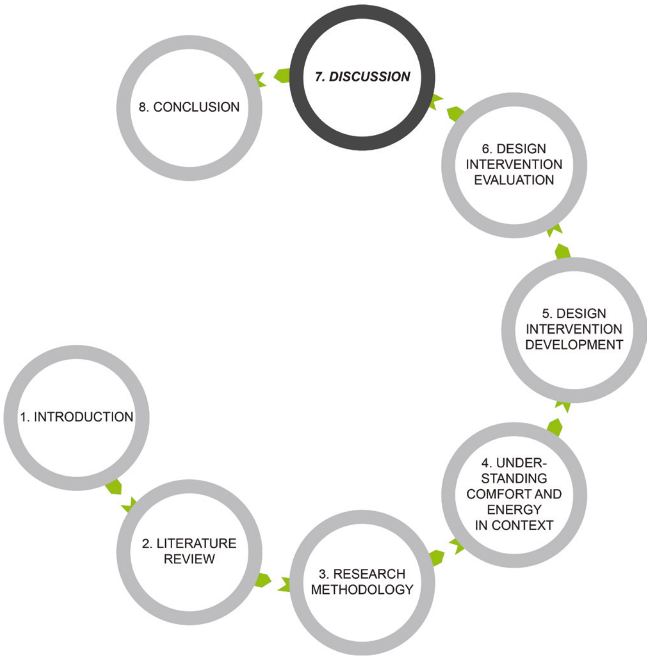
In evaluating the intervention in line with the brief, *"to change the behaviour of opening windows with the heating system active using feedback, in order to achieve a reduction in domestic energy consumption whilst maintaining comfort",* the answer to the question, *did the produced design solution function for the specified context*, the answer is yes, potentially. The caveat to this positive answer is that the device clearly needs to be iterated to be made more in line with the participant's cognitive understanding of how 'waste' is defined or the feedback intervention requires further supplementary information to explain how the heating system actually works and what the cost benefit may be to avoiding such 'waste'. In addition, the system of feedback should be expanded to include other rooms within the house so to provide a better picture to the tenant on how their home is heated and cooled as a system, and that other tenants in other rooms within the household may be able to act upon this information.

Answering the question *has the user's behaviour changed as a consequence of the design intervention*, the answer is yes. The provision of information has not altered the motivation or intentions of the participants to act; however, by providing information feedback, it has allowed the participants to act upon these motivations and intentions more efficiently. Although the action and intentions of turning on the heating system is essentially the same as prior to installing the intervention, with no significant change, the feedback mechanism provided has superseded the habit of waiting for extreme discomfort by increasing knowledge and awareness allowing the participant to tailor its control and use.

Answering the question, *is the change in the user's behaviour sustainable*, is in effect a composite question concerning an evaluation of ethics and changes in comfort and domestic energy consumption. Whilst it is clear that the values of the intervention did not always coincide with the values of the participant, the intervention afforded the participant a large degree of flexibility in their response to the information provided, allowing them to democratically choose their desired course of action. Intentional outcomes had been identified and accounted for, with the few unintentional outcomes that did manifest themselves not resulting in unethical outcomes.

7 Discussion

7.1 Introduction



As part of our moral responsibility to maintain the ecological, social and economic base for present day society and future generations, environmental targets have been ratified by the Parliament of the United Kingdom *(2008, 2009)* and enshrined within the Climate Change Act 2008. The environmental predicament that both the UK and global communities are in, which has necessitated such legislative action, has been propagated, in part, by energy consumed within the domestic sphere and the greenhouse gases that are produced as a consequence *(Department of Energy and Climate Change, 2008)*. Prior research has illustrated that more efficient technological solutions may not be the solution *(Darby, 2006, Mintel, 2009)* and that, as many authors have argued, it is the behaviour of the user that should be the target of intervention, focussing on how the user defines and enacts comfort behaviour with the home *(Chappells and Shove, 2004, Chappells and Shove, 2005, Cole et al., 2008, Shove, 2008)*.

This research has explored such energy consuming domestic comfort behaviour and interventions that could challenge that said behaviour. Although each preceding chapter of this thesis present their own discussions and conclusions in relation to fulfilling the research's aim and objectives, this chapter positions these findings within an expanded remit, discussing the larger implications of this research for the research and design communities. As such, the overarching topics of the pursuit for fresh air; the considerations and limitations of feedback as a behaviour change strategy; and comparing the design intervention process in action to extant DfSB process theory.

7.2 The Pursuit for Fresh Air

In order to effect a behavioural change through design it therefore makes sense that a specific behaviour or set of behavioural actions need to be targeted for design intervention. A specific objective therefore was included in the aim and objectives of this thesis, research objective 1, section 1.4, designed to determine the factors that drive and facilitate the consumptive actions of the individual, to form an understanding of the complex cognitive processes and facilitating conditions that perpetrated that action. Using a qualitative approach, combining contextual interviews and guided tours, the *understanding control, comfort and energy in context* study within this chapter yielded several fascinating findings. Such findings include the unexpected use of fireplaces as an aesthetic focal point and for incidental light, not for heat provision; the dichotomy and battle for control between the *freezers* that always feel cold and those that always feel hot; and the pursuit of individuals for freshness and fresh air. The pursuit for fresh air has been of particular interest within this thesis, due to both the novelty of the subject and the lack of prior consideration for design intervention.

Bluyssen *(2009, 2010)* and Nicol and Humphreys *(2002)*, state that air quality and thermal comfort control is determined by several physical parameters, such as air pollution or temperature with prompts for change manifested through levels of unacceptable discomfort, which facilitates corrective action. The *intention* to act is prompted, considered and acted upon; dependent upon the *facilitating conditions*. Can the window be opened or closed? Can the thermostat be turned up or turned down? An example of this was closing the window when feeling *chilly*. However, what this research has also established is that habitual response is also present within the pursuit of fresh air, and furthermore, is a powerful influencing variable to action. It was apparent that the propensity and vigour of this pursuit for fresh air within this study sample illustrated many of the prerequisite conditions for habitual action. Self-reported actions in both pre and post intervention studies illustrated that regardless of the indoor air quality and weather, windows were routinely opened, often without consideration for the heating system. So can we still assume that intentions are always considered and acted upon?

Frequency of past behaviour and high levels of automaticity was evident; with actions performed regardless of the external weather conditions and time of year when opening windows, although closing windows remained ruled by discomfort prompts rather than habitual behaviour. Interestingly, this view of fresh air and airing out as being habitual has also been discussed by Hauge *(2010)*, supporting a wider *ritualised* perspective of fresh air. In addition, an interesting comment from one of the participants encapsulated a notion of social and national identity, which has over time become automated: "*We've always been told us Welsh you've got to open your windows every morning...to air the house…my mother always used to do it...and my grandmother so..."* CA02F. The wider ramifications for behavioural theory are that an *intention* to act may be prompted and acted upon, such as the social norm of being a *Welsh mother* or the weighting of values towards comfort, however, cognitive process over time becomes *automated* with actions performed without consideration of alternatives; dependent upon the *facilitating conditions*, such as time of day or knowledge of heating system control. Intentions are in fact, not always considered and acted upon.

This research has illustrated that attempting to change the *intention* of an individual with feedback alone does not correlate with a substantial change in overall behaviour, as the high degree of cognitive automation exhibited by the individuals does not provide an effective or prolonged point in time for the consideration and assessment of their intentions and to act upon them. Illustrating the temperature of the radiator and 'waste' in an attempt to alter the individual's perception and evaluation of outcomes had only a limited effect in this doctoral study. Behavioural action, it would appear, remains largely unaffected unless the behaviour change mechanism illustrates a dramatic enough change to *motivate* conscious and on-going *consideration* and reassessment. Even in the depths of winter when thermal discomfort and energy bills were at their highest, windows were still opened daily (pre, during and post intervention) with little conscious consideration for its thermal and cost impact. This appears in line with Triandis' Theory of Interpersonal Behaviour, which as Darnton *(2008)* discusses, prioritises habitual cognition over intention and facilitating conditions. The use of antecedent strategies, such as commitment or goal setting strategies may have helped to concentrate or motivate the individual towards more sustainable action, however, disentangling the effects of feedback with additional behaviour change strategies would have proven problematic without several large groups for comparison and control.

Targeting a second antecedent of behaviour, habit, by increasing awareness of action, again did not gain much traction in changing behaviour although it did help individuals to tailor their current action and to inform them of any erroneous consumptive events. Although the individual may have been initially prompted to consider their actions within a framed problem, without any significant change in intentions or facilitating conditions it was likely that the individuals simply went back to repeating their actions in a way that they once found satisfactory until again it became (or continued being) automated and habitual. Therefore, making the individual only aware of their actions was not sufficient motivation to change them. Framing the problem and informing the individual that their window was open with the heating on would not change action, logically, if there was no motivation or change in intent to do so. An additional explanation for the return to existing behaviour may be that the predictability and consistency of the ambient feedback features had become less effective over time as receptiveness to new information fades, an issue as noted in the WaterBot trials by Arroyo et al. *(2005)* and as described by Van Dam et al. *(Van Dam et al., 2010)* as feedback becomes a *background* technology. The results of the WaterBot trials suggest that variety in reinforcement could prevent this cognitive stagnation.

Changing the third antecedent of behaviour, the structure or facilitating conditions may have yielded a change in behaviour, as it may have been possible to facilitate or constrain direct action as well as to activate goals *(Steg and Vlek, 2009)*, however, this was not explored within this doctoral research. It may be reasonable to expect, however, that without due consideration of the behavioural structure and decision making processes of the individual, such a change may have manifested itself in negative outcomes, such as avoidance, misuse or rebound effects in much the same ways as the government's policy on CFLs, which are still widely rejected by the public *(Crosbie and Baker, 2010)*.

This work represents an important and significant step in the research of domestic energy consumption and occupant behaviour. Prior to this work, research into heating and air management has been primarily restricted to an engineers, quantitative perspective of the built environment, with occupants within office buildings perceived as static elements, hence the predisposition for measurable parameters as supported by authors including Fanger *(1970)* which have become enshrined in technical standards (for example, BS EN 15251:2007 *(British Standards Institution, 2007)*). Difficulties in changing an offices environment to suit each individuals comfort preference has often led to searches for universal solutions. Research in this field from the social sciences, meanwhile, is limited to a hand full of discursive studies, such as Hauge's *(2010)*, that don't effectively capture or consider in depth the link between comfort behaviour and action. This discussion proposes that designing to environmental quality parameters alone would not provide sufficient motivation to change ingrained individual behaviour and that an alternative approach that more fully considers the individuals cognitive processes and the behavioural framework in which it is situated is required. There is, after all, no single technical standard that adequately accounts for the socio-history of Welsh mothers.

7.3 The Considerations and Limitations of Feedback as a Behaviour Changing Strategy

7.3.1 Considerations of Feedback

Feedback, in essence, is an educational tool; a tool that illustrates general consumption back to the individual for reflection and framing of a problem, or links a specific interaction to a consequence, thereby bridging (and influencing) the gap between the individuals intentions and actions with the ensuing consequences *(Abrahamse et al., 2005, Burgess and Nye, 2008, Fischer, 2008, Darby, 2010)*. Wood and Newborough *(2007)* suggest that feedback should be designed in order to motivate action, as the informational content within feedback alone may not be enough to prompt action. To this end, a series of feedback considerations were drawn together from existing studies (section 2.5) which were considered and applied within the design (Chapter 5) and evaluation criteria of a feedback intervention (section 6.2).

This research has discussed and confirmed several key considerations of feedback design. The frequency, duration and accuracy of the information allowed the participants to see relatively instantaneously the effects of their action, with the impact immediately displayed. This, in combination with the location of the device on the radiator in close proximity to the window, allowed for accurate real-time monitoring of the status of their heating system and facilitated an initial period of exploration and optimisation; this is all in line with the literature. A breadth of authors, including Fisher *(2008)*, Darby *(2006)* and Abrahamse et al. *(2005)* have all stated that quick feedback after an action reinforces the bridge between action and effect. In addition, Wood and Newborough *(2007)*, Hargreaves *(2010)* and Fischer *(2008)* have all suggested that duration (for example, instantaneous or weekly consumption) and accuracy of the information contribute to maintaining the interest of the individual, also making the information meaningful and helping to strengthen the cognitive connection between action and effect. This research supports these features of feedback.

The location of the feedback device, according to Fitzpatrick et al. *(2009)*, Anderson and White *(2009)* and Ofgem's Energy Demand Research Project *(2011)*, should be installed in the individuals preferred location, which they found to be the kitchen, living room or main hallway, as this will facilitate deliberation. This presents a problem, as rapid feedback should be located in a position that improves the association between action and effect. If an instantaneous feedback device illustrating heating system and window use was positioned in an area without either of these interactive elements, such as the hallway, one may assume that the benefits of instantaneous delivery and interpretation of feedback would be negated. Within this research, the visible location of the intervention on the radiator not only helped to strengthen the connection between action and effect, but was also welcomed by the participants as it afforded consideration whilst being in a position of comfort.

One could extrapolate from these findings that the future for instantaneous ambient feedback devices should be as integral devices, installed within the device itself to strengthen the cognitive link between action and effect. As a separate unit, which may display more complex or detailed information, the acceptance of such a device is contingent on the individual's preference for location, which as illustrated, may not be near the performed action, thus weakening its impact.

A consideration that has not been discussed by other authors is the effectiveness of feedback where multiple occupancy is concerned. Within this research it was found that whilst feedback is useful for an individual to assess the impact another occupant had on the heating system (such as opening a window), that second occupant didn't have either the opportunity to assess their *own* impact (due to location), or that the information that was provided was not relevant to *their* intentions. Clearly as the number of user's and actions increase, this will have a manifold effect on the number of variables that the device will need to consider and be designed for in order to be suitable and relevant to all users. Two possible directions come to mind, either the connected system could illustrate every consequence of every action upon itself, such as the effect of opening a window upstairs whilst the heating is on downstairs, or alternatively, the feedback device itself would need to be adaptable to the individual motivations and intentions of *each* individual. One possible direction that this could take would be to tailor the information (which as suggested by Darby *(2006)*, is an effective method of providing information relevant to an individual's distinct intentions) through context and user aware technology. Durrell Bishop in exploring the use of items tagged with RFIDs, considers the connection between the user, control and the physicality of devices *(Moggridge, 2007)*; suggesting an interesting direction whereby interactions could both be physical and bespoke. A feedback device in this way may conceivably respond to the different physical interactions of differing individuals with information tailored upon their specific intentions.

It is also worth discussing the ambient nature of feedback as this research can make an important contribution to this area of feedback research. Whilst the literature clearly indicates that ambient feedback must be easy to cognitively map and support implicit evaluation *(Fitzpatrick and Smith, 2009, Maan et al., 2011)*, how such mapping *develops* is unclear. Are we to assume that the individual has a clear mental model of how the feedback relates to the action and consequence prior to initial interaction with the feedback device, or should we provide a mechanism through which this cognitive relationship can be developed, and perhaps more appropriately, be shaped? Interestingly, this research study has shown how the participants had generated their own cognitive maps in parallel to receiving feedback on action; relating the feedback to physical sensation. Initially it was found that ambient feedback was only a prompt for the participants to touch the radiator to determine its temperature, however, over the course of the user trials the participants began to accept that certain touch temperatures related to specific lights and sounds, generating the desired implicit evaluation; eventually the lights replaced touching the radiator all together. The combination of feedback and physical stimulus had created a new cognitive mapping between temperature and light that previously had not existed, suggesting an interesting direction for the shaping of an individual's perception and interaction with information.

In some respects, this period of finding and generating of understanding by the individual draws parallels with the work of Routarinne and Redström *(2007)*, who apply the concept of *domestication* to understand how the individual creates new meaning in intervention technologies through reference to their intentions and context. Applying this concept to feedback, it would appear that feedback information does not have a static meaning, but is shaped by the individual over time thus affecting the perception and framing of the problem and resulting action; a theory supported by the findings of this thesis. The concept of feedback as a dynamic mechanism for behaviour change is also suggested within the work of Zachrisson et al. *(2011)* and Tromp et al. *(2011)*, who contend that the *distribution of control spectrum*, akin to Lilley et al.'s *(2006) axis of influence*, is not a static axis at all but changes over time as the individuals perception of the intervention changes. Feedback itself, therefore, may not always be in the same position on the axis.

An interesting point to consider is whether a form of ambient feedback that has developed a strong associated habitual response is still in fact within the users control and decision making capabilities and isn't, at its most extreme, a form of conditioned *user automation*? One could easily envisage an axis whereby the two extreme poles (user and product) are automated, one through cognitive mechanisms and the other through mechanical mechanisms. Each strategy on this DfSB axis could potentially have a sliding scale of effectiveness and control dependant on cognitive process over time.

7.3.2 Limitations of Feedback

As advocates of DfSB will contend, feedback is a non-coercive approach used to change an individual's behaviour through visual, tactile or aural indicators of information; of significance, is that the control of decision making resides with the user *(Wever et al., 2008, Lilley, 2009b, Tang and Bhamra, 2011, Zachrisson and Boks, 2012)*. Tang and Bhamra through their Design Behaviour Intervention Model *(Tang and Bhamra, 2011)* posit that the stages of habit formation dictate how receptive an individual is to this information and that the DfSB strategy should be selected according to this criteria. Aside from any debate concerning specificity and alignment within this model (as discussed previously in section 2.6), the general notion, which is valid, suggests that feedback is most effective when the stage of habitual formation affords the intake of new information, when the individual is aware of their actions during the early stages of habit formation. Working on this principle, establishing significant change in domestic energy consuming behaviour, concerning strong habitual drivers to control heating and window systems, could be defined, from a theoretical perspective at least, as being limited. This is evident in the results of the user trials, whereby despite being able to make an impact concerning the slight curbing of behaviour and limited reflection by the participant on their own habitual action, ultimately significant savings were not realised.

Lack of savings may also be attributable to the simple fact that low income and low consumption households might not have any opportunity to save, according to an analysis of feedback studies by Fischer *(2008)*, however, to consider such a stance with those that participated in the user trials within this thesis, despite being in social housing, would be a fallacy. Although the tenants may be considered to be of relatively low income, the qualitative research within this thesis has illustrated several forms of wasteful behaviour that would provide ample and relatively simple to enact opportunities for energy saving should the household have been driven by fiscal and not other concerns, such as the pursuit of fresh air and comfort.

The described limitations of feedback as a behaviour change mechanism also potentially has additional significance for UK government policy and the associated initiative of rolling out smart meters to all UK households starting in 2014 *(Department of Energy and Climate Change, 2009)*. Although conceived to aid the UK in reaching the aims of the Climate Change Act 2008 *(Parliament of the United Kingdom, 2008)* one clearly has to question how effective feedback through such mechanisms is going to be beyond giving load information to suppliers, especially as they are unlikely to shift any stout, habitually driven behaviours. This research has pointed towards considerations that would improve the quality and effectiveness of feedback provided, however, this author hopes that the government are also considering supplementing the feedback from smart meters with other strategies and forms of behaviour change intervention. Policies that seek to modify facilitating conditions and unsustainable social and ecological norms will be required, along with a combination of antecedent and consequence interventions. Products that involve automation or the use of behaviour steering, such as Nokia's zero waste chargers and Fiat's eco:drive system (examples taken from the design-behaviour website *(Lilley, 2011)*) will need to be also supported and encouraged by government policy in order to cover the gamut of intentions, habits and facilitating conditions that result in unsustainable, energy consuming behaviour. Whilst feedback has its remit for changing behaviour, it is not a large enough basket in which to place all the eggs of unsustainable behaviour.

Expanding this section to include limitations of other feedback *studies*, it has been difficult to compare this feedback intervention study to others as the focus primarily for other studies has been centralised upon the interventions and per cent energy savings rather than the design process and the behavioural impact of the intervention. Although focussing on per cent reduction targets does appear to carry some logic (as this is how the Climate Change Act 2008 *(Department of Energy and Climate Change, 2009)* is framed, for example) focussing on per cent savings as a meter of the success of feedback is an illadvised tactic. This precludes any debate over the actual success of the mechanism itself for behaviour change and inhibits progress towards better understanding and feedback design. How has the behaviour framework of the individual changed? What actions are they doing differently? Are the results transferrable to another country with different social norms and conventions? How initially was the context and user understanding explored and how do the behaviour change results of the evaluation compare? How was the intervention designed, and what was the key criterion considered? In addition, a change in behaviour does not necessarily correlate to a change in energy consumption, especially when one considers rebound effects, and to assume so would be grossly simplifying the results. A result of this 'per cent reduction' way of thinking is that certain research projects concerned with behaviour change may be inclined to take the target of their research as matching or beating the often cited 5-15% reduction with direct feedback *(Darby, 2006)* without consideration of other behaviour change mechanisms (which don't offer such a formalised and tantalising 15% energy reduction). Had the Carbon, Control and Comfort project (the project to which this thesis is aligned) considered the type of behaviour change mechanism required following the understanding of the 'problem' that it was trying to solve, it would have been evident that the 20% target for reducing domestic energy consumption with feedback *(EPSRC, 2010)* was unattainable and that another DfSB strategy should have been considered. A more suitable approach to this project would have been to set the target reduction required and to allow the project to determine the most suitable mechanism or combination of mechanisms by which to reach this goal after the behavioural components of the problem were understood.

7.4 Comparing the Design Intervention Process in Action to Extant DfSB Process Theory

Described in depth in section 5.2, the decision was made to use an augmented model of UCD rather than to generate a new and bespoke interpretation of the DfSB design process. It made sense, to this author, to describe the DfSB design process in terms comparable to a design process that already exists rather than create another nascent model that lacks supporting case studies.

The salient points as to this decision concerned the desire not to add to the one-hundred plus design processes as catalogued by Dubberly *(2004)*; to create and adhere to a formalised and structured process in order to yield good solutions efficiently which can be generalised against extant theory and case studies; and to observe UCD principles and iterative design process which seem implicit to the aims of DfSB. This is especially relevant as the current DfSB process models are unsubstantiated, linear and without many supporting case studies for comparison. This thesis has transparently illustrated, in detail, the design process employed, allowing it to be compared to and results generalised against other UCD and DfSB methods, processes and cases studies to further the impact of this doctoral research beyond the scope of this thesis.

In terms of producing a formalised and structured process of DfSB, it is difficult to argue against the viability of the design process contained within this thesis, despite the lack of apparent behaviour change results (the reasons for which are as outlined in the previous section). The Design Intervention Process (as presented in section 5.2), illustrates a framework that moves from understanding and specifying the context and user, through synthesising phases which define the problem space, design direction and solution space, and concludes with a rigorous evaluation of the intervention. All the key components are present, theoretically at least, in order to design a behavioural intervention; limited only by the lack of a strategy selection process, which was considered outside of the remit of this research. If this remit were to be expanded, this process would likely be contained within the Intervention Opportunities phase, to shape the solution space and design direction.

7.4.1 First Steps towards Intervention Design

The initial phase of the Design Intervention Process, *understand and specify the context and user*, is the founding platform on which the rest of the ensuing design process must follow. Although other DfSB authors have included additional components for research within this initial phase, it is clear that if the aim of a DfSB intervention is to alter the intentions, habits and facilitating conditions of the user, in other words their behaviour, then this must be the initial priority.

Selvefors et al.'s *(2011)* suggestion that a project should be initially focussed through a product analysis, identifying user behaviour and consumption as intended and expected from the designer, *prior* to actually investigating and understanding the user and context, to an extent seems nonsensical. Although it may help to direct the research effort towards a general product area or inefficiency, it still seems somewhat erroneous to be attempting to identify or quantify anticipated behaviour in any meaningful way prior to carrying out qualitative (or quantitative) behavioural research. Indeed, having an expectation of what you presume to find, if the researcher is not careful, could lead to bias in research protocol or analysis. A similar argument could be levied at the Design Behaviour Intervention Model Design process as posited by Tang and Bhamra *(2011)*, that includes a current product and market analysis prior to any form of behavioural understanding. It is unlikely that the unexpected use of fireplaces, battles for control between multiple occupants and the pursuit for fresh air would have been predicted through such narrow attempts to identify expected behaviour and consumption targets. In order to affect behaviour change, understanding the user and their behaviour is an essential first step, as that is what drives product interaction, not the other way around. After all, technologies are multistable, and products and interactions are an interpretation by the user of the device within the facilitating conditions in which the interaction resides, not an interpretation by the designer.

This research has illustrated that with contextual interviews and guided tour data collection techniques, analysed with thematic analysis, a designer can effectively understand and specify the context and user in a level of psychological detail that affords a full and rich understanding of the antecedents of behaviour change; intention, habits and the facilitating conditions. Whilst other researchers have posited the use of such UCD-centric techniques, this is the first to use the technique of guided tours, which has been particularly fruitful in the collection of data. The combined benefits of contextual memory prompts for the participant and the heighted level of empathic understanding and realistic contextual textual for the researcher is far beyond that which is likely to occur through a static interview alone or through any other non-contextual exploratory methods. With this knowledge, the designer is in an informed positioned, able to move to the second phase of the Design Intervention Process, the development of design opportunities.

There is value, at this point, in offering a posteriori reflection on the insights gathered through the later, evaluation methods of focus groups and user trials in relation to the context and user study methods of interviews and guided tours. Could the insights gathered later in this research, during evaluation, have been useful during the initial stages of the research when the problem space was being defined? For example, a particularly strong negative reaction was noted during the focus groups concerning the concept of feedback and information on what to the participants perceived as behaviours weighted by 'normal' values, such as interacting with their heating systems or opening windows. Although the initial context and user investigation had made explicit that such actions regularly took place, it had not illustrated any particular insights into how the user would react to potential behaviour change mechanisms; the values and motivations evoked by the mechanism itself. It is clear that providing a 'solution', in effect also provided a prompt for the self-reporting of intentions, habits and facilitating conditions that may have been unconscious without such elicit prompting, concerning both the problem itself and potential corrective measures. For further work this presents an interesting opportunity, suggesting that the use of *technology, domestication* or *disruptive probes*, physical embodiments of a potential solution space within the defined problem space, may uncover such values at the front end of research *(Routarinne and Redström, 2007, Backlund et al., 2006, Löfström, 2007, Hoonhout, 2013)*. Probes could be developed, for example, that specifically test perceived ethical boundaries.

It is also worth reiterating that the evaluation phase of the Design Intervention Process does not necessarily mean the last phase of the process, and that the explicit requirement of design iteration (as defined within section 5.2) would therefore expect any relevant new information uncovered during this phase of research to be considered. The feedback intervention prototype offered within this thesis could, therefore, itself be considered the technological or disruptive probe that fires off a new iterative research and design investigation cycle.

7.4.2 Focussing the Problem and Defining the Solution Direction

The second phase of design process activity developed and applied within this thesis was entitled the *intervention opportunities* phase. This phase has been described by this author as a point of synthesis, moving the design process from a backwards facing establishing of the problem space, towards a processing of qualitative information in order to establish and bound the solution space. In practical terms, with the user and their context understood and specified, attention was turned towards defining opportunities for behavioural intervention.

Other DfSB authors have argued for similar reductive and expansive phases *(Selvefors et al., 2011, Tang and Bhamra, 2011, Zachrisson et al., 2011)*, suggesting the need for an identification of the problems (consumption and/or behaviour) proceeded by an identification of design direction. For these other authors, the key focus within these models (and DfSB itself), is primarily focussed upon the *identification* of behaviour and *selection* of DfSB strategy, culminating in what may be argued as unbalanced models of design process as other key phases and processes, such as the evaluation phase, are represented, and subsequently explored, to a lesser extent. The design process as discussed within this thesis corrected this issue by engaging equally with all aspects of the design process and amalgamating the majority of these dominant phases within other DfSB process models into the single phase within this model; the intervention opportunities phase.

In the majority of DfSB case studies, and indeed, in design studies in general, there is an apparent lack of explanation as to how one systematically and robustly moves from the collection and processing of data through to the establishing of a new design direction or the refocusing of an existing design brief. Information is collected and analysed with decisions and selections made to define the problem space, however the process through which it is selected and manoeuvred is usually not adequately described, aside from a solely quantitative perspective which may negate the subtleties underlying behaviour (such as that proposed by Elias et al. *(2008b)*). This is a big issue for cross-case comparisons, especially for those that are primarily engaged in a qualitative understanding and approach to behaviour change.

This doctoral research has added to this debate by illustrating through practice a method whereby the problem space can be successfully managed through a combination of methods and interdisciplinary partners to identify and understand the constituent components of behaviour and action, and secondly, to control the subsequent path of the design process to ensure a robust definition of the problem space and design direction. The defined, and more importantly *applied*, movement of data within this thesis (from insights to insights matrix, and then to opportunity statements and finally refocused design brief, as described in great detail in Chapter 5), and the requirement for involving team members with disparate epistemologies and skill sets has verified a work flow that is open for comparison to other studies due its transparency and documentation. This phase has illustrated its value through the quality of the refocused briefs at the end of this phase; a phase ill-defined in other theoretical DfSB models.

7.4.3 Designer or Researcher, or Both?

The *intervention design* phase is the phase in the design process in which the creativity of the designer is at the fore, generating a range of solutions that formalise design knowledge towards the addressing of the opportunities as defined in the preceding phases. Within this thesis, a typically convergent approach was followed, starting with the brainstorming of possible design directions, followed by the generation of six intervention concepts; culminating in a single advanced design concept and an intervention prototype. No specific design tools, DfSB or otherwise, were applied during the intervention design phase of this research, however, Zachrisson et al.'s *(2011)* proposed use of the Design with Intent toolkit *(Lockton et al., 2010b)* during the design process in their process model suggests an interesting point to discuss; is there a need for design tools during this phase of the design process?

Implementing a design tool that seeks to change behaviour without fully understanding the behavioural antecedents and action that it seeks to change may result in product failure due to the potential for misunderstanding or misalignment between the designer and their solution with the actual behaviour. A tool such as the Design with Intent toolkit can only offer a series of suggestions, the uptake and success of which are dependent on the designers in-depth understanding of the user and context, coupled with innate abilities and experience. In some respects, this tool is a superficial prompt, providing examples for comparison rather than a method for solving the 'problem'. However, given the relative complexity of behaviour change and the number of disparate approaches to change (the toolkit itself presents in excessive of one-hundred applied examples *(Lockton et al., 2010b)*), such a tool may be appropriate for facilitating discussion within a design team rather than an outright linear use of behaviour in, approach out.

In situations where the designer was not part of the original investigation or is new to behaviour change processes and strategies, such as in a classroom study or in a limited design case study where the research was collected by a facilitator prior to the task, such tools do help to add structure and framework, offering direction to the design process. As illustrated, for example, in the pilot studies of Lockton et al. *(2009)* when tasking students and recent graduates to address home lighting and printing inefficiencies. However, as the success of this approach is dependent on the designer's ability as well as their understanding of the problem, perhaps a more pertinent question to ask is must the researcher of the problem also be the designer of the solution, as it seems vital for the designer to understand all behavioural antecedent research and resulting impact in order for the intervention to succeed?

In this research, the author has been both the researcher and designer, so it is therefore impossible to disentangle data collection and design synthesis to extrapolate the potential of the designer in just engaging in the latter design phase without the former phase. This is also the case with Tang and Bhamra's *(2011)* study on the use of refrigerators and Lidman et al.'s study on washing detergent *(2011a)*. In all of these cases, design success could be attributable to the designer conducting the research, thereby becoming the researcher, and developing empathic knowledge; forming a deep understanding and experience of realistic contextual texture. Even with multi or interdisciplinary support, it would be time consuming and difficult, although not impossible, for a fresh designer to step into these case studies with a hundred-plus page thematic analysis document and copious photos and household maps, for example, and still be expected to yield the same quality of output. In this authors opinion, that leaves two possible outcomes, either the designer must undertake the research (as required in the understand and specify the context and user phase) themself, or there must be a development in the standardised recording of research findings in order for an outside designer to be able to replicate a comparable level of quality.

A more succinct method for the transferring of rich and detailed user and contextual information from a study through to design may possibly be achieved through the generation of *personas*, as explored in the work of Elizondo *(2011)*. One conclusion from Elizondo's work with creating multicultural personas within the context of manual dishwashing practices was that they were particularly suitable for increasing the level of empathy and understanding from the designer towards the user, especially useful during the early creative stages of the design process. Keeping the personas *alive* throughout the design process using mixed media, such as persona-posters and videos of personas in action, helped the designers within Elizondo's *(2011)* study to remain focussed on the user from different perspectives and reduced self-referential designing. Personas have been identified as a useful mechanism for translating the complex wealth of user and context data into a succinct and comprehensible format for designers. Whilst the weighty thematic analysis document and bulk of contextual materials may contain the same data, it is not necessarily presented in the most appropriate or digestible format for designers, an issue for consideration in future work.

In addition, personas are specifically useful for evaluating concepts against archetypes where the original users and context are no longer accessible. Within the context of this doctoral study, the Merthyr Tydfil cohort was continuously available for study and for concept evaluation, therefore, the consideration of archetype generation was not discussed until post study (as it was never explicitly required).

7.4.4 Evaluating an Intervention

If there is one particular area within the DfSB field that has been under represented thus far in existing DfSB cases studies or models, it is how to evaluate and what criteria to consider when evaluating a design intervention that seeks to change behaviour. Selvefors et al. *(2011)* consider the evaluation phase as sitting outside of the remit of their DfSB approach; Tang and Bhamra *(2011)* suggest the use of focus groups, which have their limitations, to validate concepts; and Zachrisson et al. *(2011)* suggest the use of their developed DfSB to evaluate the potential of the intervention according to relational factors (for example, the correlation between obtrusion and chance for breaking habitual action). Consideration of the evaluation phase has, as has been previously discussed in section 2.6, noticeably absent or poorly defined bar a few tentative steps. In this author's opinion, this is due to a predisposition for existing authors to focus on DfSB strategy selection, or, the lack of prototyped interventions that can be effectively evaluated for behaviour change (possibly due to PhD or project time constraints). Only Lidman et al. *(2011a)* have implemented a similar process with prototypes to that explored in parallel within the *intervention evaluation* phase of this research, correlating a post intervention state to a base line recorded prior to installation.

Key to the success of this evaluation phase was the prototype. The use of low-fidelity part prototyping (part as it lacked the aesthetics and final form of the intended concept) was instrumental throughout both the focus group and the user trials. The prototype was used in the focus group as a physical prompt and within a video storyboard to illustrate both pre and post intervention scenarios, helping the participants to focus and understand both the concept and the context of use. Participants were prompted and inspired to compare the actions that they saw on the screen, with the actions that they themselves perform. Interestingly, whereas the designer is generally encouraged within a UCD to explore actions in situ to develop an empathic level of understanding of the participant, this was almost like a mirror image of that process, asking the participant to empathise with the artificial scenario construct generated by the designer in order to better *their* understanding for evaluation. In addition, without the prototype, simply put, the user trials would not have existed. Evaluation of the function, behavioural antecedents and sustainability aspects would have been limited or constrained to theoretical deduction rather than generating the qualitative data *necessary* for evaluation. Issues pertaining to the user's cognitive interpretation of the devices functions as well as multistable interactions between the user and the device would have been non-existent, as would the effects of behaviour change and interaction with the device over time. *Without a prototype, there can be no DfSB evaluation*.

Findings through practice in this thesis have indicated that focus groups are a suitable evaluative data collection method when discussing the designer's interpretation of the user and the problem; gain insight into changes concerning the individual's intentions; and help to frame these changes within the user's ethical framework. User trials are ideal for cyclical formative evaluation, due to the propensity of information provided for iteration, as well as for the summative evaluation of change in behavioural antecedents and the resulting sustainable impact. Environmental and energy monitoring, it is predicted, would have provided a measure of any change in comfort and illustrate any quantifiable change in energy consumption. One further point worth discussing within this chapter is whether the three evaluation questions used to evaluate the feedback interventions are transferable to other DfSB strategies and case studies?

To recap, the three questions were: did the produced design solution function for the specified context; has the user's behaviour changed as a consequence of the design intervention; and is the change in the user's behaviour sustainable? Whilst it could be argued that the sub-questions that reside within each of these three questions are more bespoke towards evaluating feedback in this study context, there is indeed a great deal of overlap and potential for evaluating other DfSB strategies applied in different contexts.

Using Lilley's *(2009b)* strategies as a jump off point for this discussion, namely *eco-feedback*, *behaviour steering* and *persuasive technology*, there is a common target, namely to alter behaviour through design towards sustainable benefit. To that end, each of these three questions is highly relevant, as each map to the composite parts of the driving theory of Design for Sustainable Behaviour, the *design* of the intervention, the *sustainable* impact of the intervention, and the resulting *behaviour* change. Sub-questions within this thesis related to the design of the intervention, such as *how does the medium of presentation affect a user's ability to engage with the feedback information*, clearly, however, are weighted towards feedback alone and are not applicable to the other strategies. The overarching question is still valid; however, if these evaluator questions were to be applied to a different strategy then the sub-questions would need to be more appropriate to the mechanism employed. Feedback seeks to change behaviour through the provision of information and therefore these sub-questions are related to this. If the author was considering the evaluation of a behaviour steering intervention then questions related to cognitive interaction expectations (such as design semiotics) and the use and performance of affordances and constraints (perhaps requiring a physical ergonomics assessment) would be required. Persuasive technologies that negate the user's interaction would perhaps need to be evaluated in terms of installation issues and the requirements of monitoring or maintaining the technology. These sub-questions are *dependent* on the *strategy*, suggesting an area for further research beyond the scope of this thesis that investigates and categorises in a similar fashion the questions required under each broad strategy.

The second question, related to the change in behaviour, is different to the first in so far as it is not anchored by the strategy, or indeed the application context. Although behaviour itself is different dependant on the user and context, ultimately the same questions need to be asked, for instance, *how did the facilitating conditions constrain options prior to the introduction of the intervention a*nd, *how frequently is the behavioural act enacted, post introduction of the design intervention?* These behavioural sub-questions can be asked of any behaviour change strategy asked in any context, as the antecedents of behaviour are present to an extent within in all action, habitual or not.

The final overarching question set pertains to the sustainability impact of the behavioural intervention, asking questions such as, *what was the domestic energy consumption by inhabitant prior to the introduction of the design intervention* and *are the intervention methods employed by the designer, in order to change the user's behaviour, ethical?* Whereas the first set of questions related to design were dependent upon the specific strategy employed, this category of sub-questions is *dependent* upon the specific *context* in which it is applied. Again, the overarching question is still valid; however, the sub-questions would need to be honed towards the sustainable attribute that one wishes to change. Whilst sustainability is commonly defined in terms of *three pillars (Bhamra and Lofthouse, 2007)*, namely economic, environmental and social pillars, each of these pillars are contextual. For example, this project is concerned with reducing the amount of Co2 (environment) generated from domestic energy consumption, whilst ensuring that comfort (social) is maintained or increased, and that financial burden (economy) is maintained or reduced. Lidman et al.'s study on washing detergent *(2011a)* may, as a comparative example, be focussed on reducing the overdosing of washing detergent (environmental), saving the user money (economy) whilst maintaining or improving the quality of the cleanliness of clothing (social). Questions that evaluate the ethical impact of changing the user's behaviour and the ethics of the process itself are not tied to any strategy or context, and are applicable to all design interventions. As previously stated by Albrechtslund *(2007, p.66)*, the question of ethics in design is "*not optional"*, and is always present in design and technology.

7.4.5 The Ethical Thread

To reiterate Albrechtslund's *(2007)* point, ethics, the ethics of the designer and the ethics of the user, are a constant presence, to a lesser or greater effect, within all technology and action. Therefore, this discussion, holistically speaking, is not limited only to DfSB and its goal of changing behaviour towards a sustainable future, but is relevant to all design schemes. However, in order to frame this discussion within the remit of this doctoral work, the pertinent question to ask is whether feedback as a behaviour change strategy is an ethical strategy, and moreover, why has this topic not been effectively engaged with from a DfSB perspective aside from a minute sprinkling of authors such as Pettersen and Boks *(2008)*?

As both Vries *(2006)* and Dorst and Royakkers *(2006)* have discussed, ethics and design are akin, in so far as they both require the creative solving of ill-structured problems. Ethical problems, like design problems, rarely have a single solution, with multiple options and directions explored throughout the ethical or design process. Considering ethics within this vein as a problem solving process, it is unsurprising the lack of progress in expanding knowledge in this field due to the lack of relevant DfSB case studies that have engaged with the entirety of the design process. Without case studies and the problem solving processes contained therein, ethics have never really been considered as an on-going concern. Theorists, such as Berdichevsky and Neuenschwander *(1999)*, propose lists of principles or suggestions as statements, often used towards a post rational reflection as to what it should be rather than how it can be or is applied and achieved through practice. As a process, the use of a checklist of principles can only have a limited impact. It therefore may be more appropriate to consider the *process* of solving ethical problems.

Furthermore, as a physical device, feedback is neither inherently ethical nor unethical, as the moral responsibility resides with both the designer that creates the device and the user that has freedom of choice and action. Feedback as a mechanism has no sense of morality or ability to make decisions; this is the responsibility of the designer and user *(Berdichevsky and Neuenschwander, 1999, Fogg, 2003, Pettersen and Boks, 2008)*. Therefore, it is the application of the designer's motivations and intent; how moral responsibility is distributed and democracy balanced; and finally how the intended and unintended outcomes have been anticipated and accounted for within the design process that is important to the ethical understanding, control and management surrounding feedback. How can the ethical thread running throughout the design process be maintained and managed and to what effect? Excluding a discussion on the data results per se of the design process within this thesis, as they are discussed within each relevant chapter, it is perhaps more logical to discuss this overarching question and the methods applied at strategic junctions of the design process.

Ethics within this design process have been carefully considered throughout. The motivation and intentions of the designer were documented and reflected upon throughout the design intervention development phase. The methods of feedback for each concept were clearly presented and potential outcomes, both positive and negative were discussed. By transparently laying bare the rationale behind decisions made, the designer and the process become open for internal and external scrutiny and further deliberation, as well as allowing the decision making process to be generalizable and transferable to other case studies. As part of this scrutiny, it is insufficient for the designer alone to critically evaluate their own process and decision-making, as their own ethical framework is unlikely to yield a change in subjective perspective or fully account for the larger ethical frameworks at play. For example, what the designer originally considered a non-coercive approach may be more unlikely, upon reflection, to be classified as coercive. Involving a disparate perspective or ethical framework may shed light upon aspects not previously considered by the designer, thereby helping the designer to navigate the ethical minefield towards a more robust moralised solution.

So how can this discursive and ultimately subjective process be managed? Clearly, it is impractical for the designer to be perpetually shadowed by an external council of ethical guardians, and furthermore, it is this authors view that the use of self-regulating principles and matrices, such as the ethical evaluation matrix *(Lilley and Lofthouse, 2010)*, aside from the previously discussed debate over its representation of ethical variables (section 2.7), enforces a false sense of validity. To elaborate upon this point, as discussed in the previous paragraph the designer's ethical framework may not be the same as the user, or indeed the same as anyone else's for that matter. To only reference one's own ethical framework, does not validate the morality of the intervention for a wider audience other than that of the designer; the intervention may still be ethically unsound from the user's perspective despite the designer's conscious effort to prevent this from happening.

The design phase, however, affords natural points for an expanded form of discussion and evaluation, an illustration of which is the divergent concept selection process within this thesis (discussed throughout Chapter 5). Taking the form of interdisciplinary reviews and a design intervention evaluation, a critical review of the motivation, intentions and methods of the designer can be implemented, ethically evaluated and deliberated upon; as can the number of potential outcomes (the technologies multistability) be built upon from disparate perspectives and their impact considered. This interdisciplinary perspective is critical throughout the entirety of the design process, as it helps to add different ethical perspectives upon the same material for review and guidance upon design direction. Throughout this thesis, interdisciplinary teams had been consulted during the generation of insights, the creation of the insights matrix, the generation of opportunity statements, the process of consolidating these statements into briefs, and the evaluation and selection of intervention concepts. At each of these stages, these further perspectives provided an additional lens through which to view the progressing work; raising, discussing and answering ethical questions that the designer working independently may not have considered or may have considered, but then subsequently reached an unethical conclusion.

The end user of the technology also has a clear role to play in this ethical deliberation process of designing a behaviour changing intervention; as stated, moral responsibility resides with both the designer and the user that interacts with an intervention. Therefore, aside from helping to assess the motivations and intent of the designer and the methods and multistability of the intervention from their own perspective throughout the design process, in a similar reviewing process as the involvement of interdisciplinary team members, contributions from the user can also help to ensure that the developed technology is democratic. Involving the user helps to ensure that their decision-making concerns are exercised and accounted for during the design process and that future decisions made during the users interaction with the resulting technology will be facilitated, thereby inhibiting the rise of technocracy. Users within this doctoral research were involved in the design process at two key points, the understanding control, comfort and energy in context and the design intervention evaluation phase; vastly supplementing the designers understanding of the user's requirements and their ethical framework.

The conflict between the effectiveness of an intervention (which may require the use of morally dubious methods and/or total technological agency) and its acceptability by the user, as discussed by Lilley and Lofthouse *(2010)*, can also be explored by the designer. The opening section of this thesis, 1.1 Research Context, explicitly states that within the UK there is an overarching target of reducing greenhouse gases by 2050 to at least 80% of those recorded in 1990 *(Parliament of the United Kingdom, 2008)*. However, whilst it may be possible to reduce energy consumption through choice, given the inherent democracy of decision-making choice afforded by the use of feedback mechanisms (as illustrated by the findings of Chapter 6), it is unlikely that the lofty target of 80% is likely to achieved through accurate and ethical feedback and individual choice alone. As the boundary between the individuals accepted values and actions gets closer to those decisions and actions that are required to meet this target, given free choice, it is likely that the individual will reject what would be perceived to be the more negative of outcomes. Even with multiple iterations of the feedback concept presented within this thesis to be more in line with the intentions and motivations of the user, it can be assumed that the use of accurate and ethical feedback as a behaviour change and energy reduction mechanism can only go so far, which may not be far enough, with free choice.

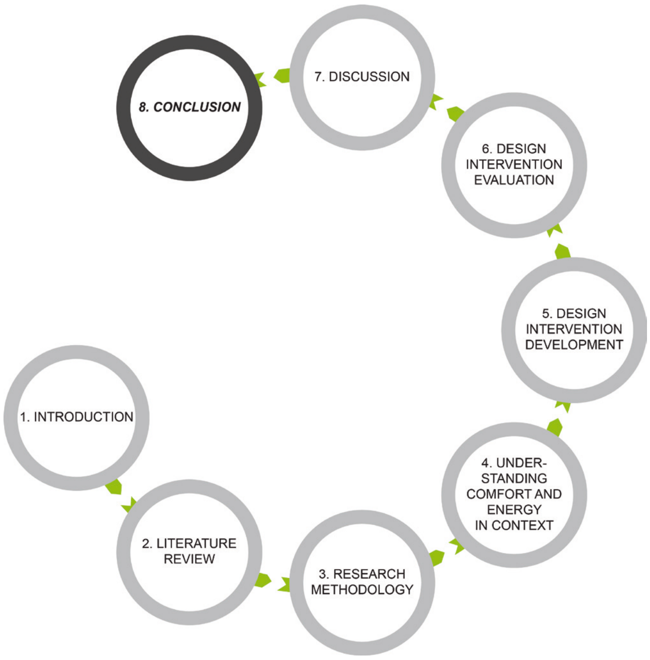
This presents two options, either feedback itself should be replaced or supplemented with additional, more technocratic DfSB strategies and mechanisms or the question of 'what is ethical' needs to be revised. The framework as developed by Berdichevsky and Neuenschwander *(1999)* provides a moral constant, a benchmark against which to hold behaviour changing technologies without question. However, what is/isn't ethical changes over time, and given the impending urgency of the climate change agenda and what the designer perceives their social responsibility to be, it is likely that what Berdichevsky and Neuenschwander may consider to be unethical forms of persuasion (such as a feedback mechanism that is intentionally inaccurate) may become more necessary. It is this researcher's belief, however, that despite the perceived justification or necessity for *any* behaviour change, such decisions by the designer should not be made in a decision vacuum without incorporating and reflecting on the values of all relevant stakeholders.

The list of questions asked by the designer in the intervention evaluation phase, as listed in section 6.2, do not seek to be moralistic, rather they are a proposition of considerations by the designer. They are not necessarily designed to be solely reflective, but as a platform from which to integrate other *relevant* perspectives. Rather than stating that *"the motivations behind the creation of a persuasive technology should never be such that they would be deemed unethical if they led to a more traditional persuasion" (Berdichevsky* *and Neuenschwander, 1999, P.52)*, from the perspective outlined above it would be more logical to ask *"was the designers original motivation for designing a behaviour intervention ethical?".* This allows for a wider discussion with the users and independent experts without relying on an implicit understanding of the universal moral framework of 'traditional' methods, that may not be applicable in every context. Decisions can be made in reference to the moral frameworks of relevance.

To conclude this section of the discussion, it is fair to state that the on-going dialogue between the designer, an interdisciplinary team and the user, has been shown through the work contained within this thesis to assist in the democratisation of the design process and the resulting intervention, and furthermore, aid in the predication, evaluation and solving of moral problems. The ethical thread within this design process has been shown to greatly enhance the ethical robustness of the resulting intervention.

8 Conclusions and Future Work

8.1 Introduction



In this, the final chapter of the thesis, the body of work that has comprised this doctoral study is concluded. Describing how the research aim and objectives were met, this section goes on to state the overall conclusions that arose from this PhD, bringing together the conclusions of the preceding chapters. The limitations of this research are then reflected upon and this research's contribution to knowledge is clearly stated. This thesis is then concluded with recommendations for further work.

8.2 Meeting the Research Aim and Objectives

This section details the research activities as carried out within this thesis, describing how they fulfil the objectives of the research aim *to investigate how DfSB models and strategies can be implemented within a structured design process towards the reduction of domestic energy consumption*.

1. *To execute a comprehensive literature review that will cover factors that influence household energy use, strategies that promote behaviour change, DfSB theory and practice and the ethical implications of changing behaviour through design.*

This objective was achieved within the second chapter of this thesis - Chapter 2 Literature Review. Within this chapter, research questions were developed to guide the literature review, directing the research's scope towards five areas of research interest: the factors that influence domestic household energy use and consumption; the antecedent and consequence interventions that aim to promote a change in behaviour; feedback as a behaviour changing strategy; DfSB theory as a framework and process of designing for behaviour changing strategies; and finally, the ethical implications and challenges of attempting to change behaviour through design. Knowledge in these five fields was accumulated and major gaps in knowledge were identified, completing this research objective.

2. *To understand how inhabitants of social housing properties define and control comfort and its associated impact on their domestic energy consumption.*

This second objective was achieved within the fourth chapter of this thesis – Chapter 3 Research Methodology. Following a pilot study, seven social housing homes within Merthyr Tydfil, Wales, participated in semi-structured contextual interviews and guided tours. The data collected and subsequently analysed with thematic analysis, presented four themes: type (thermal, safety, aesthetic, activity based, light, aural, physical and freshness); place (micro, meso and macro placement); social (people, community, negotiations and conflicts); and regulation (knowledge, controls, money and meters). The findings were discussed in relation to an augmented behaviour model, the Theory of Interpersonal Behaviour, completing the second objective and informing the third objective of this research.

3. *To design and produce a feedback intervention prototype that intends to reduce domestic energy consumption whilst maintaining inhabitant defined comfort levels.*

This third objective was achieved within the fifth chapter of this thesis, Chapter 5 Design Intervention Development. Within this chapter, the design process was discussed, culminating in the Design Intervention Process, of which the remainder of the chapter was concerned with implementing the *intervention opportunities* and *intervention design* phases. The themes from the previous chapter were developed through a moving of data from defining the problem space towards design direction. This was achieved through a process of drawing out insights from the themes, the use of an insights matrix followed by an abstracting of relevant insights into opportunity statements and finally, into refocused briefs. The selected brief was followed by an expansion of knowledge concerning comfort parameters, before the intervention design phase went through a convergent and divergent series of design and evaluation activities, supported throughout with interdisciplinary teamwork. The chapter ends with the production of a feedback intervention prototype and a reflection on the design phase activities, thus completing this third objective and providing a viable physical intervention mechanism for objective four.

4. *To evaluate the feedback intervention prototype, using assessment criteria developed from the literature review.*

This final objective was achieved within the sixth chapter of this thesis, Chapter 6 Design Intervention Evaluation. Concerning the *intervention evaluation* phase, this chapter developed evaluation criteria and used this knowledge towards the evaluation of the prototype. Evaluation criteria developed from the literature review were sub divided into three key questions: did the produced design solution function for the specified context; has the user's behaviour changed as a consequence of the design intervention; and is the change in user's behaviour sustainable? Through the thematic analysis of focus group interviews in Loughborough and Manchester, and prototype user trials with two of the Merthyr Tydfil social housing participant homes, these three questions were answered and the use of data collection techniques was reviewed, completing the fourth and final objective of this research.

The aim of this doctoral research was to investigate how DfSB models and strategies can be implemented within a structured design process towards the reduction of domestic energy consumption. In using an exploratory research approach, this research has gained new insights into these fields, addressing several key gaps in knowledge concerning their theoretical underpinnings and implementation in practice. The aim of this research has been achieved. The following section draws together the key conclusions from the findings and discussion points throughout this thesis.

8.3 Conclusions

In establishing an understanding of the user and their context, comfort has been shown to be a complex assemblage of thermal aspects, dimensions related to light, sound quality, physicality and the desire for freshness. Within this assembly, the pursuit for fresh air has been shown to be a vigorously pursued behaviour that intersects on varying levels with the users comfort and intentions, the user's ability to control their surroundings and is often strongly habitual. Overtime the cognitive processes that initialised the intention to open windows for the purposes of airing out have become automated with actions performed without consideration of alternatives and are dependent upon the facilitating conditions, such as time of day or year. Understandably, therefore, the application of a feedback intervention to instigate new intentions has not produced a substantial change in overall behaviour, as the high level of automation did not allow an adequate cognitive window through which the user could consider and assess the new information. This low level of awareness coupled with low motivation, resulted in any small changes in behaviour returning to their original state (although the benefits of prompting one off actions such as balancing the heating system for winter have clearly been stated as a success). Clearly, for a feedback intervention to succeed in changing the behaviour of habitual action, it must not only break through this level of cognitive automation but also be tailored such that the information emphatically motivates the user to change according to their intentions. Without these two key qualities, a feedback intervention that changes habitual behaviour, as shown, is limited. The limitation of feedback when attempting to challenge entrenched habitual behaviour also has obvious significant implications for the UK governments policy on the mandatory role out of smart meters in 2014 *(Department of Energy and Climate Change, 2009)*. This thesis concludes that supplementary measures are required if there is to be any hope of reaching the targets of the Climate Change At 2008 *(Parliament of the United Kingdom, 2008)*.

Although this research confirms prior knowledge that frequency, duration and the accuracy of information are key components in the design of feedback interventions, it also substantially builds upon an understanding of criteria concerning the feedbacks location and ambient features, as well as its interface with multiple users. Ambient feedback interventions should be viewed as a distinct subcategory of feedback with different requirements to, for example, home energy feedback monitors that present aggregated measurements. If device specific, ambient feedback should be integral to the device on which they report to strengthen the cognitive link between action and effect. When designing an ambient feedback intervention, consideration needs to be given to how the associated cognitive map develops in order to support implicit evaluation. This thesis has illustrated how a new cognitive map can be developed in response to physical stimulus, suggesting a new direction in the designing of DfSB strategies. It can also be concluded that the interaction of multiple users has an impact upon the effectiveness of information as a static form of feedback (i.e. one that cannot changes its metrics, format and media) cannot adequately tailor itself to each individual set of intentions and facilitating conditions (such as level of education). Where a feedback intervention is required to be used by multiple users, consideration needs to be given by the designer as to how this can be achieved without compromising the other key components of information display.

Several conclusions can be drawn from the construction and practical implementation of the Design Intervention Process throughout this thesis. In general, the augmented model of user-centred design [UCD] has been shown to be effective in the design of a feedback intervention, even though the feedback intervention itself was unsuccessful in changing behaviour. The design process within this thesis has successfully illustrated a path from understanding and specifying the context and user, through a synthesising phase that has defined the problem space and the design direction, the designing of a DfSB strategy-led feedback intervention and concludes with a rigorous evaluation, considering the functionality, sustainable impact and ability of the intervention to change behaviour.

It can be concluded that the use of contextual interviews and guided tours are very effective data collection techniques for the designer to understand and specify the context and user in rich level of behavioural detail. Contextual memory prompts help the participant to recall or situate himself or herself within the interview, whilst the deep levels of empathic understanding and immersion in realistic contextual texture help the designers understanding, leading to better definitions of the problem and solution spaces.

Augmenting a standard model of UCD with an interdisciplinary intervention opportunities phase, it can be concluded, provides a much needed robust stepping-stone between defining the problem space (understanding and specifying the context and user phase) and engaging with the solution space (intervention design phase). Without this phase, the problem and solution spaces would be too ill-defined for practical design direction.

It is impossible within this research to disentangle the data collection activities and the design synthesis and evaluation phases. It is, therefore, impossible to determine what the relative success of each phase would have been if they were conducted independently. Whilst this has not been an issue for this doctoral thesis, it is important to conclude that this potentially leaves two potential directions for the designer. The designer either becomes both the designer and the researcher, engaging with the user directly in all phases of the design process, such as in this thesis, or the designer is only the designer, and the research aspect is outsourced to other agents. If the latter option were to be considered, new methods of transferring the contextual elements of researcher would need to be developed as this is vital to a designers understanding of the actions and behaviours of the user, and therefore, is vital to the interventions success.

The evaluation phase of the implemented design process is by far the most important phase concerning this body of works contribution to new knowledge. It can be concluded that the use of a prototype is invaluable to the evaluation of a behaviour changing intervention. Used as a research tool within focus groups a physical manifestation of the concept, at whatever fidelity, can be used as a physical prompt and can also be used in defining pre and post intervention scenarios; prototypes focus the participants and help them to understand the context and its envisaged context of use. Within a user trial, a functioning prototype is a necessity. Without a working intervention model, it would be impossible to evaluate the interventions functionality and changes over time of the user's behavioural antecedents and sustainability impact that constitute a DfSB intervention evaluation. Furthermore, vital issues related to the user's cognitive interpretation of the products functions and potential multistable interactions could not be discussed or considered. Concerning evaluation methods, it can be concluded that whilst focus group interviews are useful for gaining discursive insights into the intentions and ethics of a user, as well as how the technology may be interpreted and appropriated, they are not ideal for summative evaluation or evaluation over time or in context. User trials coupled with pre and post intervention base lining, however, afford this evaluation over time and in context, allowing for a fuller evaluation of the designs functions, the change in behavioural antecedents of the user and the consideration of sustainable impacts. In order to provide a quantitative evaluation, a form of consumptive or environmental monitoring would be required over time.

This thesis has demonstrated that the questions asked by the evaluator of a DfSB intervention can be subdivided into three fundamental questions: did the produced design solution function for the specified context, has the user's behaviour changed as a consequence of the design intervention, and finally, is the change in user's behaviour sustainable? These three fundamental questions can be further disaggregated to give additional resolution to these questions (please refer to section 6.2); broadly concerning the:

- functionality and usability of the intervention (criteria dependant on the DfSB strategy);
- the intentions, habits and facilitating conditions of the user in context – the behavioural antecedents (criteria applicable to all DfSB strategies);
- and thirdly, the sustainability impact of the intervention which in this context was considered in terms of energy, comfort (criteria dependant on the intervention context) and ethics (criteria applicable to all DfSB strategies).

These three questions have been applied within the intervention evaluation phase of the Design Intervention Process within this thesis, with the results answering the change (or apparent lack thereof) in behaviour and the sustainable impact of the intervention. The richness and depth of the understanding as to the interventions success and failings is vital to an iterative design process, such as the Design Intervention Process, in order to improve the intervention in subsequent iterations.

Feedback as a strategy is neither inherently ethical nor unethical, as it has no capacity to make decisions. This thesis has concluded that as the designer and the user are those tasked with the freedom of choice, it is the rationale and decision making structure that underlies the designer's motivations and intent that is of interest; how moral responsibility is distributed and democracy balanced to avoid technocracy; and finally how the intended and unintended outcomes have been anticipated and accounted for within the design process.

Furthermore, a transparent and documented design process is a necessity, supported with interdisciplinary reviews and user involvement throughout the design process. Transparent documentation of the processes of the designer lays bare the work for internal and external ethical review as well as allowing the results and design making processes to be generalized and transferable to other case studies. Interdisciplinary reviews throughout the design process afford a critical review of the motivations, intentions and methods employed by the designer from disparate perspectives, allowing the decisions made to be evaluated and deliberated upon and potential outcomes considered. Interdisciplinary working adds additional expert lenses through which to view and review the intervention outside of the designers own perspective. The design process has several convergent points in which interdisciplinary reviews naturally fit, such as in the selection of insights or concepts and the evaluation of prototypes. Users must also contribute significantly to the design process in much the same way as the interdisciplinary team. Not only does this help in an evaluation of the surrounding ethical issues and a consideration of an interventions multistable possibilities, but also helps to ensure that the decision making concerns of the user are exercised and accounted for, thus inhibiting the rise of technocracy. User involvement during the understand and specify the context and user, and, intervention evaluation phases has been shown to be beneficial to the design of an intervention. Open and on-going dialogue between the designer, user and an interdisciplinary team throughout the design process is a necessity to maintain the ethical thread throughout the design process and which culminates in the resulting intervention.

8.4 Contribution to Knowledge

Design for Sustainable Behaviour is in an embryonic state, evolving from its foundation and focus on defining strategies within an axis of influence by early researchers such as Lilley et al. *(2006)*, Wever et al. *(2008)*, and Elias et al. *(2008b)*, into a cohesive and applied approach to affecting sustainable behaviour through design. With several concurrent researchers active in the field, focussing on a broad range of DfSB considerations such as further refining the axis of influence or working out methods, guides or tools for strategy selection *(Lockton et al., 2010a, Selvefors et al., 2011, Tang and Bhamra, 2011, Zachrisson et al., 2011)*, it is unsurprising that there is not one single DfSB model or categorisation of strategies to which all researchers subscribe. Equally disparate are the ways in which this knowledge has been accumulated and applied, with the design processes and methods used varying from project to project. As such, several areas of DfSB interest either overlap or have not been adequately explored to ensure that DfSB reaches maturity.

The research contained within this doctoral thesis has addressed many of these gaps in knowledge, focussing on the practical application of a Design Intervention Process, whilst also supplementing knowledge of behavioural research, the design of feedback interventions and the surrounding ethical questions. The contribution to knowledge made by this doctoral thesis can be succinctly stated as:

- The development and implementation of a practical, qualitative approach to understanding user behaviour within a design process. Through this approach, which involved the use of contextual interviews, guided tours and thematic analysis, it has been possible to disaggregate the behavioural antecedents that drive action; the users' intentions, habits and facilitating conditions.
- The definition and linking of theories of comfort within this study, yielding several unexpected findings and contributions to our understanding of

comfort within social housing. These include the purchase and use of fireplaces as an aesthetical focal point of the living room and not for heat provision; the on-going battle and conflict between those that always feels cold and those that always feel hot, and of key significance and novelty, the individual's pursuit for fresh air.

- The exploration in detail of the considerations and limitations of feedback as a behaviour changing strategy. Several key considerations have been confirmed and further refined from the pertinent literature, with several new considerations, including the location of ambient feedback, the consideration of multiple users and issues pertaining to implicit evaluation and domestication having been explored. The limitations of feedback in changing the behaviour of engrained habitual behaviour have been defined within this research context.
- The formulation and application of an augmented user-centred design process in its entirety based on the implicit requirements of DfSB as discerned from the review of literature. Through its practical application, phases and techniques concerning the understanding and specifying of the context and the user have been developed; a synthesising phase that defines the problem and solution spaces as well as design direction has been applied; and the steps towards the designing of an intervention have been enacted - all building upon the limited partial design processes previously defined by DfSB authors.
- A key contribution to knowledge within this Design Intervention Process, was the final phase, the intervention evaluation phase. This phase discussed and applied a series of evaluative methods and formulated a tripartite questioning framework targeted specifically at evaluating the constituent parts of DfSB. The significance of prototyping within a DfSB design process was established through design practice.
- The definition and practical implementation of an approach for maintaining an ethical thread throughout the design process, illustrating how the intent, motivations and methods of the designer can be assessed, multistable outcomes considered and democracy in decision

making maintained. The significance of user and interdisciplinary input throughout the design process was established through design practice.

8.5 Limitations of the Research

Whilst this research has made significant contributions to knowledge, it is worth considering the limitations of this research in order to put the accrued knowledge into context.

Aside from the limitations as noted in the project context, section 1.2, temporal considerations have had an impact on this doctoral research. The three-year duration of the PhD in parallel to the three year duration of the wider Carbon, Control and Comfort project to which this body of work is attached has to an extent dictated the research timetable. Although this doctoral work is not beholden to the wider project, in order to maximise the interdisciplinary approach and involvement of participants, as described elsewhere within this thesis, a certain degree of project synergy was required. Such time considerations have manifested themselves in the limitation of the Design Intervention Process, only allowing one pass through the design process with no time available for iteration; the user trial not being longitudinal (four months can hardly be considered as such) and the lack of available time for an evaluation of post intervention residual effects on behaviour change.

A further limitation arising from association with the CCC project was the limited number of participating households available for the user trials. As the homes initially recruited to this study had to be used for a series of different interventions (from both within Loughborough University and from other project partners), the resulting number of households available in which to run the user trials was limited to two. Such a small sample size makes the evaluation of any prototype, from a design perspective, difficult, as it is difficult to extrapolate or generalise findings beyond the small sample. From a theoretical perspective, learning occurred through enacting the process and practice, and therefore to an extent the number of homes installed with a prototype is a moot point. It was considered that different interventions could be installed concurrently or sequentially within the homes, however, it would be impossible to disaggregate the effects of each intervention.

8.6 Recommendations for Further Work

Although this thesis has contributed to knowledge and the developing field of Design for Sustainable Behaviour, it is acknowledged that there remain many questions yet to asked and directions pursued to progress this field. This, the final section of this chapter, outlines a few key areas that are ripe for such further work and investigation.

A key recommendation for further work is for a second iteration of this Design Intervention Process in practice in order to further refine and hone the process of design. Iteration is also a fundamental requirement of UCD, with the designer furthering their understanding of the user and context through design and evaluation phases. Iteration *of* the design process and *within* the design process is fundamental to the optimisation of behaviour changing interventions.

This thesis has illustrated that interdisciplinary work throughout the design process, in parallel with working with the user, is a necessary requirement of intervention design. Further work must be done on how best to incorporate this interdisciplinary teamwork aspect within the Design Intervention Process, encouraging discursive dialogue without hindering progress over debates concerning ontology or approach (such as the on-going debate within this field of practice theory versus behaviour theory). It may be more appropriate within the design process to consider the feasibility of interdisciplinary deliverables to foster responsibility and research direction or the use of knowledge transfer sessions between disciplines. Further work must also be done on establishing the feasibility of disaggregating the design and research aspects of the Design Intervention Process whilst maintaining the ethical thread, user/context understanding, and the movement of data and design intent; as in the real world application of this process, the designer cannot be guaranteed to be the researcher.

The evaluation criteria derived from Chapter 2, applied in Chapter 6 and discussed in Chapter 7.4 have demonstrated the limitations of these questions, highlighting that further work is necessary in order to develop these questions to be more appropriate to different intervention strategies and contexts, and the sustainable metric under investigation. Applying the same questioning criteria to other feedback intervention case studies will also help to make the questions more robust, as the questions developed within this thesis can be considered a first exploratory iteration.

References

ABRAHAMSE, W. & STEG, L. 2011. Factors Related to Household Energy Use and Intention to Reduce it: The Role of Psychological and Socio-Demographic Variable. *Human Ecology Review,* 18**,** 30-40.

ABRAHAMSE, W., STEG, L., VLEK, C. & ROTHENGATTER, T. 2005. A review of intervention studies aimed at household energy conservation. *Journal of Environmental Psychology,* 25**,** 273-291.

AECOM 2011. Energy Demand Research Project: Final Analysis. Ofgem.

AJZEN, A. 1985. *Action Control: From Cognition to Behavior*, Springer-Verlag.

AJZEN, A. 1991. The Theory of Planned Behaviour. *Organizational Behavior and Human Decision Processes,* 50**,** 179-211.

AJZEN, A. 2002. Residual Effects of Past on Later Behavior: Habituation and Reasoned Action Perspectives. *Personality and Social Psychology Review,* 6**,** 107-122.

AJZEN, A. 2011. *TPB Diagram* [Online]. Available: http://people.umass.edu/aizen/tpb.diag.html [Accessed 5th June 2012].

ALBRECHTSLUND, A. 2007. Ethics and Technology Design. *Ethics and Information Technology,* 9**,** 63-72.

ANDERSON, J. R. 1982. Acquisition of Cognitive Skill. *Psychological Review,* 89**,** 369-406.

ANDERSON, W. & WHITE, V. 2009. Exploring Consumer Preferences for Home Energy Display Functionality: Report to the Energy Saving Trust. Centre for Sustainable Energy.

ARROYO, E., BONANNI, L. & SELKER, T. 2005. Waterbot: Exploring Feedback and Persuasive Techniques at the Sink. *CHI 2005.* Portland, Oregon, USA.

ASPELUND, K. 2010. *The Design Process*, Fairchild Books.

BACKLUND, S., GYLLENSWÄRD, M., GUSTAFSSON, A., HJELM, S. I., MAZÉ, R. & REDSTRÖM, J. 2006. STATIC! The Aesthetics of Energy in Everyday Things. *WonderGround - Design Research Society International Conference.* Lisbon, Portugal.

BARBOUR, R. 2007. *Doing Focus Groups*, SAGE Publications.

BARGH, J. A. 1994. The Four Horsemen of Automaticity: Awareness, Efficiency, Intention, and Control in Social Cognition. *In:* R. S. WYER, J. & SRULL, T. K. (eds.) *Handbook of Social Cognition.* 2nd ed.: Hillsdale, NJ:Erlbaum.

BARGH, J. A. 1999. The Unbearable Automaticity of Being. *American Psychologist,* 54**,** 462-479.

BERDICHEVSKY, D. & NEUENSCHWANDER, E. 1999. Toward an Ethics of Persuasive Technology. *Communications of the ACM,* 42**,** 51-58.

BHAMRA, T. A., LILLEY, D. & TANG, T. Sustainable Use: Changing consumer behaviour through product design. Changing the Change, 11-12 July 2008 2008 Turin, Italy.

BHAMRA, T. A. & LOFTHOUSE, V. A. 2007. *Design for Sustainability A Practical Approach*, Gower Publishing Limited.

BLUYSSEN, P. M. 2009. *The Indoor Environment Handbook - How to Make Buildings Healthy and Comfortable*, Earthscan.

BLUYSSEN, P. M. 2010. Towards new methods and ways to create healthy and comfortable buildings. *Building and Environment,* 45**,** 808-818.

BOKS, C. Design for Sustainable Behaviour Research Challenges. Proceedings of EcoDesign 2011 International Symposium, 2011 Kyoto, Japan.

BOURDIEU, P. 1977. *Outline of a Theory of Practice*, Cambridge University Press.

BRAUN, V. & CLARKE, V. 2006. Using Thematic Analysis in Psychology. *Qualitative Research in Psychology,* 3**,** 77-101.

BRITISH STANDARDS INSTITUTION 2007. *BS EN 15251:2007 Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics*.

BRITISH STANDARDS INSTITUTION 2010. *BS EN ISO 9241-210:2010 Ergonomics of human-system interaction. Part 210: Human-centred design for interactive systems*.

BRUSEBERG, A. & MCDONAGH-PHILP, D. 2002. Focus Groups to support the industrial/product designer: a review based on current literature and designers' feedback. *Applied Ergonomics***,** 27-38.

BUCHENAU, M. & SURI, J. F. Experience Prototyping. *In:* BOYARSKI, D. & KELLOGG, W. A., eds. DIS '00, 2000 Brooklyn, New York, USA. ACM.

BURGESS, J. & NYE, M. 2008. Re-materialising energy use through transparent monitoring systems. *Energy Policy,* 36**,** 4454-4459.

CARBON TRUST. 2011. *Employee Awareness and Office Energy Efficiency* [Online]. Available: http://www.carbontrust.com/awareness [Accessed 14 December 2011.

CHAPPELLS, H. & SHOVE, E. 2004. Comfort: A Review of Philosophies and Paradigms. *Future Comforts: Re-Conditioning Urban Environments.*

CHAPPELLS, H. & SHOVE, E. 2005. Debating the Future of Comfort: Environmental Sustainability, Energy Consumption and the Indoor Environment. *Building Research & Information,* 33**,** 32-40.

CHARITY, M. 2001. *Blackbody Color Datafile* [Online]. Available: http://www.vendian.org/mncharity/dir3/blackbody/UnstableURLs/bbr_color.html [Accessed 25 January 2011].

CHATTERTON, T. 2011. *An Introduction to Thinking About 'Energy Behaviour': A Multi Model Approach*, Department for Energy and Climate Change, London.

COLE, R. J., ROBINSON, J., BROWN, Z. & O'SHEA, M. 2008. Re-Contextualising the Notion of Comfort. *Building Research & Information,* 36**,** 323-336.

CRESWELL, J. W. 2007. *Qualitative Inquiry & Research Design*, SAGE Publications.

CROSBIE, T. & BAKER, K. 2010. Energy-efficiency interventions in housing: learning from the inhabitants. *Building Research & Information,* 38**,** 70 - 79.

CROSS, N. 2007. *Designerly Ways of Knowing*, Birkhauser.

CROSS, N. 2010. *Engineering Design Methods*, Wiley.

DARBY, S. Making it Obvious: Designing Feedback into Energy Consumption. 2nd International Conference on Energy Efficiency in Household Appliances and Lighting, 2000 Italian Association of Energy Economists / EC-SAVE programme.

DARBY, S. 2006. The Effectiveness of Feedback on Energy Consumption. *A Review for DEFRA of the Literature on Metering, Billing and Direct Displays.* Environmental Change Institute, University of Oxford.

DARBY, S. Why, What, When, How, Where and Who? Developing UK Policy on Metering, Billing and Energy Display Devices. ACEEE Summer Study on Energy Efficiency in Buildings, August 17-22, 2008 2008 Asilomar, CA.

DARBY, S. 2010. Literature Review for the Energy Demand Research Project. Ofgem (Office of Gas and Electricity Markets), London.

DARNTON, A. 2008. *GSR Behaviour Change Knowledge Review: An Overview of Behaviour Change Models and their Uses*, Government Social Research Unit, London.

DARNTON, A., VERPLANKEN, B., WHITE, P. & WHITMARSH, L. 2011. Habits, Routines and Sustainable Lifestyles: A summary report to the Department for Environment, Food and Rural Affairs.

DECC 2008. 2008 Greenhouse Gas Emissions, Final Figures by End-User.

DECC 2009. Energy Consumption in the UK Domestic Data Tables 2009 Update. National Statistics.

DEPARTMENT FOR COMMUNITIES AND LOCAL GOVERNMENT. 2011. *Social Housing* [Online]. Available: http://www.communities.gov.uk/housing/socialhousing/ [Accessed 04 November 2011].

DEPARTMENT OF ENERGY AND CLIMATE CHANGE 2008. 2008 Greenhouse Gas Emissions, Final Figures by End-User.

DEPARTMENT OF ENERGY AND CLIMATE CHANGE 2009. Energy Metering: A Consultation on Smart Metering for Electricity and Gas.

DORST, K. & ROYAKKERS, L. 2006. The Design Analogy: A Model for Moral Problem Solving. *Design Studies,* 27**,** 633-656.

DRURY, C. G. 2005. Designing Ergonomic Studies. *In:* WILSON, J. R. & CORLETT, N. (eds.) *Evaluation of Human Work.* 3 ed.: CRC Press.

DUBBERLY, H. 2004. How do you design? A Compendium of Models. Dubberly Design Office.

ELIAS, E. W. A. 2011. *User-efficient Design: Reducing the Environmental Impact of User Behaviour Through the Design of Products.* Doctor of Philosophy, University of Bath.

ELIAS, E. W. A., DEKONINCK, E. A. & CULLEY, S. J. 2008a. Assessing user behaviour for changes in the design of energy using domestic products. *Proceedings of the 2008 IEEE International Symposium on Electronics and the Environment.* IEEE Computer Society.

ELIAS, E. W. A., DEKONINCK, E. A. & CULLEY, S. J. 2008b. Prioritisation Methodology for the User-Centred Design of Energy Using Domestic Products. *International Design Conference - DESIGN 2008.* Dubrovnik, Croatia.

ELIZONDO, G. M. 2011. *Designing for Sustainable Behaviour in Cross-Cultural Contexts: A Design Framework.* Doctoral Thesis, Loughborough University.

ELLIOT, A. J., MAIER, M. A., BINSER, M. J., FRIEDMAN, R. & PEKRUN, R. 2009. The Effect of Red on Avoidance Behavior in Achievement Contexts. *Personality and Social Psychology Bulletin,* 35**,** 365-375.

ELLIOT, A. J., MAIER, M. A., MOLLER, A. C., FRIEDMAN, R. & MEINHARDT, J. 2007. Color and Psychological Functioning: The Effect of Red on Performance Attainment. *Journal of Experimental Psychology: General,* 135**,** 154-168.

ENERGY SAVING TRUST 2006. The Rise of the Machines - A Review of Energy Using Products in the Home from the 1970s to Today.

EPRI 2009. Residential Electricity Use Feedback: A Research Synthesis and Economic Framework. EPRI, Palo Alto, California.

EPSRC. 2010. *Carbon, Control and Comfort: User-centred control systems for comfort, carbon saving and energy management, EPSRC reference: EP/G000395/1* [Online]. Available: http://gow.epsrc.ac.uk/ViewGrant.aspx?GrantRef=EP/G000395/1 [Accessed 2 June 2010].

FANGER, P. O. 1970. *Thermal Comfort Analysis and Applications in Environmental Engineering*, Danish Technical Press.

FISCHER, C. 2008. Feedback on household electricity consumption: a tool for saving energy? *Energy Efficiency,* 1**,** 79-104.

FITZPATRICK, G. & SMITH, G. 2009. Technology-Enabled Feedback on Domestic Energy Consumption: Articulating a Set of Design Concerns. *IEEE Pervasive Computing,* 8**,** 37-44.

FOGG, B. J. 2003. *Persuasive Technology: Using Computers to Change What We Think and Do (Interactive Technologies)*, Morgan Kaufmann.

FOGG, B. J. A Behavior Model for Persuasive Design. Persuasive '09, 2009 Claremont, California, USA.

FOGG, B. J. & HREHA, J. 2010. Behavior Wizard: A Method for Matching Target Behaviors with Solutions. Persuasive Technology Lab, Stanford University.

FRENCH, M. J. 1998. *Conceptual Design for Engineers*, Springer.

GOWRI, A. 2004. When Responsibility Can't Do It. *Journal of Business Ethics,* 54**,** 33-50.

HAINES, V., MITCHELL, V. & MALLABAND, B. 2012. Merging a Practice-orientated Approach with an Engineering-driven Product Development: a Case Study on Home Improvement. *Journal of Design Research,* 10**,** 50-66.

HAM, J., MIDDEN, C. J. H. & BEUTE, F. Can Ambient Persuasive Technology Persuade Unconsciously? Using Subliminal Feedback to Influence Energy Consumption Ratings of Household Appliances. Persuasive '09, April 26-29, 2009 Claremont, California, USA.

HAMMERSLEY, M. & GOMM, R. 2000. Introduction. *In:* HAMMERSLEY, M. & GOMM, R. (eds.) *Case Study Method.* 1st ed.: SAGE Publications.

HARGREAVES, T. 2010. The Visible Energy Trial: Insights from Qualitative Interviews. *Tyndall Centre Working Papers.*

HAUGE, B. 2010. Fresh Air at Home: A Sensory Experience and Social Ritual. *Daylight & Architecture.*

HIGNETT, S. 2005. Evaluation of Human Work. Qualitative Methodology. *In:* WILSON, J. R. & CORLETT, N. (eds.) *Evaluation of Human Work.* 3 ed.: CRC Press.

HINTON, E. & WILSON, G. T. 2010. Merthyr Tydfil Spring 2010 Social Fieldwork Thematic Analysis. Carbon, Control and Comfort.

HOLZINGER, A., BAERNTHALER, M., PAMMER, W., KATZ, H., BJELIC-RADISIC, V. & ZIEFLE, M. 2011. Investigating Paper vs. Screen in Real-life Hospital Workflows: Performance Contradicts Perceived Superiority of Paper in the User Experience. *International Journal Human-Computer Studies,* 69**,** 563-570.

HOONHOUT, J. Interfering with Routines: Disruptive Probes to Elicit Underlying Desires. CHI'13, 2013 Paris, France, 27th April - 2nd May 2013.

IDEO 1999. Human Centered Design Toolkit. 2nd ed.

IDEO 2003. *IDEO Method Cards: 51 Ways to Inspire Design,* Palo Alto, William Stout

JACKSON, T. 2005. *Motivating Sustainable Consumption: A Review of Evidence on Consumer Behaviour and Behavioural Change, a Report to the Sustainable Development Research Network*, Centre for Environmental Strategy, University of Surrey.

JELSMA, J. & KNOT, M. 2002. Designing environmentally efficient services: a 'script' approach. *The Journal of Sustainable Product Design,* 2**,** 119-130.

JONES, J. C. 1992. *Design Methods*, John Wiley & Sons, Inc.

KODAK. 2011. *The Nature of Light and Color* [Online]. Available: http://motion.kodak.com/US/en/motion/Publications/Film_Essentials/index.htm [Accessed 25 January 2011].

KRUEGER, R. A. & CASEY, M. A. 2009. *Focus Groups: A Practical Guide for Applied Research*, SAGE Publications.

KUIJER, L. & DE JONG, A. M. A Practice Oriented Approach to User Centered Sustainable Design. 6th International Symposium on Environmentally Conscious Design and Inverse Manufacturing, 7-9 December 2009 2009 Sapporo, Japan. The Japan Society of Mechanical Engineers.

KUIJER, L. & DE JONG, A. M. 2012. Identifying Design Opportunities for Reduced Household Resource Consumption: Exploring Practices of Thermal Comfort. *Journal of Design Research,* 10**,** 67-85.

LALLY, P., VAN JAARSVELD, C. H. M., POTTS, H. W. W. & WARDLE, J. 2009. How are habits formed: Modelling habit formation in the real world. *European Journal of Social Psychology,* 40**,** 998-1009.

LIDMAN, K. M. E. & RENSTRÖM, S. E. 2011. *How to Design for Sustainable Behaviour? - A Review of Design Strategies & an Empirical Study of Four Product Concepts.* Master of Science, Chalmers University of Technology.

LIDMAN, K. M. E., RENSTRÖM, S. E. & KARLSSON, I. C. M. The Green User: Design for Sustainable Behaviour. *In:* ROOZENBURG, N. F. M., CHEN, L. L. & STAPPERS, P. J., eds. Diversity and Unity, IASDR2011, The 4th World Conference on Design Research, 31 October - 4 November 2011a Delft, The Netherlands.

LIDMAN, K. M. E., RENSTRÖM, S. E. & KARLSSON, I. C. M. I Don't Want to Drown the Frog! A Comparison of Four Design Strategies to Reduce Overdosing of Detergents. Proceedings from Conference on Sustainable Innovation 2011, 'Towards Sustainable Product Design', 2011b Farnham, UK.

LILLEY, D. 2007. *Designing for Behavioural Change: Reducing the Social Impacts of Product Use Through Design.* Doctoral Thesis, Loughborough University.

LILLEY, D. 2009a. Carbon, Control and Comfort: User-Centred Control Systems for Comfort, Carbon Savings and Energy Management. D1 - Report on the Integration and Operationalisation of User Centred Sustainable Design Methods. Loughborough University,.

LILLEY, D. 2009b. Design for sustainable behaviour: strategies and perceptions. *Design Studies,* 30**,** 704-720.

LILLEY, D. 2011. *design-behaviour.co.uk* [Online]. Available: http://homepages.lboro.ac.uk/~cddl/ [Accessed 24th October 2012].

LILLEY, D., BHAMRA, T. A. & LOFTHOUSE, V. A. 2006. Towards Sustainable Use: An Exploration of Designing for Behavioural Change. *DeSForm 2006: European Workshop on Design and Semantics of Form and Movement.* Eindhoven, The Netherlands.

LILLEY, D. & LOFTHOUSE, V. A. 2010. Teaching Ethics For Design For Sustainable Behaviour: A Pilot Study. *Design and Technology Education: An International Journal,* 15.

LOCKTON, D. & HARRISON, D. 2012. Models of the User: Designers' Perspectives on Influencing Sustainable Behaviour. *Journal of Design Research,* 10**,** 7-27.

LOCKTON, D., HARRISON, D., HOLLEY, T. & STANTON, N. 2009. Influencing interaction: Development of the design with intent method. *Proceedings of Persuasive 2009: Fourth International Conference on Persuasive Technology.* Claremont, CA: ACM.

LOCKTON, D., HARRISON, D. & STANTON, N. 2010a. The Design with Intent Method: A Design tool for Influencing User Behaviour. *Applied Ergonomics,* 41**,** 382-392.

LOCKTON, D., HARRISON, D. & STANTON, N. 2010b. Design with Intent: 101 Patterns for Influencing Behaviour Through Design. Windsor, Berkshire, UK: Equifine.

LÖFSTRÖM, E. 2007. Visualizing Energy in Households: The Power Aware Cord as a Means to Create Energy Awareness. *ENHR International Conference. Sustainable Urban Areas.* Rotterdam, The Netherlands.

LÖFSTRÖM, E. & PALM, J. 2008. Visualising Household Energy Use in the Interest of Developing Sustainable Energy Systems *Housing Studies,* 23**,** 935-940.

LOFTHOUSE, V. A. & LILLEY, D. 2006. What They Really, Really Want: User Centered Research Methods for Design *International Design Conference - Design 2006.* Dubrovnik, Croatia.

LUDVIGSSON, M. 2005. *Reflection through Interaction: Raising Energy Awareness among Young People with Interaction Design and Speculative Re-design of Personal Objects.* MSc Thesis in Interaction Design, IT UNIVERSITY OF GÖTEBORG, GÖTEBORG UNIVERSITY AND CHALMERS UNIVERSITY OF TECHNOLOGY.

MAAN, S., MERKUS, B., HAM, J. & MIDDEN, C. J. H. 2011. Making it not too Obvious: The effect of Ambient Light Feedback on Space Heating Energy Consumption. *Energy Efficiency,* 4**,** 175-183.

MACNAGHTEN, P. & MYERS, G. 2010. Focus Groups. *In:* SEALE, C., GOBO, G., GUBRIUM, J. F. & SILVERMAN, D. (eds.) *Qualitative Research Practice.* 1 ed.: SAGE Publications.

MAGUIRE, M. 2001. Methods to support human-centred design. *International Journal Human-Computer Studies,* 55**,** 587-634.

MCCALLEY, L. T. 2006. From motivation and cognition theories to everyday applications and back again: the case of product-integrated information and feedback *Energy Policy,* 34**,** 129-137.

MCCALLEY, L. T., DE VRIES, P. W. & MIDDEN, C. J. H. 2011. Consumer Response to Product-Integrated Energy Feedback: Behavior, Goal Level Shifts, and Energy Conservation. *Environment and Behavior,* 43**,** 525-545.

MCCLELLAND, I. & SURI, J. F. 2005. Evaluation of Human Work. Involving people in design. *In:* WILSON, J. R. & CORLETT, N. (eds.) *Evaluation of Human Work.* 3 ed.: CRC Press.

MERTHYR TYDFIL COUNTY BOROUGH COUNCIL 2008. Built Heritage Strategy and Action Plan.

MINTEL 2009. Domestic Central Heating (Industrial Report) - UK - May 2009.

MOGGRIDGE, B. 2007. *Designing Interactions*, The MIT Press.

NHS ESTATES 1998. *'Safe' Hot Water and Surface Temperatures. Health Guidance Note.*, The Stationery Office.

NICOL, J. F. & HUMPHREYS, M. A. 2002. Adaptive Thermal Comfort and Sustainable Thermal Standards for Buildings. *Energy and Buildings,* 34**,** 563-572.

NIELSEN, J. 1997. The Use and Misuse of Focus Groups. *IEEE Software,* 14**,** 94-95.

NORMAN, D. 1988. *The Psychology Of Everyday Things*, Basic Books.

OFFICE FOR NATIONAL STATISTICS 2010. Statistical Bulletin: Life Expectancy, 2007-2009.

OFFICE FOR NATIONAL STATISTICS. 2012. *Labour Market Profile: Merthyr Tydfil* [Online]. Available: https://www.nomisweb.co.uk/reports/lmp/la/2038432110/report.aspx#tabempunemp [Accessed 18th July 2012.

OFGEM 2010. Energy Demand Research Project. Review of Progress for the Period March 2009 - September 2009.

OFGEM 2011. Consumer Bulletin: Getting Smart - Preparing for Change.

OXFORD ENGLISH DICTIONARY. 2012. *"model, n. and adj."* [Online]. Oxford University Press. Available: http://www.oed.com/viewdictionaryentry/Entry/120577 [Accessed 5th June 2012].

PAHL, G., BEITZ, W., SCHULZ, H.-J. & JARECKI, U. 2007. *Engineering Design: A Systematic Approach*, Springer.

PARLIAMENT OF THE UNITED KINGDOM 2008. Climate Change Act 2008. Chapter 27. The Stationery Office Limited.

PARLIAMENT OF THE UNITED KINGDOM 2009. The Climate Change Act 2008 (2020 Target, Credit Limit and Definitions) Order 2009. Order No. 1258. The Stationery Office Limited.

PETTERSEN, I. N. & BOKS, C. 2008. The Ethics in Balancing Control and Freedom when Engineering Solutions for Sustainable Behaviour. *International Journal of Sustainable Engineering,* 1**,** 287-297.

PHILLIPS, P. L. 2004. *Creating the Perfect Design Brief*, Allworth Press.

PINK, S. 2007. Walking with Video. *Visual Studies,* 22**,** 240-252.

PINK, S. 2010. Visual Methods. *In:* SEALE, C., GOBO, G., GUBRIUM, J. F. & SILVERMAN, D. (eds.) *Qualitative Research Practice.* 1 ed.: SAGE Publications.

POLITES, G. L. Counterintentional Habit as an Inhibitor of Technology Acceptance. Eighth Annual Conference of the Southern Association for Information Systems Conference, 25-26 February 2005 Savannah, Georgia.

PUGH, S. 1990. *Total Design: Integrated Methods for Successful Product Engineering*, Prentice Hall.

RECKWITZ, A. 2002. Toward a Theory of Social Practices: A Development in Culturalist Theorizing. *European Journal of Social Theory,* 5**,** 243-263.

ROBSON, C. 2002. *Real World Research*, Blackwell Publishing.

RODRIGUEZ, E. & BOKS, C. How Design of Products Affects User Behaviour and Vice Versa: the Environmental Implications. Environmentally Conscious Design and Inverse Manufacturing, 2005. Eco Design 2005. Fourth International Symposium on, 12-14 December 2005 2005. 54-61.

ROUTARINNE, S. & REDSTRÖM, J. 2007. Domestication as Design Intervention. *Design Inquiries 2007.* Stockholm, Sweden.

SCHATZKI, T. R. 2001. Introduction: Practice Theory. *In:* SCHATZKI, T. R., KNORR-CETINA, K. & VON SAVIGNY, E. (eds.) *The Practice Turn in Contemporary Theory.* Routledge, London.

SCOTT, K., QUIST, J. & BAKKER, C. 2009. Co-Design, Social Practices and Sustainable Innovation: Involving Users in a Living Lab Exploratory Study on Bathing. *Joint Action on Climate Change Conference.* Aalborg, Denmark.

SELVEFORS, A., PEDERSEN, K. B. & RAHE, U. Design for Sustainable Behaviour - Systemising the use of Behavioural Intervention Strategies. Designing Pleasurable Products and Interfaces, June 22-25, 2011 2011 Milan, Italy.

SHELTER. 2012. *What is Social Housing* [Online]. Available: http://england.shelter.org.uk/campaigns/why_we_campaign/Improving_social_housing/what_is_social_housing [Accessed 7th March 2013].

SHOVE, E. 2003. Converging Conventions of Comfort, Cleanliness and Convenience. *Journal of Consumer Policy,* 26**,** 395-418.

SHOVE, E. 2006. POPD Manifesto. Durham University.

SHOVE, E. 2008. Comfort in a Lower Carbon Society. *Building Research & Information,* 36**,** 307-311.

SHOVE, E. 2010. Beyond the ABC: Climate Change Policy and Theories of Social Change. *Environment and Planning A,* 42**,** 1273-1285.

SHOVE, E., WATSON, M., HAND, M. & INGRAM, J. 2008. *The Design of Everyday Life*, Berg.

SHOVE, E., WATSON, M. & INGRAM, J. 2007. Designing and Consuming: Objects, Practices and Processes. Lancaster University, University of Durham, University of Central England.

SILVERMAN, D. 2001. *Interpreting Qualitative Data*, SAGE Publications.

SNIEHOTTA, F. F. & PRESSEAU, J. 2012. The Habitual Use of the Self-Report Habit Index. *Annals of Behavioral Medicine,* 43**,** 139-140.

SORRELL, S. 2007. The Rebound Effect: An Assessment of the Evidence for Economy-wide energy Savings from Improved Energy Efficiency. UKERC.

STAKE, R. 2000. The Case Study Method in Social Inquiry. *In:* GOMM, R., HAMMERSLEY, M. & FOSTER, P. (eds.) *Case Study Method.* 1st ed.: SAGE Publications.

STEG, L. 2008. Promoting household energy conservation. *Energy Policy,* 36**,** 4449-4453.

STEG, L. & VLEK, C. 2009. Encouraging pro-environmental behaviour: An integrative review and research agenda. *Journal of Environmental Psychology,* 29**,** 309-317.

STERN, P. C. 1999. Information, Incentives, and Proenvironmental Consumer Behavior *Journal of Consumer Policy,* 22**,** 461-478.

STICKDORN, M. & SCHNEIDER, J. 2010. *This is Service Design Thinking. Basics-Tools-Cases.,* Amsterdam, BIS Publishers.

TANG, T. & BHAMRA, T. A. Improving Energy Efficiency of Product Use: An Exploration of Environmental Impacts of Household Cold Appliance Usage Patterns. 5th International Conference on Energy Efficiency in Domestic Appliances and Lighting, 18 June 2009 2009a Berlin, Germany.

TANG, T. & BHAMRA, T. A. Understanding Consumer Behaviour to Reduce Environmental Impacts through Sustainable Product Design. Undisciplined! Design Research Society Conference 2008, 16-19 July 2008 2009b Sheffield, UK. 1-13.

TANG, T. & BHAMRA, T. A. Applying a Design Behaviour Intervention Model to Design for Sustainable Behaviour. The Tao of Sustainability: An International Conference on Sustainable Design in a Globalization Context, 27th -29th October 2011 2011 Beijing, China.

TROMP, N., HEKKERT, P. & VERBEEK, P. P. 2011. Design for Socially Responsible Behavior: A Classification of Influence Based on Intended User Experience. *Design Issues,* 27.

UK GOVERNMENT. 2013. *Benefits & Credits: Winter Fuel Payment* [Online]. Available: https://www.gov.uk/winter-fuel-payment/overview [Accessed 29th January 2013].

VAN DAM, S. S., BAKKER, C. & VAN HAL, J. D. M. 2010. Home Energy Monitors: Impact over the Medium-term. *Building Research & Information,* 38**,** 458-469.

VERBEEK, P. P. 2006. Materializing Morality: Design Ethics and Technological Mediation. *Science Technology Human Values,* 31**,** 361-380.

VERPLANKEN, B. 2006. Beyond Frequency: Habit as Mental Construct. *British Journal of Social Psychology,* 45**,** 639-656.

VERPLANKEN, B., MYRBAKK, V. & RUDI, E. 2005. The Measurement of Habit. *In:* BETSCH, T. & HABERSTROH (eds.) *The Routines of Decision Making.* Psychology Press.

VRIES, M. J. D. 2006. Ethics and the Complexity of Technology: A Design Approach. *Philosophia Reformata,* 72**,** 118-131.

WARDE, A. 2005. Consumption and Theories of Practice. *Journal of Consumer Culture,* 5**,** 131-153.

WEVER, R., VAN KUIJK, J. & BOKS, C. 2008. User-centred design for sustainable behaviour. *International Journal of Sustainable Engineering,* 1**,** 9 - 20.

WEVER, R., VAN ONSELEN, L., SILVESTER, S. & BOKS, C. 2010. Influence of Packaging Design on Littering and Waste Behaviour. *Packaging Technology and Science,* 23**,** 239-252.

WILSON, G. T., BHAMRA, T. A. & LILLEY, D. Reducing Domestic Energy Consumption: A User-Centred Design Approach. *In:* WEVER, R., QUIST, J., TUKKER, A., WOUDSTRA, J., BOONS, F. & BEUTE, N., eds. Proceedings of Knowledge Collaboration & Learning for Sustainable Innovation ERSCP-EMSU Conference, 2010 Delft, The Netherlands, 25th-29th October 2010. 200-222.

WOOD, G. & NEWBOROUGH, M. 2007. Energy-use information transfer for intelligent homes: Enabling energy conservation with central and local displays. *Energy and Buildings,* 39**,** 495-503.

YIN, R. K. 2009. *Case Study Research. Design and Methods*, SAGE Publications.

ZACHRISSON, J. & BOKS, C. 2012. Exploring Behavioural Psychology to Support Design for Sustainable Behaviour. *Journal of Design Research,* 10**,** 50-66.

ZACHRISSON, J., STORRØ, G. & BOKS, C. Using a Guide to Select Design Strategies for Behaviour Change; Theory vs. Practice. Proceedings of EcoDesign 2011 International Symposium, 2011 Kyoto, Japan.

Appendix

Appendix A. Main Study Interview Guide

PROJECT INFORMATION:

Who we are

(a) My name is <name> and this is <name> from <University>.

Project details

(b) We are working on a project, called CCC (Carbon, Comfort, and Control) with a group of universities looking at comfort and heating in the home. We are visiting a lot of local properties to find out what people think and do. You should have already received information about this study.

- Are you happy to take part?
  - Any questions?
  - Sign consent forms if they have not already done so
  - We should be finished within an hour, is that ok?

GENERAL INFORMATION/NOTES:

TOPICS	RESPONSES
1. Background First of all we'd like to find out a bit more about you, if that's ok. (a) Could you tell us a little bit about yourself? (b) How long have you lived here? Where did you live before? (c) Who else lives here? - Do you have any children? How old are they? School? University? - Do you look after anybody Other children, elderly relatives, others requiring care - Do you have any pets? (d) What do you do during the day? What do you do in the evenings? What do you do at the weekends? - [if working] What kind of work do you do? Where do you work? - [if retired] What kind of work did you do? (e) What kinds of things do you do when you're at home? Do you invite people over? What do you do together? (f) What kinds of things do you do for fun?	

TOPICS	RESPONSES
2. Comfort We'd like to find out what makes you feel comfortable. (a) When you're at home, what kinds of things do you do to feel comfortable? (b) Do you use any particular objects to help you feel comfortable when you're at home? (c) What do you do when you feel too warm? (d) What do you do when you feel too cold? NON TEMP: - SECURITY (GOING OUT, NIGHT) - NOISE - LIGHT - FOOD - COLOUR	

TOPICS	RESPONSES
3. Building (a) We'd like to ask a few questions about your home, now. Has anything changed with your home since you moved in? (b) What sort of heating system have you got? - What kind of boiler have you got? How old is it? - Do you have a hot water tank? - Do you have radiators? Do you have any extra heaters When do you use them? (c) So you've lived here .... years, how does this system compare to your previous home? (d) How do you control your heating? - Do you have a thermostat? What temperature do you set it to? Who tends to do this? - Do you have a programmer? Do you use it to set your heating to come on at different times in the day? Do you program it so that the heating comes on different times on weekends? Who tends to do this? - Do you have controls on your radiators? Do you use them? Do you set them differently in different rooms? Who tends to do this? (e) Do you do anything else to make your home more comfortable? Do different people in your home have different ideas about how to make it comfortable? (f) How do you pay for your energy bills? Are you happy with how much it costs? Do you keep an eye on your meters? Do you do anything to try and use less energy? [If yes] Why do you do this?	

TOPICS	RESPONSES
4. Variability We'd like to find out a bit more about how the things you do in your home to feel comfortable might change at different times and in different situations. (a) [Refer to info on who is at home and when] When X is at home, do you do anything differently? (b) When you have guests, do you do anything differently? (c) We've had quite a cold winter. - Are winters here normally this cold? - Does your house get quite cold in this weather? - What kinds of things have you been doing to keep warm? - Could you run me through what you do when you get home on a cold day? (d) Thinking about the warmer months, - Does your house get warm in the warmer weather? - Does what you do in the warmer weather differ much from what you do in the colder weather? - What kinds of things do you do to keep cool in the warmer weather? (e) Thinking about how you keep comfortable at night, - Do you have the heating on at night? - Do you leave windows open at night? - Do you leave any lights on at night? Why? - Is there anything else about how you keep comfortable at night that's different to what you do during the day? - Could you briefly run me through what you do when you wake up?	

TOPICS	RESPONSES
(f) Thinking about times when you don't feel well - What kinds of things do you do to feel comfortable at home? - Do you find that the weather affects your health? - When you feel unwell, how do you keep warm, or cool down at home?	

TOPICS	RESPONSES
5. Environment We'd like to find out whether you do anything to try and help the environment, Recycle? Grow own food? Try to use less energy? Etc. 6. Other Is there anything else that you think we should know about how you keep comfortable at home?	

PROJECT INFORMATION:

Closing Statements

(a) That's it; we are finished for the day, thank you for your time and <the cup of tea>.

(b) This second visit involves an audio tour of your home, and would again last approximately one hour. This would involve you taking the researchers around your home and answering questions on what areas are more comfortable than others and how you make areas more comfortable. You do not have to take the researchers to any part of your home you do not wish to. With your permission, the researchers will record the tour using a digital audio recorder and a digital camera, in addition to taking notes. You can select areas where we may take photographs, or you can refuse the use of audio and photographic equipment in your home.

(c) We would like to come back in a few days for the next visit; it should take around the same amount of time, when would that be convenient?

GENERAL INFORMATION/NOTES:

Appointments

Monday	Tuesday	Wednesday	Thursday	Friday
Monday	Tuesday	Wednesday	Thursday	Friday

Appendix B. Main Study Guided Tour Guide

PROJECT INFORMATION:

Introduction

(a) Ask participant(s) if ok to give them an audio recorder, and notetaker to have other audio recorder (attach to clipboard).

(b) Ask permission to take every picture, and notetaker to note why picture was taken and where. Afterwards, show pictures to participants to get permission to use, offer to crop or pixellate/delete when requested

(c) Break tour into sections, spending the most time on the most and least comfortable spaces and asking about these first:

- Heating system
  Ask to see boiler/other, fireplaces, radiators, portable heaters, heating controls etc
  Weave into the rest of the tour, but make sure you look out for these and ask about them.
  Ask participants to show you how they use them, what they do to change how they work, who normally uses it and when, etc.
- Most comfortable space
- Least comfortable space
- Rest of house/garden/garage/shed etc if relevant

GENERAL INFORMATION:

Date:
Day:
Time:

Weather:
Participants:
Researchers:

Home Type:
Exterior Wall Type:
Interior Wall Type:

H	hall	B1	main bedroom
L	living room	B2	2nd bedroom
D	dining room	Ba	bathroom
La	landing	T	toilet
U	utility room	G	garage

Layout:

Loughborough University_audio guide_V0.1

ROOM	RESPONSES
1. General Observations (a) Room Description (e.g. living room, most comfortable): (b) Windows - number; glazing; curtains/blinds/other - open/closed? (c) Vents - number, type, location (d) Heaters – number, type, on/off (e) Lighting – number of lamps, type, location, lightbulbs, candles... etc (f) Flooring – type, rugs (g) Miscellaneous points of interest – For example: damp, condensation, noticeable gaps. 2. Comfort Questions (a) What make this space most/least comfortable (adjust as appropriate)? e.g. temperature, lighting, gets the sun/shady, ventilation, aesthetics, furnishings... (b) Look for points of interest, also draw from interview data to ask relevant questions e.g. 'I see you have two duvets on the bed – why?'; 'I see you have bedside lamps as well as a ceiling light – when do you use these?'; 'I see you have curtains as well as blinds – how do you tend to use these?'; 'I see you have a dressing gown and a pair of slippers by the bed – when do you use these?'	

ROOM	RESPONSES
(c) What kinds of activities do you do in this space? e.g. storage, guests, relaxing, TV, reading, working, sleeping, gaming, corridor, laundry, drying clothes, ironing clothes, preparing food, cooking, eating...) Why do you do these things here? (d) When do you use it? - How much time do you spend here? - Is this room more comfortable at different times of the day, or different times of year? (e) Has how comfortable this room is to you changed for any reason since you've been living here? (f) Does anything about the physical features of this room affect how comfortable you feel here? e.g. windows, amount of space, walls, doors, insulation, heaters, pipes, lighting, fans... (g) Do you or others in your household use any particular objects or things to make this space more comfortable? e.g. heating controls, windows, clothing, furnishings, lighting, baths, showers (when and why?) How effective are they? (h) Is there anything you'd like to do to make this space more comfortable, but you can't for some reason? - What would you do? - What prevents you from doing it? e.g. cost, knowledge, skills, landlord, household role, other concerns	

Appendix C. Main Study Information Sheet

CCC (Carbon, Comfort and Control) Project

INFORMATION SHEET FOR PARTICIPANTS

We would like to invite you and any other members of your household that would like to, to take part in this study for the CCC project.

You should only participate if you want to; choosing not to take part will not disadvantage you in any way. Before you decide whether you want to take part, it is important for you to understand why the research is being done and what your participation will involve.

Please take time to read the following information carefully, including the accompanying Consent Form, and discuss it with others if you wish. Ask us if there is anything that is not clear, or if you would like more information before deciding to take part. If after reading this information and discussing any issues you have you are happy to take part, **please** sign the Consent Form.

Study Information

The CCC project involves several UK Universities[1]. The aim of the project is to find out how to reduce the amount of energy we use in the home whilst remaining comfortable. To do this, we would like to find out how people use energy in the home and what they do to feel comfortable. The activities you are being asked to take part in will help us to do this. We would like to invite you to participate in three different activities, as a part of this project.

Part 1:
First, we would like to invite you and any other members of your household that would like to, to take part in a brief (approximately one hour) interview with two of the CCC researchers. We are interested in how you use your heating and

[1] Loughborough University, University College London, Kings College London, Leeds Metropolitan University, Cardiff University, De Montfort University and University of Greenwich

how you keep comfortable in your home. There are no right or wrong answers to the general questions we will ask – we are keen to get your thoughts and opinions. With your permission, we would like to record this interview using a digital audio recorder. At the same time, one of the researchers will make a note of your responses.

Part 2:
At the end of the interview, these two researchers will arrange with you a convenient day and time to come back to your home, for the second part of the study. This second visit involves an audio tour of your home, and would again last approximately one hour. This would involve you taking the researchers around your home and answering questions on what areas are more comfortable than others. You do not have to take the researchers to any part of your home you do not wish to. With your permission, the researchers will record the tour using a digital audio recorder and a digital camera, in addition to taking notes. You can select areas where we may take photographs, or you can refuse the use of audio and photographic equipment in your home.

Part 3:
At the end of the audio tour, the researchers will leave a pack with you, which we would like you to complete at your leisure, and send back to us once you've finished using a pre-paid envelope. There is a variety of activities within the pack; you can choose which ones you do, although we would ideally like you to complete as many of them as possible. It will take one week to complete the whole pack. The short activities involved in the pack include questions regarding your daily activities, energy use at home and comfort at home. Most activities can be completed at any time, but one of the activities requires you to fill in information on a chart everyday for a week. One of the activities asks you to take photographs around your home, and we will supply you with a disposable camera for this purpose.

Confidentiality

The information provided during this study will remain anonymous and confidential; names and addresses will not be used in any written reports for the research. Any identifying personal details obtained will only be available to those directly

[1] Loughborough University, University College London, Kings College London, Leeds Metropolitan University, Cardiff University, De Montfort University and University of Greenwich

carrying out the research and will be stored securely. Your involvement in all elements of the project is entirely voluntary. Please note that you have the right to withdraw from the study at any point, without having to give a reason.

If you feel happy to take part in the study described above, please now read the Consent Form then sign and date at the bottom of the form.

For further information or assistance, please feel free to contact us with any questions – our contact details are:

Researchers:		
Name:	Garrath Wilson	Emma Hinton
Institution:	Loughborough University	King's College London
Email:	G.T.Wilson@lboro.ac.uk	Emma.Hinton@kcl.ac.uk
Telephone:	07709 497 308	07904 888 876
Lead Researchers:		
Name:	Prof. Tracy Bhamra	Dr Karen Bickerstaff
Institution:	Loughborough University	King's College London
Email:	T.Bhamra@lboro.ac.uk	Karen.Bickerstaff@kcl.ac.uk
Telephone:	01509 228316	020 7848 2625
Address:	Design & Technology, Loughborough University, Loughborough LE11 3TU	Department of Geography, King's College London, Strand, London WC2R 2LS

[1] Loughborough University, University College London, Kings College London, Leeds Metropolitan University, Cardiff University, De Montfort University and University of Greenwich

Appendix D. Main Study Consent Form

KING'S College LONDON

Loughborough University

CCC (Carbon, Comfort and Control)

CONSENT FORM

I have been given a copy of the Information Sheet and I have read and understood it. I have had the opportunity to consider the information and ask any questions to my satisfaction. I understand what taking part in this research involves.

I understand that my participation is voluntary and that I have the right to withdraw from part or all of the study, at any time, without giving reason. I understand that if I withdraw my participation my information may still be included in the results, but it will not be possible to identify me in any way.

I understand that the information I provide will be anonymous and confidential. I agree to photos being used for research purposes (e.g. written reports) and understand that no personally identifiable features (e.g. anything with your name or address on it) will be included in these images.

I agree to the processing of my personal information for the purposes explained to me. I understand that this information will be treated in accordance with the terms of the Data Protection Act 1998.

I agree to participate in the study, as outlined in the Information Sheet.

Signed: ______________________________

Print Name: ______________________________

Date: ______________________________

Researcher's statement:

I, ______________________________

confirm that I have carefully explained the nature, demands and foreseeable risks (where applicable) of the proposed research to the volunteer.

Signed: ______________________________

Date: ______________________________

Appendix E. Main Study Guided Tour Reference Sheets

H-a - box and electricity meter, situated at ceiling level in hallway
H-b - showing the draught-proofing on the front door.
H-c - showing front door with curtain and some draught-proofing. This door will be replaced with a plastic [uPVC?] replacement in the next few days and so the curtain and draught-proofing will be removed.
L-a - one of the two sofas in the living room, showing cushions, throws, rug, many unused candles
L-b - view from the lounge floor, from underneath/behind the condemned gas fire: back boiler controls
L-c - contents of gas meter cupboard in lounge, used also for storage
L-d - the jacket that CA01F1 jammed down the back of the one working radiator in the lounge to prevent the vent behind it from functioning is just visible
L-e - the gas meter cupboard in the lounge, with furniture moved out of the way so that Dylan could install monitoring equipment – it is normally completely inaccessible and used for storage
L-f - showing yellowing mastic coming away from the window sill in the lounge


L-d

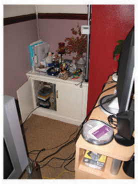
H-a



H-b


H-c

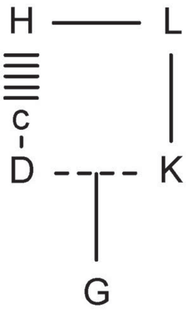

L-c


L-e


L-b


L-f

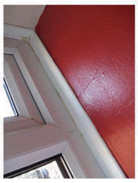

L-a




D-a


D-b


D-c


D-d

K-a


K-b



K-c


K-d


G-a

G-c



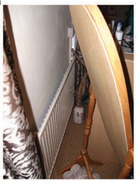
G-b

K-a - heating system control: programmer/timer. Only the buttons are used by the current householders, not the timer.
K-b - damp in corner of window in kitchen
K-c - one of the two sofas in the living room, with cushions, throws, rug, unused candles
K-d - the worktop above the damp kitchen cupboard, showing ill-fitting unsealed surfaces
G-a - two of the participants' cats in the garden, with some of the solar garden lights. The neighbour's gardens are visible from the participants garden, and vice versa
G-b - view of garden from kitchen, showing washing line with washing hanging out to dry
G-c - two of the participants' cats, with the rotary washing line in the background.
D-a - thermostat on kitchen wall
D-b - the kitchen radiator, with table and cat bed in front of it, with lino visible
D-c - damp at base of adjoining kitchen wall where paint has bubbled up
D-d - discoloured mastic around kitchen window, much of which is missing

AUDIO TOUR

GROUND FLOOR LAYOUT AND PHOTOS CA01F1 10MAR10

B1-a



B1-b

B1-e

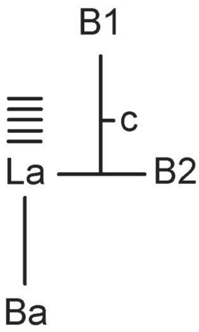
B1-c

B1-d

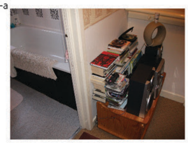
c-a

c-c

c-b



La-a

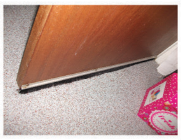


B2-a

B2-b

Ba-a

Ba-b



Ba-c

B1-a - the radiator in CA01F1's bedroom, showing distance between furniture in front and radiator.
B1-b - mastic around second window in CA01F1's bedroom showing discolouration from mould growth.
B1-c - gap between carpet and skirting board; draught associated with this area. A rug had been lifted from this piece of carpet to demonstrate the gap – CA01F1 uses the rug to block the draught.
B1-d - mastic removed from window/windowsill juncture, exposing gap. Mastic discoloured. Gap between net curtains and windowsill. Windowsill used to store trinkets.
B1-e - CA01F1's bed, showing hot water bottle, blankets and throw, and cushions and pillows. Bedside tables with bedside lamps. Alarm clock on bedside table records ambient temperature. New headboard and recently redecorated, something CA01F1 finds important for each room.
c-a - showing the extra-large hot water tank, which is both gas- and electric-heated, although the electric immersion element is never used. Also showing storage of clothes.
c-b - hot water tank thermostat and connections
c-c - inside the airing cupboard on the landing, showing cold water header tank and clothes stored in cupboard
B2a - showing sofa bed, bed and electric extension set-up
B2b - CA01F2's bed, jammed up against the radiator, showing candelabra affixed to wall but decorative only (never used) and curtains, always closed
Ba-a - leaking radiator in bathroom has toothbrush pot underneath 'repaired' valve to collect drips
Ba-b - brush draught-proofing strip attached to bottom of bathroom door
Ba-c - showing discoloured mastic around window in bathroom
La-a - CA01F2's 'stereo system' with DVDs and CD's, on landing at top of stairs and just outside bathroom. Showing lamp that is decorative and never plugged in or provided with light bulb.

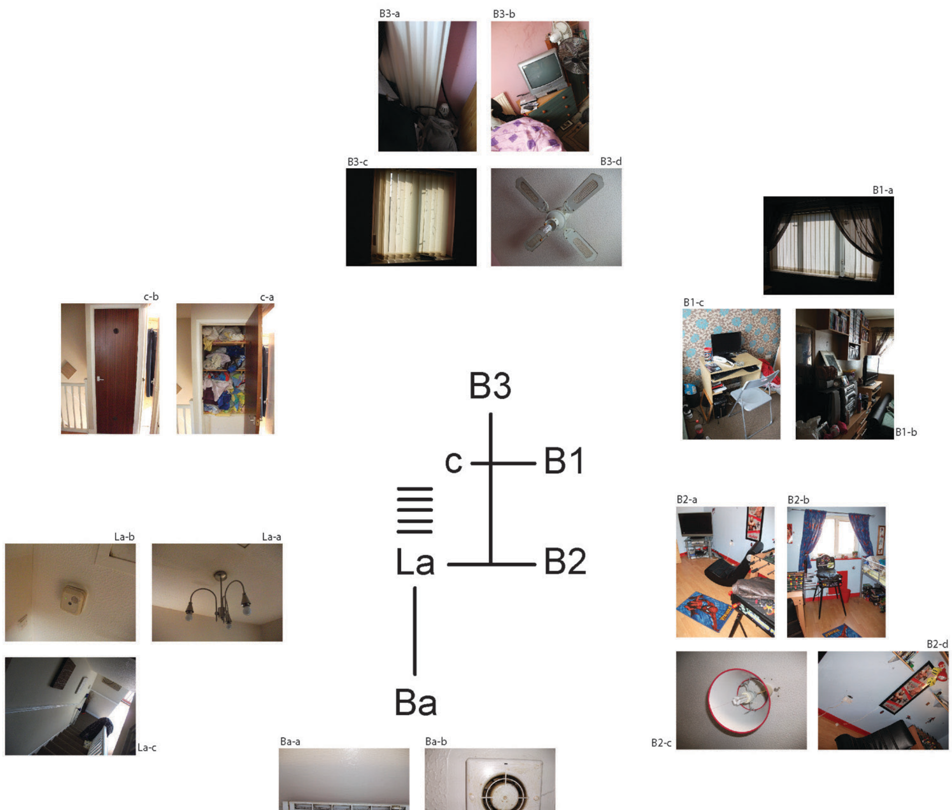
AUDIO TOUR

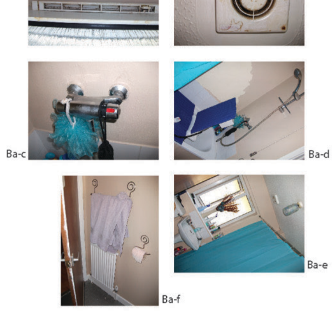
UPSTAIRS LAYOUT AND PHOTOS CA01F1 10MAR10

H-a - Decorative MDF cover over the radiator.
H-b - The thermostat is located at the bottom of the stairs.
H-c - The hallway lights are left on at night but are not on during the day.
H-d - Decorative net curtain. The door also features draught proofing measures.
L-a - Seating which contributes to the occupants comfort levels.
L-b - The radiator is set to 3. It is turned to 4/5 during early morning or when it is very cold.
L-c - The fan is on when it is very hot. The bright lights are not on when the occupant wishes to relax.
L-d - The electric heating element is never on, only the light on the fire is used in the evening when it gets dark.
K-a - The extractor above the oven is frequently used during cooking.
K-b - The boiler is a 'Vaillant' combination boiler which was installed around three years ago by MTHA.
K-c - There is an extractor in the wall situated near to the door although this is never switched on.
K-d - General view of the boilers positioning.
K-e - The occupant wants to get rid of the spot lights as she finds replacing the bulbs to be very expensive.
K-f - The dining room table which is occasionally used by two of the occupants.
G-a - View of the outside light and extractor vent.
G-b - Close-up of the drier vent.
G-c - The rabbits are usually free to run around the garden during the day, and occasionally the house.
G-d - They usually only keep flowers in the front garden of the house as the rabbits have a tendency to eat them.
WC-a - The frosted window in the downstairs WC is often left open regardless of the weather.
WC-b - The curtains are closed in a decorative fashion and are never opened.

AUDIO TOUR

GROUND FLOOR LAYOUT AND PHOTOS CA02Fe 23APR10





B3-a - The radiator is positioned on the blue * setting.
B3-b - There are two large desk fans although it is unclear when or where these are used.
B3-c - At the moment there are no curtains just blinds in preparation for decoration.
B3-d - Large ceiling fan with a single energy saving light bulb.
c-a - There is a radiator in the cupboard for airing clothes.
c-b - The door has two circular vents, located at the top and bottom of the door.
La-a - The light fitting is a chandelier type fixture with three small tungsten bulbs.
La-b - The extractor fan for the bathroom is high up the wall and is always switched off.
La-c - General view down the stairs.
Ba-a - The trickle vent in this room is open.
Ba-b - The extractor in this room is switched off.
Ba-c - The shower controls have a controllable temperature dial built in.
Ba-d - There is an over the bath shower and a mechanical seat lift.
Ba-e - There are no curtains or blinds although the windows are frosted glass.
Ba-f - There is a radiator located behind the door set to the blue * setting.
B2-a - There is a large TV and PS2 left on standby. The Sky box is switched on.
B2-b - There are no blinds in this room, only curtains, as this room is not over-looked.
B2-c - Ceiling light with low energy bulb.
B2-d - Large wall mounted spot light used as a child's night light.
B1-a - The windows and blinds are closed, the curtains are open.
B1-b - The large TV has been left on standby. The SkyHD box and PS3 are switched off.
B1-c - There is a computer that has been left on standby,

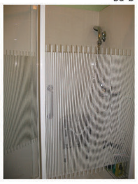
AUDIO TOUR

UPSTAIRS LAYOUT AND PHOTOS CA02Fe 23APR10

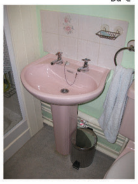
Ba-a - close up of the extractor fan that is controlled by the light, with the safety cable tucked behind the tiles to prevent accidental use.
Ba-b - shower installed by previous tenant that is connected to the hot water tank.
Ba-c - dressing gown that forms part of CA03M's morning routine.
Ba-d - The electric fan heater is never used because 'things like that are expensive to run'.
Ba-e - CA03M wasn't allowed to change the pink bathroom suite due to too many restrictive regulations. He finds the current suite 'bloody depressing'.
H-a - Close up of the draught-proofing brush fixed to the door leading to the corridor. It doesn't fit very well.
H-b - View down the hall of the door safety/intercom unit which never works properly.
B1-a - The bedroom window is always open, even when leaving the property.
B1-b - Although little time is spent in this room, there is a TV. When it gets cold in the winter, CA03M uses additional duvet's on the bed.
B1-c - The bedside table has an alarm clock and a small bedside light. There is also a book on one of the shelves.
B1-d - The radiator in this room is never on, as the window is always open and CA03M believes this to be a waste of electricity.

L-a - an electric storage heater. CA03M dislikes this heater, finding that the controls never work, providing only basic on/off functionality.
L-b - the TV and clock that gives temperature readings (19oC at time of visit).
L-c - the most comfortable place in the flat is the settee. It is close to the storage heater, is next to a standing lamp for reading, and has a good view of the TV.
L-d - the window is open during our visit, angled open from the top. There are also blinds and curtains.
K-a - the microwave was purchased by CA03M to replace the social housing provided oven (who also provided the fridge) which he finds to be inadequate.
K-b - overview of the kitchen. There is no extractor fan but a vent behind the cupboards. CA03M only uses the hob of the oven.
K-c - the electric heater is mounted behind the door which CA03M never uses as he believes it to be a waste to heat the back of the door (which is always open). The pull cord of the safety alarm looks very similar to the heater cord.
K-d - The ceiling light is a spot light which CA03M believes will not take low energy light bulbs.
K-e - There are no curtains on the windows, only blinds. The window is open.

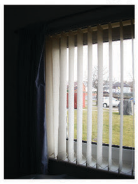
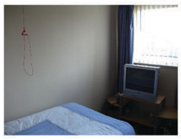
Ba-a

Ba-b

Ba-c

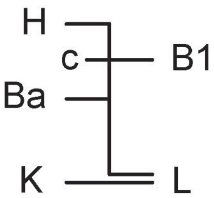
Ba-d

Ba-e

H-a

H-b

B1-a

B1-b

B1-c

B1-d

K-a

K-b


K-c
K-d


K-e
L-a

L-b

L-c

L-d


AUDIO TOUR

GROUND FLOOR LAYOUT AND PHOTOS CA03M 11MAR10


Communal Garden
The draught-proofing that CA03M did to the doors in the lounge that lead to the garden area comprises PVC and plastic draught-proofing strips; this has helped to solve the problem, although there is still a draught that comes in under the door.




Communal Communication
There is an information board on the wall, and there are poster-signs on many of the doors saying 'keep warm' (advising residents to keep the doors shut to keep the heat in). Outside one of the doors to the lounge area there is an information desk dedicated to information provided by the housing association.

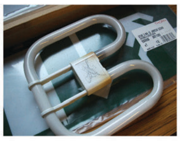
Communal Laundry
There is a shared laundry area, the cost of which is shared amongst all residents in the service charge. You can't control how each person chooses to use the facilities – 1 person recently left a pair of trousers going in the machine for a whole night.




Communal Lounge
The communal lounge area comprises many seats, a wall-mounted flat-screen TV, a stereo, electric piano and a large fish tank. The heaters in the lounge and some communal parts are the same type of storage heater that the residents previously had in their flats; these ones are the ones that give out heat for longer and that the residents preferred, in contrast to the storage heaters they now all have in their flats and many corridors which they perceive as being less effective with dials and controls that fail to work. CA03M believes that the insulated ceiling tiles in these areas also help to keep the heat in the room.

Communal Kitchen
The kitchen is accessible via the communal lounge area. Cookery classes have been held here for the residents as well as being regularly used for cooking communal meals. The residents are looking for a grant to improve the kitchen so that it has capacity to cook for more people.


Recycling and Refuse
A room previously used as a 'treatment room' has changed use, and is now the room for recycling, containing multiple recycling bins. CA03M puts the recycling bins out every Thursday morning; the ordinary waste is collected by the local authority, they have a key for the bin store room, which is separate to this recycling room. The recycling room is also used to store food and drink for communal events such as the regular fish & chip evenings.

Meters and Fittings
Only the warden has the key to the meter room and residents aren't allowed in there. When bills come in, the warden reads the meters for the residents. The lights in the communal areas are in use 24/7, but break daily. Costing £25 per bulb, the past three months has cost the residents over £1000 already. If residents want to replace all light fittings and bulbs then they have to pay to do this. The residents are not happy about not being consulted on the original fittings



Quiet Room/Library/Computer Room
There are 5 computers, 2 printers and 1 laptop. In contrast to the way that other communal bills are shared, only those who use the computers will share the cost of internet access. Because security could be an issue as carers, cleaners and workers don't always check that external self-closing doors close behind them, the laptop is kept locked away.

AUDIO TOUR

COMMUNAL AREAS AND PHOTOS CA03M 11MAR10

G-a - electricity meter cupboard at front of house beside front door – not easily accessible yet contains slot for prepayment and so is accessed weekly
H-a - hallway leading to kitchen, showing radiator in cupboard and floor tiles
H-b - thermostat in hallway at foot of stairs, at eye-level height
H-c - ceiling lights in hallway, using 3x tungsten filament bulbs
H-d - front door in hallway, single glazed, with toilet to left and lounge to right
L-a - lounge windows showing open vents but closed windows, and curtains
L-b - lounge, showing laminate flooring, rug chosen for aesthetics (it matches), table lamps (used in preference to ceiling lights), and electric fire (light used but not for heat)
L-c - lounge showing partially glazed door, windows (double glazed throughout except for doors), curtains, radiator below window and TV
L-d - lounge, showing two sofas
WC-a - ground floor toilet beside front door, noticeably warmer than other rooms, door kept shut; showing small radiator immediately adjacent to toilet and decorative net curtain. Window closed.

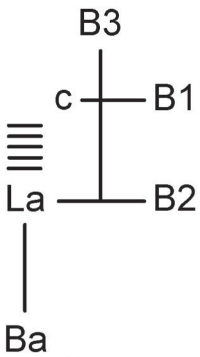
AUDIO TOUR

GROUND FLOOR LAYOUT AND PHOTOS CA04F 12MAR10

B3-a

B3-b

c-a



B1-a

B1-b

B1-c

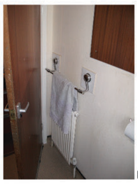
La-a

B2-a

B2-b

Ba-a

Ba-b



Ba-c

Ba-b - upstairs bathroom window, closed, with decorative curtains
Ba-c - upstairs bathroom with small radiator behind door, over which a towel hangs on a rail
Ba-a - upstairs bathroom, on/off pull switch for operation of electric power shower, left on and cord tied up high +- out of reach
c-a - vent in cupboard door at top of stairs
La-a - ceiling light on landing at top of stairs next to loft hatch, with CFL
B3-b - small bedroom at front of house, vents open and window open, also showing curtains
B3-a - small bedroom at front of house showing small radiator and TV/DVD player, on standby
B1-a - main bedroom at front of house, showing small radiator at foot of bed, curtains, and open window
B1-b - main bedroom at front of house, showing open window
B1-c - main bedroom at front of house, showing TV with DVD player etc on standby
B2-a - second bedroom, showing small radiator under window; net curtains and curtains; carpet and rug
B2-b - second bedroom, showing TV, DVD player etc on standby

AUDIO TOUR

UPSTAIRS LAYOUT AND PHOTOS CA04F 12MAR10

L-a - the main lounge window, showing vertical blinds and voile curtains in the positions they are typically in during the day. Below the window the radiator is visible, beside which is the chair in which CA05F sits in the evenings, beside the radiator to keep warm.
L-b - a close-up of the TRV on the lounge radiator
L-c - lounge area: fireplace with fire light on (but heat off) – also showing the settee on which CA05M sits, and a table lamp beside the chair in which CA05F sits in the evenings
L-d/e - in the lounge, the small second window – which has vertical blinds – has been sealed with mastic to stop the draught.
H-a - the top of the front door seal, which is sagging and discoloured [possible mould?] – this door is considered draughty
H-b - the bottom of the front door, showing a draught-proofing brush
H-c - the hallway, showing the tiled area in front of the front door (installed because the door dragged on the carpet and spoilt it; now this area is considered draughty); the stairs to the left and the entrance to the lounge to the right; and the hall radiator.
H-d - the thermostat is situated at eye-level on the wall between the radiator in the hallway and the door to the kitchen. It is normally set at 20°C.
K-a - the combi gas boiler located on the kitchen wall beside the back door, which has programmable controls that are no longer used since CA05F is not working.


L-a


G-a


L-b

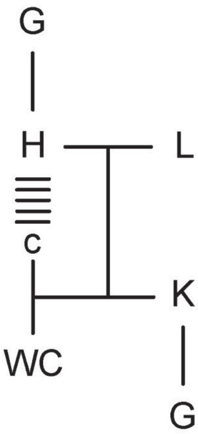

G-b


L-c


H-a


L-e


L-d

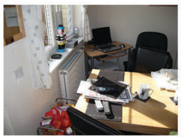


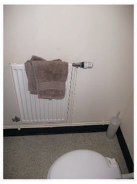

H-b


H-d


H-c


K-a


K-b


WC-a


K-d


K-c


G-c


WC-b


G-d


G-e

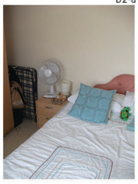
K-b - the kitchen, showing one of the windows overlooking the back garden; the radiator below it; the voile curtains (no blinds); the computer workstation, which CA05F likes to use regularly; and the dining table, on which meals are regularly eaten.
K-c - the combi gas boiler
K-d - the kitchen, showing the cooker which is normally in use in the evenings and sometimes during the day, and generates heat. CA05F enjoys cooking and uses the bread machine on the work surface, as well as regular cups of tea provided through using the kettle.
Ga/b – the gas and electricity meters are stored beside the front door.
G-c/d - the rotary line is used normally to dry clothes on; these clothes are CA05F's daughter's. The raised beds beside the greenhouse and the pots on the patio and beside the fence are also used to grow food crops. The property is situated on a hill, providing views of the surrounding hills and a nearby open-cast coal mine.
G-e - one of two greenhouses in the back garden, showing compost bins and a wheelbarrow full of harvested mole hills from the surrounding area (which are apparently good for growing crops). This is used to provide food during the summer months.
WC-a - the radiator in the ground floor toilet, on which the towel is normally left.
WC-b - the net curtain in the ground floor toilet window, showing a vent.

AUDIO TOUR

GROUND FLOOR LAYOUT AND PHOTOS CA05F 11MAR10

La-a - the 'drymaster' vent from the loft, located in the landing ceiling at the top of the stairs. A draught can be felt around this.
La-b - the landing, showing the layout.
c-a - one of the cupboards on the landing; this one is at the top of the stairs and includes a radiator.
c-b - all the cupboard doors have vents in, like this one.
B1-a - the master bedroom, in which CA05F&M sleep. Showing windows open as they normally are, and voile curtains and vertical blinds in the normal daytime position. Overlooks the back garden.
B1-b - view from the master bedroom window, of the open cast coal mine in the distance.
Ba-a - the main bathroom, showing the radiator and the towel in its usual position, such that the warm air can circulate.
Ba-b - the main bathroom, showing the window with blind. The window is open slightly, as normal.
Ba-c - the shower over the bath – not an electric power shower, connected to the taps. Mould around mastic is attributed to the inadequacy of the installation rather than to any particular problem with mould or condensation or damp.
Ba-d - the mirror in the main bathroom, over which there is a shaving light that is never used.
B2-a - the second bedroom, showing the double bed, the pull out bed against the wall beside the wardrobe, a bedside light, and an electric fan that is used downstairs in the kitchen in the summer. Potatoes are sprouting in this room ready for planting in the spring.
B2-b - the second window in this second bedroom; the chair is used for storing things on, clothes to be donated to charity at the moment. Sprouting potatoes can be seen beside it.
B2-c - the second bedroom, used as a guest bedroom, showing one of the windows. Each has vertical blinds and voile curtains. Clothes are dried on the clothes horse in this position in front of the radiator.

B2-a

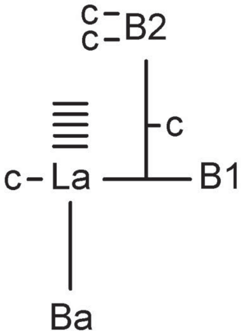


B2-b

B2-c

La-a

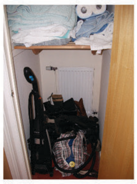
La-b



B1-a

B1-b

c-a

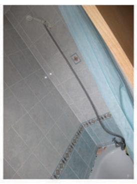


c-b

Ba-a

Ba-b

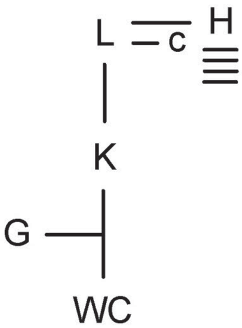
Ba-d



Ba-c

AUDIO TOUR

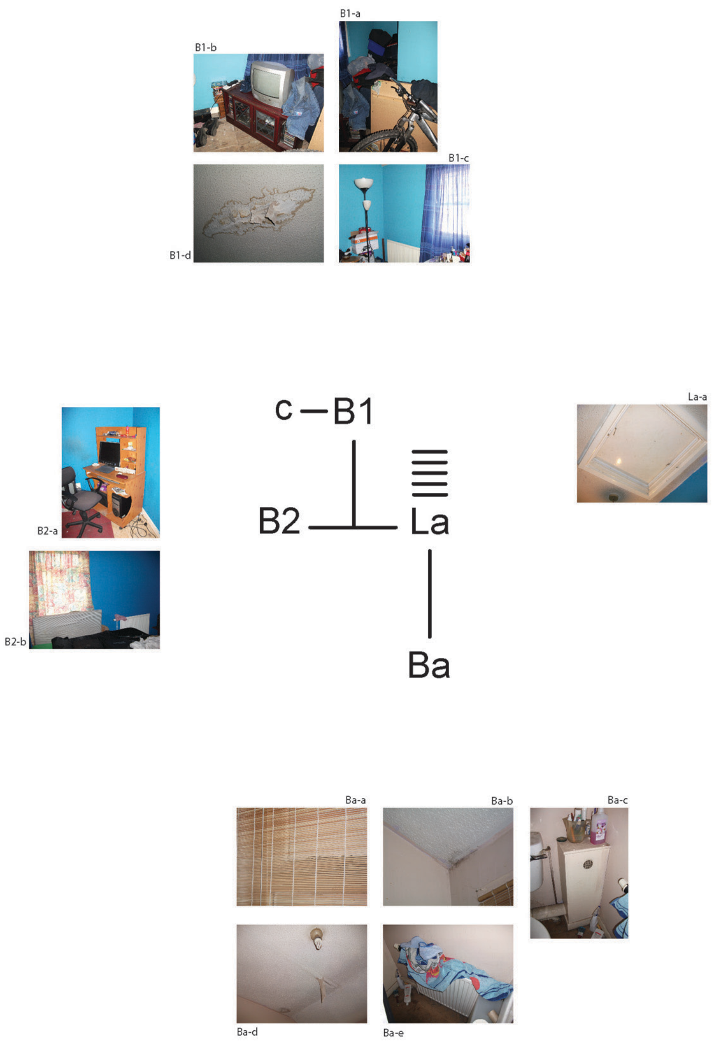
UPSTAIRS LAYOUT AND PHOTOS CA05F 11MAR10



H-a - Radiator located at the bottom of the stairs.
H-b - Draught proofing measures installed by the occupant following an attempted break in.
H-c - As above.
H-d - Prepay electronic token meter.
H-e - Fuse box and prepay gas meter located very high to the ceiling.
H-f - Cracked door following attempted break in.
L-a - There is 1 cupboard under the stairs, where the dog food is stored.
L-b - There one window, which is painted shut, which has a net curtain and a pair of curtains.
L-c - There is one radiator on the internal wall, with the TRV set to 5 normally.
L-d - CA06 sealed the vent because during the winter hailstones came in through it.
K-a - View from the kitchen into the garden, with 5 out of the 6 pets.
K-b - There used to be a fluorescent tube but now there is one ceiling light with a CFL.
K-c - There is a radiator behind the wheelie bin, normally turned on to the maximum, 5.
K-d - There is a wall-mounted gas combi boiler and no thermostat in the room
K-e - The kitchen contains a wheelie bin, a sofa, a defunct chest freezer, a washing machine, a tumble drier, a cooker and a microwave.
K-f - This lampshade, like the one in the downstairs loo, was left by a previous tenant
K-g - Door bolt installed by previous tenant.
K-h - There is mould growing around the back door and on the ceiling.
G-a - External view of the areas with mould growth.
G-b - The river is accessible over the back wall for fishing.
G-c - There is a ferret hutch, but the ferret was stolen.
G-d - CA06 normally grows veg in the warmer weather.
WC-a - There is a radiator, which is always on 5, the maximum setting.
WC-b - Two doors are missing due to animal related destruction.

AUDIO TOUR

GROUND FLOOR LAYOUT AND PHOTOS   CA06F   22APR10

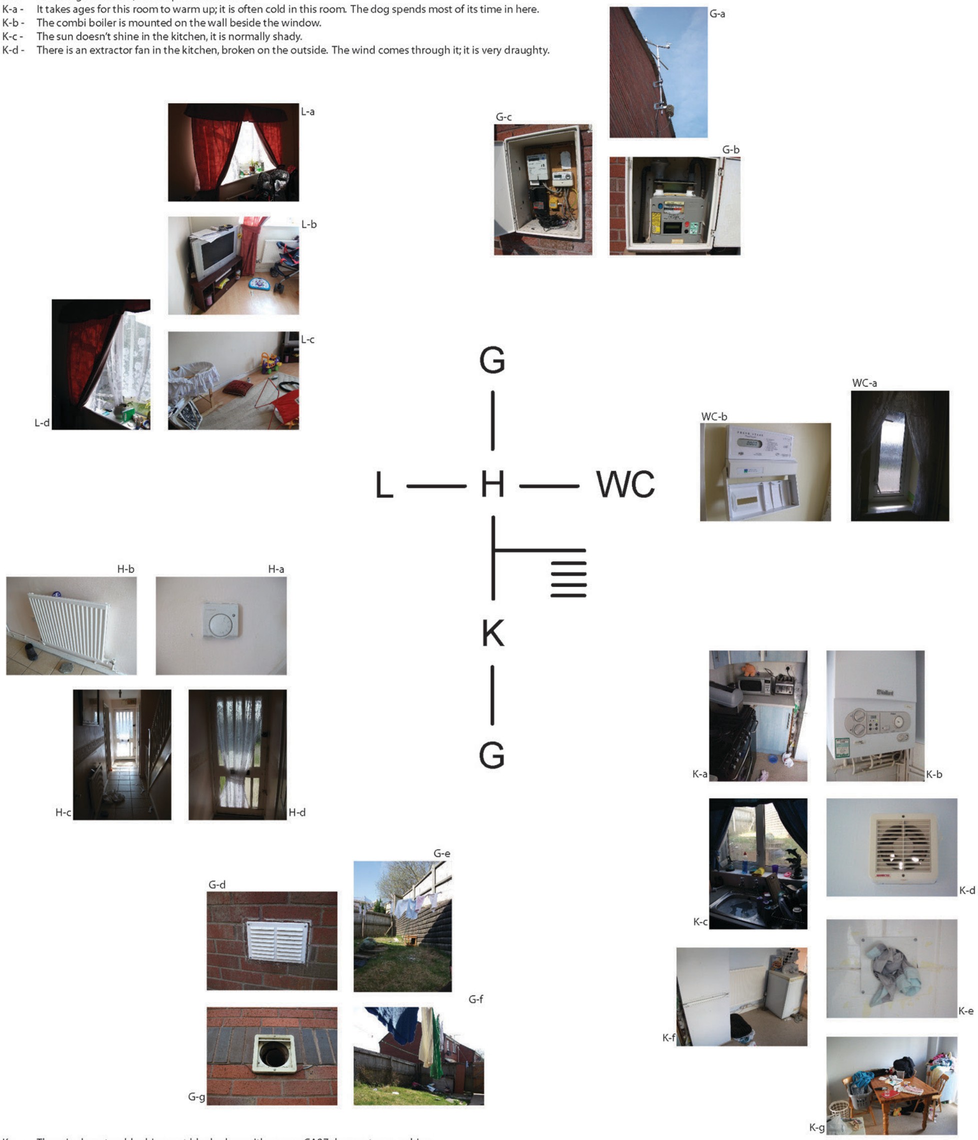


La-a - There is a smoke alarm which has been half taken apart.
This is because when the electricity goes off, it beeps and is irritating.
Ba-a - There is a bamboo roller blind, which is normally kept down for privacy.
Ba-b - Mould in the corner of the room.
Ba-c - There is a vented boxed in area beside the toilet and adjacent to the wall.
Ba-d - There is a strip of ceiling paper or artex hanging down due to a water leak in the loft.
Ba-e - There is a small radiator in this room, on which a lot of towels are jammed.
B2-a - There is one big CRT TV, a stereo, a small portable CRT TV, a computer workstation with an office chair, a double bed.
B2-b - CA06 doesn't want people looking in and seeing what she has got. The bed is broken.
B1-a - There are two smallish sash windows in this room – one of them is painted shut.
B1-b - CA06 likes to lie in bed, with a hot cup of coffee, and watch DVDs, at night with the freestanding light on.
B1-c - CA06 normally keeps all the upstairs curtains closed for privacy and security concerns.
B1-d - Further evidence of water related damage.

AUDIO TOUR

UPSTAIRS LAYOUT AND PHOTOS CA06F 22APR10

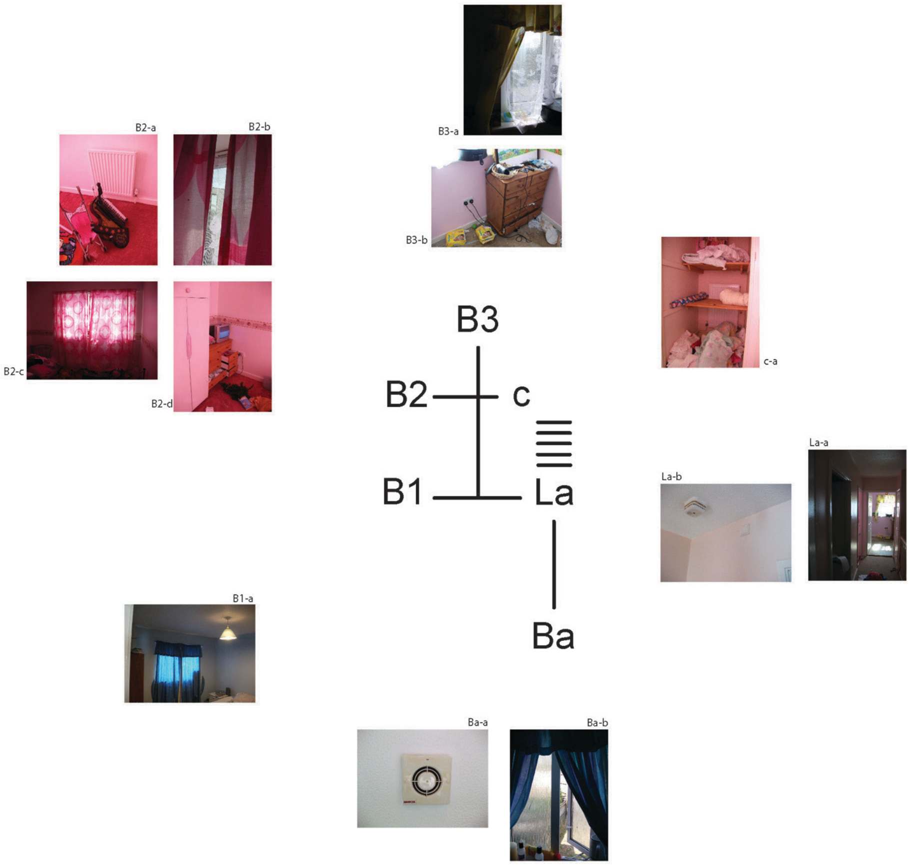
H-a - Close-up of the thermostat at the bottom of the stairs.
H-b - There is a small radiator in the hallway, which has no TRV.
H-c - There is normally a draught from the front door. The draught proofing done by MTHA is ineffective.
H-d - There is a tiled floor. CA07 chose all the decor and the flooring in the house.
L-a - One radiator, below the window at the front, overlooking the front garden and other front gardens in the cul-de-sac.
L-b - CA07 likes to sit in the front room to watch TV (soaps) in the evening.
L-c - Several cushions on floor – the 2 year old takes them off the sofa and puts them on the floor to sit on.
L-d - When it gets too hot, CA07 opens the window.
K-a - It takes ages for this room to warm up; it is often cold in this room. The dog spends most of its time in here.
K-b - The combi boiler is mounted on the wall beside the window.
K-c - The sun doesn't shine in the kitchen, it is normally shady.
K-d - There is an extractor fan in the kitchen, broken on the outside. The wind comes through it; it is very draughty.



K-e - There is also a tumble drier vent blocked up with rags as CA07 does not own a drier.
K-f - A small dog bed was close to the fridge freezer, against the radiator.
K-g - There is a dining table in the room which is often used.
G-a - Temporary weather station installed by Dylan Dixon [CCC]
G-b - Prepay electronic token meter located on the exterior front wall of the property
G-c - Prepay gas meter. Both meter doors are usually left open for convenience.
G-d - Rear of the unused drier vent.
G-e - Wants to create a flat area which will be used for the children's toys and pool etc.
G-f - There are 3 lines for washing; they are normally used if it is sunny.
G-g - Rear of the broken extractor vent.
WC-a - This bathroom is normally used during the day, especially because CA07 is currently potty training the 2 year old.
WC-b - An unused prepay water meter.

AUDIO TOUR

GROUND FLOOR LAYOUT AND PHOTOS CA07F 22APR10

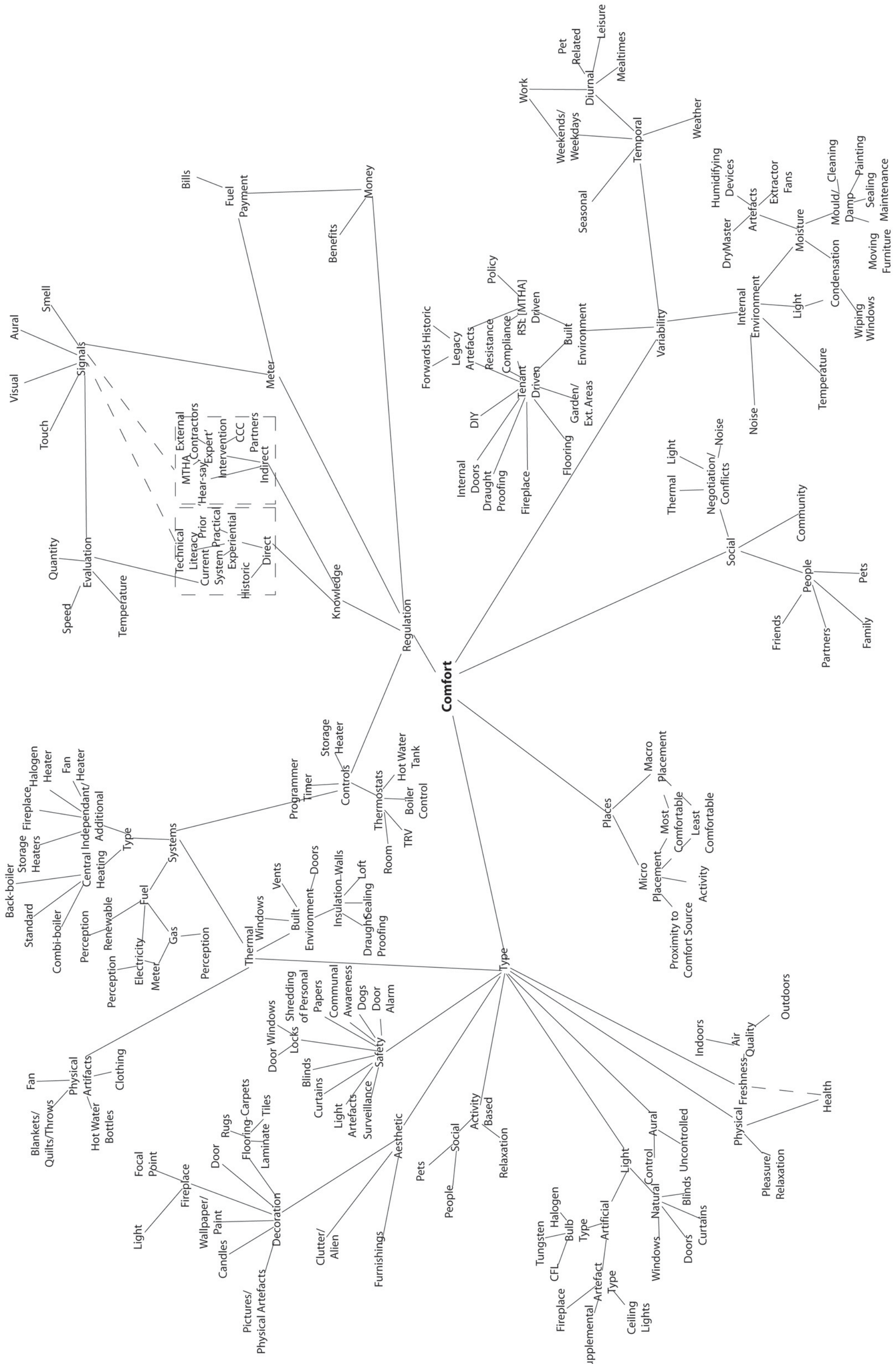


B3-a - This window is usually closed. There are net curtains, and the curtains are normally left open.
B3-b - Currently used as a spare room, for drying hair and doing the ironing. Soon to become baby's room.
c-a - Set up like an airing cupboard, but no hot water tank – instead, a radiator is built in.
La-a - General view across the landing. There is a child gate at the top, also preventing the dog.
La-b - Bathroom extractor fan switch located close to ceiling, which CA07 can easily reach.
Ba-a - One ceiling light, one radiator behind the door, a toilet, a sink and a bath. No shower.
Ba-b - There are curtains, they are sometimes closed. The curtains are normally open.
B2-a - Carpeted – used to be laminate floor when the child was younger.
B2-b - The window is normally open in the warmer weather
B2-c - The curtains are normally closed when the child is watching a video, to keep the sun off the screen.
B2-d - There is a small TV and a video player. These were both left on.
B1-a - The curtains were closed and the light was on – CA07 said she often forgets about the lights upstairs.

AUDIO TOUR

UPSTAIRS LAYOUT AND PHOTOS CA07F 22APR10

Appendix F. Main Study Thematic Map



Appendix G. Insights

Theme	Code	Insight
Primary Heating Systems and Controls	M01	Timers and programmers were not used by any tenants, finding them restrictive, redundant, and wasteful. Tenants preferred to turn on/off the heating when required, often with a stay at home occupant in control. Timers were only used to prevent pipes from freezing during extended away periods.
	M02	The heating was physically turned on/off with either the switch directly on the boiler, or by setting the thermostat. A desire for physical control.
	M03	Control and use of the heating system related to perception of the fuel type and associated costs, as well as (often incorrect) heuristic perceptions of the appliance.
	M04	Despite strong heuristics regards heating systems, there was a general lack of awareness as to the cost of electric appliances left on standby.
	M05	Often the heating was set high to compensate for windows having been left open to circulate ‘fresh’ air.
	M06	One tenant regularly adjusted the hot water temperature dependant on the task.
	M07	The lack of control over the primary heating system can lead to frustration and inefficient practices, such as the use of additional heaters, the opening of windows, or the use of kettles to supplement water temperature.
The Built Environment and the use of Built in Secondary Heating	M08	Draught and ‘problem’ resolution is delegated between the tenant and MTHA, although this is often ‘grey’, or dependent upon the tenants DIY capabilities.
	M09	Changes in the built environment or decorating may affect room usage and routines.
	M10	Faux airing cupboards with radiators are not used for this purpose.
	M11	Unwanted draughts caused by vents, as well as ill-fitting windows, doors and unsealed chimneys are a major contribution to thermal discomfort. In many cases, vents have been blocked or closed.
	M12	The attainment of ‘fresh’ air is equally or more so of importance than thermal comfort, with several observed practices involving the use of opening windows.
	M13	With the airing cupboards in the majority of properties removed, the majority of clothes drying has transferred to radiators and clothes horses, or outdoor washing lines.

Direct Experience	M14	Experiential knowledge built through occupation, such as a builder, was used to evaluate current homes.
	M15	Several tenants showed levels of computer literacy and for some, showed a preference for various human-interface social interactions.
	M16	The few tenants with technical literacy with regards knowledge of building fabric and related technical devices allowed them to carry out minor domestic repairs. Those without the technical knowledge, in a few cases attempted the work anyway, reassured that MTHA would rectify any serious errors.
	M17	Through experiential learning of how the heating system works, tenants plan or control tasks based around the systems performance and limitations, such as how many showers can be attained from a full hot water tank, or washing clothes on a day that tenants have recognised the hot water temperature is higher.
	M18	Several senses are involved in signalling functionality or comfort performance, such as thermostats and boilers that give audible ‘clicks’ when turning on, or tenants only knowing if something is wrong with the heat pump if the home or water temperature changes.
	M19	Some understand what main lights signify (on the boiler) but not all with confidence and do not always know what any warning lights are.
	M20	Tenants evaluated the comfort performance, cost, and control of their current property in comparison to homes they previously had lived.
Indirect Experience	M21	In the case of the sheltered housing complex the development of shared values or communal knowledge as to how to appropriately use the communal facilities was the subject of sustained effort for many residents.
	M22	Judgements and evaluations as to the comfort performance of the house, how to run it efficiently and judgements were often made on the basis of comparisons with what they had heard from friends, neighbours, family members, or locals with the same heating system type.
	M23	Some tenants referred to knowledge of their house or heating that had been imparted by ‘experts’ of various kinds. This was not always agreed with, in several cases causing conflict against the tenant’s opinion.

Additional Artefacts	M24	Throws and blankets form both thermal and aesthetic comfort.
	M25	Sheltered housing tenants with electric storage heaters have to supplement the heat at different times of the day with halogen heaters due to a lack of control over output.
	M26	Clothing can balance out the different thermal comfort preferences between household members.
	M27	Tenants may actively seek to reduce thermal discomfort when too hot using electric fans; in most cases found in the living rooms or bedrooms and used in the warmer weather.
	M28	Particular items of clothing, such as dressing gowns, and quantity of clothing may become routinized or activity dependant.
Room and Heating Control	M29	Most of the households with room thermostats were located in the hallway (with one in the kitchen).
	M30	Many tenants reported the thermostat being set between 15^{o}C and 20^{o}C, although some turned the thermostat to its maximum if they wanted the house to warm up quicker, then returning back to the original setting.
	M31	Several thermostats were believed to be positioned poorly, such as in the kitchen or near to a heat source, resulting in practices where the thermostats being turned higher to compensate.
	M32	Most tenants with gas central heating had TRV's. Those tenants without any form of regulation or control wish that they did.
	M33	Set on different settings in different room's dependant on: how cold the room normally gets; how warm or cold the room feels at any given time; the activity planned for the space; to reflect individual thermal preferences for particular rooms.
	M34	Poorly positioned heat sources reduce heat distribution, in many cases leading to disuse.
Lighting	M35	Sidelights, lamps, and candles were found to be preferred by many of the participants when trying to relax.
	M36	Ceiling lights were perceived to be harsher; suitable for completing tasks.
	M37	Many participants consider fireplaces in the living room as an aesthetic focal point, to provide incidental lighting and not heat.
	M38	Tenants regulate natural light (and the thermal comfort it may provide) through the use of windows, blinds, doors, and curtains.

Cost and Meters	M39	Those houses with a prepayment or credit meter installed for gas and electric interacted regularly with their meters and to monitor energy consumption (in terms of how much money was left on the meter).
	M40	Some tenants routinely checked meters, going to a regular purchase point, and topping up on specific days of the week.
	M41	Some prepayment meters are not ideally situated for physical access.
	M42	The use of meters allowed participants to be aware of the consequences of using more energy intensive appliances.
	M43	Those households, who had direct debit meters, never read their own meters, relying on external meter readers to routinely read their meters and provide them with accurate bills.
	M44	Typically, tenants reported being happy with their energy bills.
	M45	One tenant consciously tries to use less energy for fear of a high energy bill over the recent cold winter period.
	M46	Waiting for a bill can be stressful, affecting energy use.
	M47	Cost factors extend beyond bills, to include the payment of consumables such as light bulbs.
	M48	Several tenants found low energy light bulbs prohibitive due to their aesthetics, or to the cost associated with sourcing more aesthetically suitable replacements.
	M49	One tenant believed that the cost of energy is irrelevant as it is a necessity, and therefore doesn't worry about how much is used.
	M50	During the winter, most tenants received a payment for fuel from their energy providers, which had been positively received and covered the majority of bills.
Health	M51	Certain ailments restrict certain activities or interactions, such as reaching certain parts of the house, having access to the boiler, particular pets are no longer tenable, and some ailments require special care or management.
	M52	Ill health can generate specific routines.
	M53	Thermal comfort artefacts may also be health related (e.g. use of hot water bottle to provide localised heat on pain source, or the use of a blanket or clothing layers to compensate for the body temperature lowering effects of medication).

General Perceptions of Comfort	M54	Sound can affect comfort. Tenants showed that noise that they controlled, such as leaving a TV on when going to sleep, increases comfort.
	M55	The living room was described as the most comfortable space in the home (5/7), along with the main bedroom (1/7) and kitchen (1/7).
	M56	The definition of a comfortable space by the tenants not only includes thermal parameters, but also is dependent on activity.
	M57	The kitchen was described as the least comfortable space (3/7), along with the bathroom (2/7), living room (1/7), and upstairs (1/7).
	M58	The definition of a least comfortable space tended to focus on poor thermal comfort and poor decoration.
	M59	Tenants tend to relax in either the living room, in a chair or settee, or in bed, in the bedroom.
	M60	Leisure activities tend to be sedentary, such as watching TV or DVDs, playing games, using the computer, drinking, or reading.
	M61	Tenants tended to locate themselves within a room according to proximity to a source of comfort or discomfort, or in combination with an activity.
	M62	Noise out of the tenant's control, such as loud music from another household member or the constant sound of the heat pump, have a negative comfort impact.
'Theories' of How Things Work	M63	One tenant believed that by running the home at a constant temperature, the amount of energy used would be less.
	M64	One tenant reported turning down radiators either down or off in order to prevent their 'taking heat from elsewhere in the house.
	M65	One tenant believed that loft insulation is inadequate to retain heat with the house without additional insulation between the rafters.
	M66	Several differing theories about how to maintain the 'right' kind of internal environment, for reasons including but not restricted to health.
	M67	Differing routines and preferences with regards humidity control (especially relating to the control of mould growth, and in one case, to aide sinuses).

The Home and Social Visitors	M68	Tenants who spend a lot of time at home due to ill health, family responsibilities towards children or unemployment, tended to have 'open door' polices where neighbours and friends would pop in unannounced.
	M69	Some tenants preferred to minimise socialisation in the home, perceiving the home to be a personal space, a private domain.
	M70	The activities of visitors may dictate room usage, such as using the kitchen as the main place to socialise, due to the routinized practice of smoking in the kitchen with the windows open.
	M71	The sheltered housing scheme tenant had access to communal facilities, designed to encourage social interaction.
Multiple Occupancy	M72	Different members of the same household may have dissimilar perceptions and expectations of thermal comfort. In some cases, this has resulted in the altering of the heating system (TRV's, main home thermostat, boiler control) to suit individual needs, often without consultation or awareness by other household members.
	M73	Homes with multiple occupancy based on age tended to have their own specific room to engage in comfort activities, with other rooms serving more communal functions.
Safety and Security	M74	Security devices not only provide physical comfort, but also mental comfort.
	M75	A strong local community reduces security fears.
	M76	Age can affect security action, such as the use of a night light for a child.
	M77	The tenant's perception of safety may be different to the MTHA's legal responsibilities, leading to negative experiences.
	M78	Regulatory devices such as blinds are also used to regulate security.
Pets	M79	Social interaction with pets for some of the participants was integral to their experiences and practices of comfort.
	M80	Pets in some instances were removed from the home due to the physical damage that they cause, or the detrimental health to the occupants.
	M81	Pets (and children) have specific access to parts of the home, with regulatory devices, such as child gates, to prevent unauthorised entry.

Aesthetics	M82	Decorating, for many of the tenants, is an important way of attaining a comfortable domestic environment.
	M83	Evidence of selecting physical objects based on a combination of aesthetic characteristics and physical function.
	M84	Decorating may be used as an alternative to restricted (by MTHA) physical alterations.
	M85	The cyclic programme of refurbishment and improvement by MTHA has led to several tenants unwilling to pay to improve articles they believe may be replaced for free in time.
	M86	Many participants consider fireplaces in the living room as an aesthetic focal point, to provide incidental lighting and not heat.
	M87	Physical artefacts such as candles and curtains are objects of aesthetic desire, and not often used in a thermal capacity.
	M88	The transient nature of social housing can lead to a desire to ‘clutter’, to surround oneself with familiar items to create comfort.
	M89	Surrounding oneself with items belonging to a non-household member can negatively affect comfort.

Appendix H. Opportunity Statements

Insight Group	**Opportunity Statement(s)**
High Priority M08. Draught and 'problem' resolution is delegated between the tenant and MTHA, although this is often 'grey', or dependent upon the tenants DIY capabilities. M11. Unwanted draughts caused by vents, as well as ill-fitting windows, doors and unsealed chimneys are a major contribution to thermal discomfort. In many cases, vents have been blocked or closed. M16. The few tenants with technical literacy with regards knowledge of building fabric and related technical devices allowed them to carry out minor domestic repairs. Those without the technical knowledge, in a few cases attempted the work anyway, reassured that MTHA would rectify any serious errors. M27. Tenants may actively seek to reduce thermal discomfort when too hot using electric fans; in most cases found in the living rooms or bedrooms and used in the warmer weather. M70. The activities of visitors may dictate room usage, such as using the kitchen as the main place to socialise, due to the routinized practice of smoking in the kitchen with the windows open.	How might we... ...change the nature of draughts into a more accepted form (from piercing stream to large air movement)? ...better enable technically illiterate tenants to conduct their own appropriate DIY? ...help the tenants to locate draught sources? ...control air quality without negatively affecting thermal desirability? ...better distinguish to the tenant required draughts (vents) and non-required draughts? ...prevent tenant abuse of required vents? ...improve the tenant's acceptation of required vents? ...control domestic air quality without creating air flow? ...provide less energy intensive air movement (fans)? ...provide better control of vents? ...link controlled and uncontrolled air flows?
High Priority M05. Often the heating was set high to compensate for windows having been left open to circulate 'fresh' air. M12. The attainment of 'fresh' air is equally or more so of importance than thermal	How might we... ...display/link health to 'open window' action (e.g. health to air quality or temperature)? ...alter expectations of the effects from opening windows? ...integrate air movement and temperature with

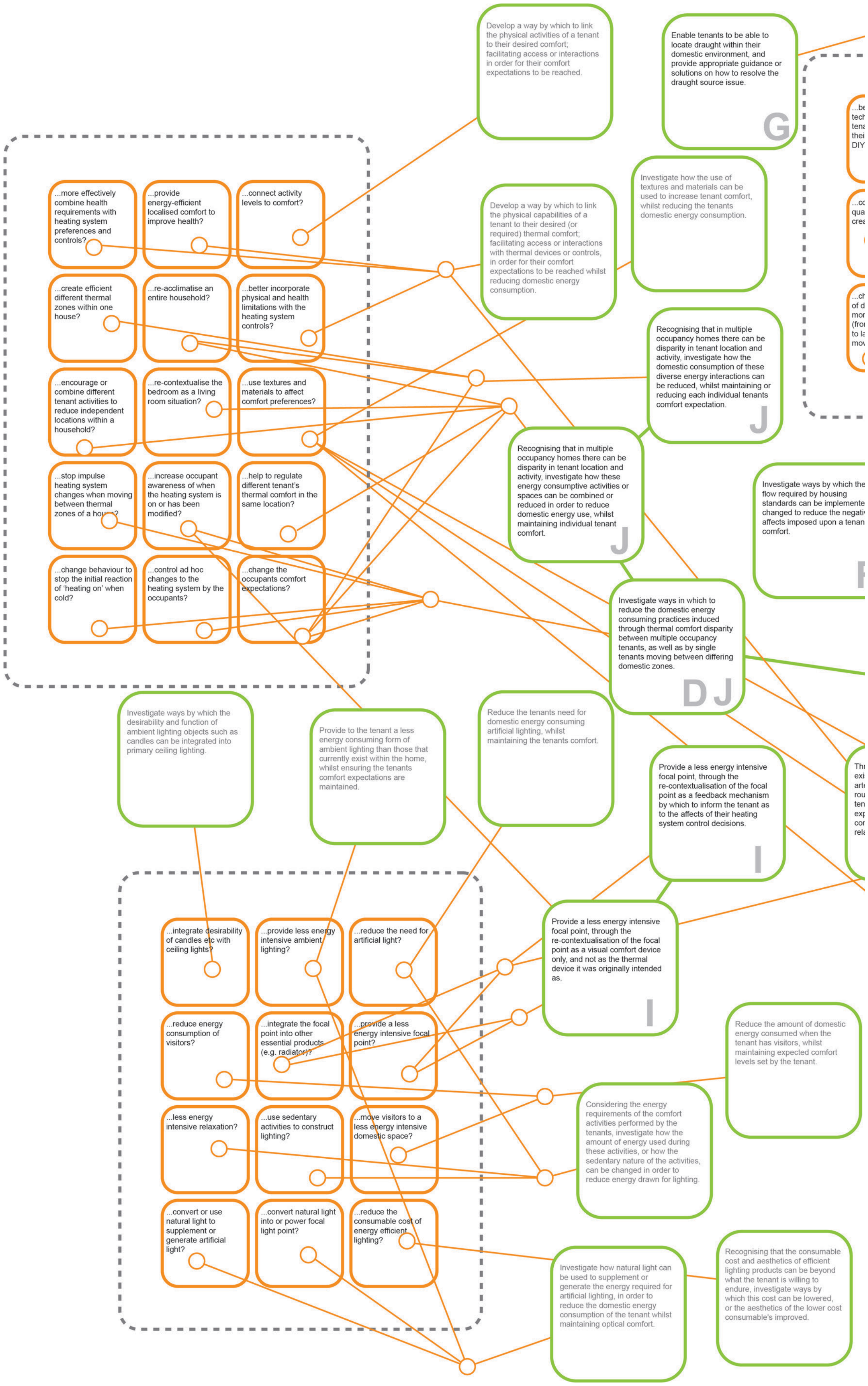
comfort, with several observed practices involving the use of opening windows. M67. Differing routines and preferences with regards humidity control (especially relating to the control of mould growth, and in one case, to aide sinuses).	a physical action (e.g. housework)? ...provide fresh air without opening windows? ...control humidity/mould without opening windows? ...make apparent the link between window use and energy? ...display to the tenant comparisons between the use of windows and alternatives (e.g. fans)? ...reduce or quantify to the tenants the 'actual' need for fresh air? ...stop the tenant from going from one extreme (open windows) to other extreme (heating on)? ...control the balance of indoor and outdoor temperatures? ...control the air flow across the entire house? ...create a modern day barometer?
High Priority M35. Sidelights, lamps, and candles were found to be preferred by many of the participants when trying to relax. M36. Ceiling lights were perceived to be harsher; suitable for completing tasks. M37. Many participants consider fireplaces in the living room as an aesthetic focal point, to provide incidental lighting and not heat. M48. Several tenants found low energy light bulbs prohibitive due to their aesthetics, or to the cost associated with sourcing more aesthetically suitable replacements. M86. Many participants consider fireplaces in the living room as an aesthetic focal point, to provide incidental lighting and not heat.	How might we... ...provide a less energy intensive focal point? ...integrate the focal point into other essential products (e.g. radiator)? ...provide less energy intensive ambience lighting? ...integrate desirability of candles etc. with ceiling lights? ...move visitors to a less energy intensive domestic space? ...use sedentary activities to construct lighting? ...convert natural light into or power focal light point? ...less energy intensive relaxation? ...reduce the need for artificial light? ...reduce energy consumption of visitors? ...reduce the consumable cost of en efficient lighting? ...convert or use natural light to supplement or generate artificial light?
High Priority M01. Timers and programmers were not	How might we... ...facilitate better understanding of room control

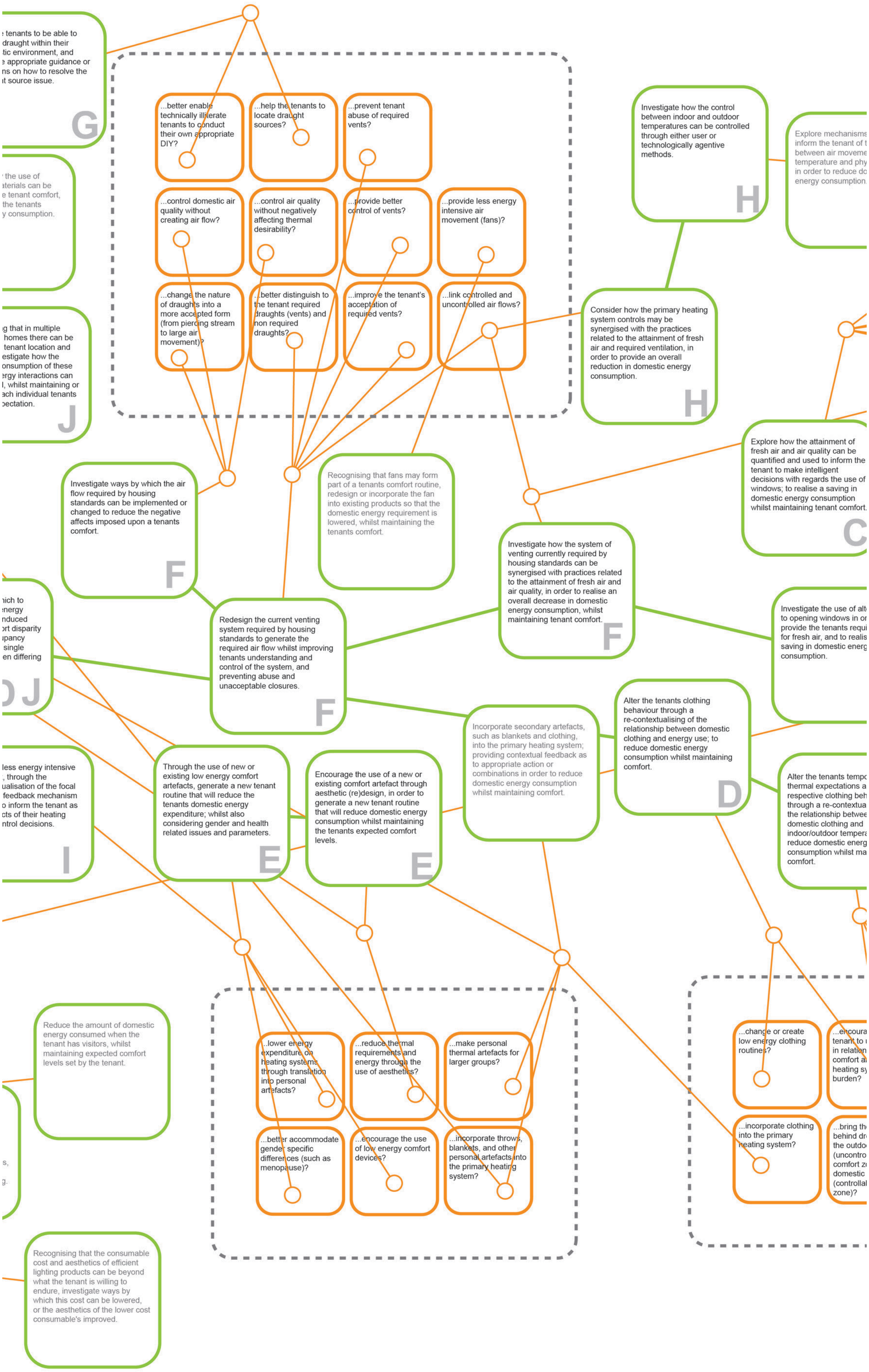
used by any tenants, finding them restrictive, redundant, and wasteful. Tenants preferred to turn on/off the heating when required, often with a stay at home occupant in control. Timers were only used to prevent pipes from freezing during extended away periods. M02. The heating was physically turned on/off with either the switch directly on the boiler, or by setting the thermostat. M07. The lack of control over the primary heating system can lead to frustration and inefficient practices, such as the use of additional heaters, the opening of windows, or the use of kettles to supplement water temperature. M32. Most tenants with gas central heating had TRV's. Those tenants without any form of regulation or control wish that they did.	systems? ...simplify the control of room temperature? ...provide temperature control in a room without TRV's? ...change perceptions to accept lack of control? ...facilitate better understanding of system controls? ...simplify the control of the heating system? ...remind users as to how the system operates (controls)? ...improve user confidence in technology in general? ...facilitate experiential learning?
High Priority M33. Set on different settings in different room's dependant on: how cold the room normally gets; how warm or cold the room feels at any given time; the activity planned for the space; to reflect individual thermal preferences for particular rooms. M51.Certain ailments restrict certain activities or interactions, such as reaching certain parts of the house, having access to the boiler, particular pets are no longer tenable, and some ailments require special care or management. M52. Ill health can generate specific routines. M72. Different members of the same household may have dissimilar perceptions and expectations of thermal comfort. In some cases, this	How might we... ...change the occupants comfort expectations? ...help to regulate different tenant's thermal comfort in the same location? ...connect activity levels to comfort? ...re-acclimatise an entire household? ...encourage or combine different tenant activities to reduce independent locations within a household? ...stop impulse heating system changes when moving between thermal zones of a house? ...change behaviour to stop the initial reaction of 'heating on' when cold? ...use textures and materials to affect comfort preferences? ...re-contextualise the bedroom as a living room situation? ...control ad hoc changes to the heating system by the occupants?

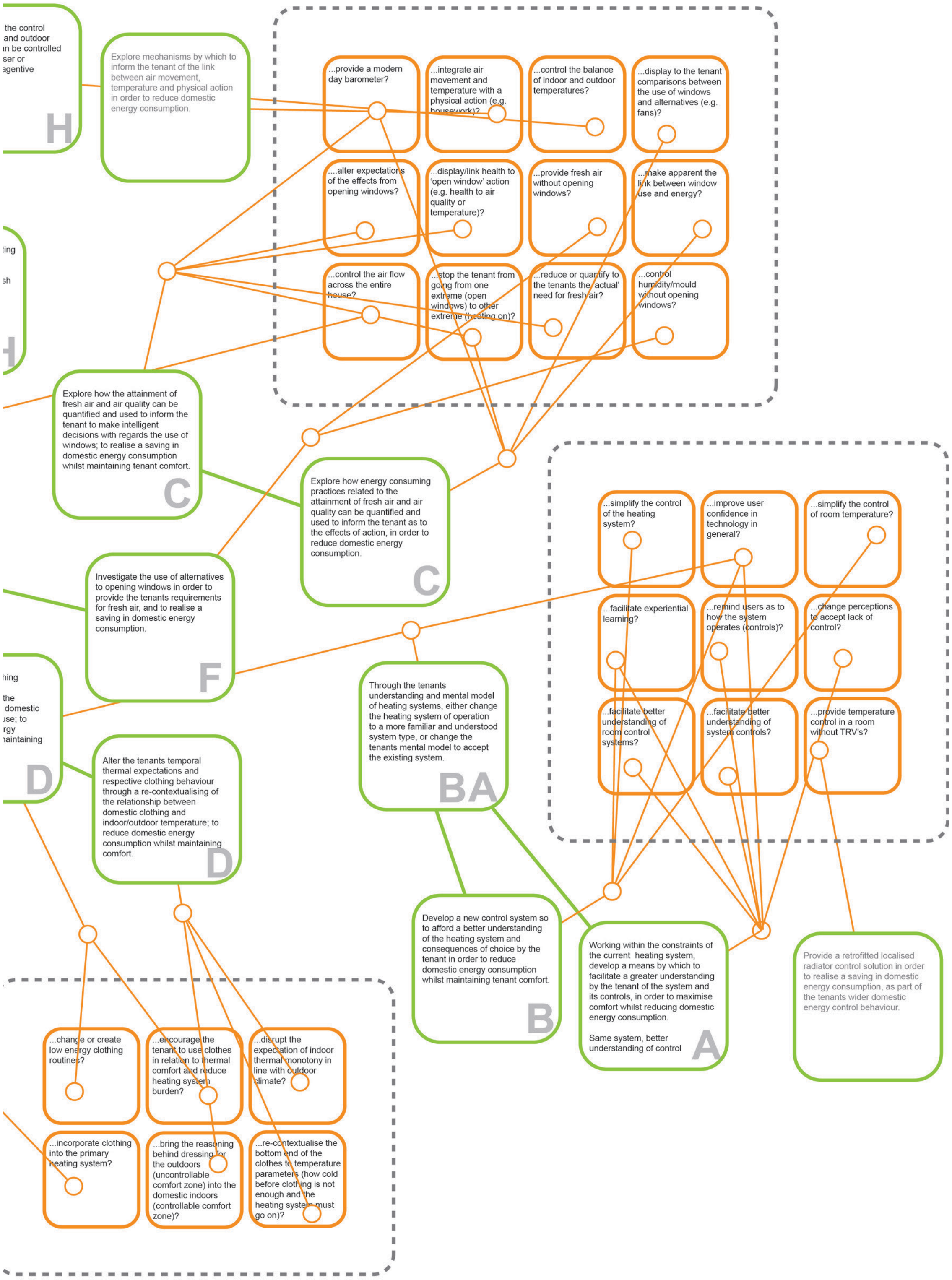
has resulted in the altering of the heating system (TRV's, main home thermostat, boiler control) to suit individual needs, often without consultation or awareness by other household members. M73. Homes with multiple occupancy based on age tended to have their own specific room to engage in comfort activities, with other rooms serving more communal functions.	...create efficient different thermal zones within one house? ...increase occupant awareness of when the heating system is on or has been modified? ...more effectively combine health requirements with heating system preferences and controls? ...better incorporate physical and health limitations with the heating system controls? ...provide energy-efficient localised comfort to improve health?
Medium Priority M24. Throws and blankets form both thermal and aesthetic comfort. M53. Thermal comfort artefacts may also be health related (e.g. use of hot water bottle to provide localised heat on pain source, or the use of a blanket or clothing layers to compensate for the body temperature lowering effects of medication).	How might we... ...incorporate throws, blankets, and other personal artefacts into the primary heating system? ...make personal thermal artefacts for larger groups? ...lower energy expenditure on heating systems through translation into personal artefacts? ...reduce thermal requirements and energy through the use of aesthetics? ...encourage the use of low energy comfort devices? ...better accommodate gender specific differences (such as menopause)?
Medium Priority M26. Clothing can balance out the different thermal comfort preferences between household members. M28. Particular items of clothing, such as dressing gowns, and quantity of clothing may become routinized or activity dependant.	How might we... ...encourage the tenant to use clothes in relation to thermal comfort and reduce heating system burden? ...incorporate clothing into the primary heating system? ...bring the reasoning behind dressing for the outdoors (uncontrollable comfort zone) into the domestic indoors (controllable comfort zone)? ...disrupt the expectation of indoor thermal monotony in line with outdoor climate? ...change or create low energy clothing routines? ...re-contextualise the bottom end of the clothes to temperature parameters (how cold

	before clothing is not enough and the heating system must go on)?

Appendix I. Opportunity Consolidation Diagram

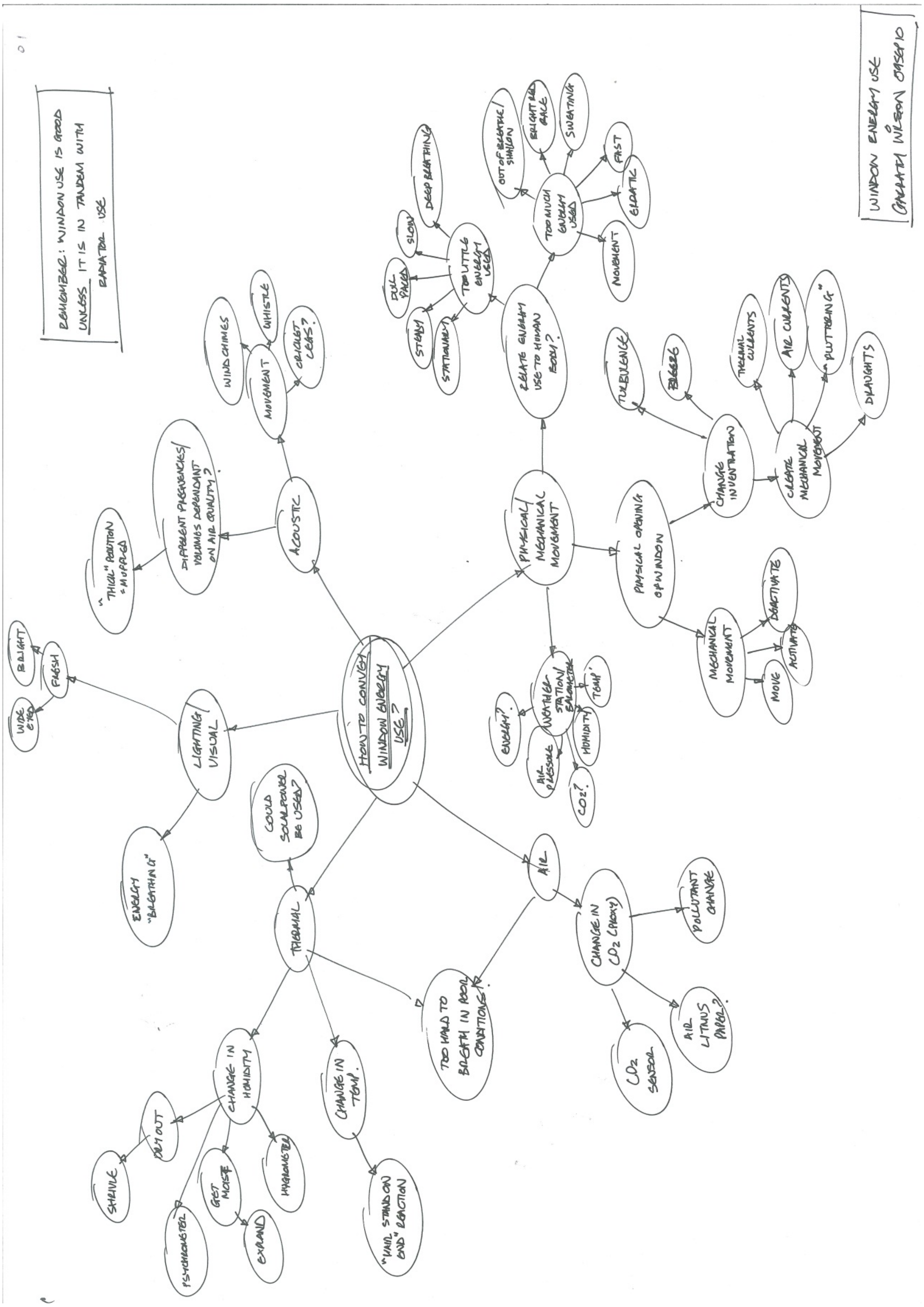


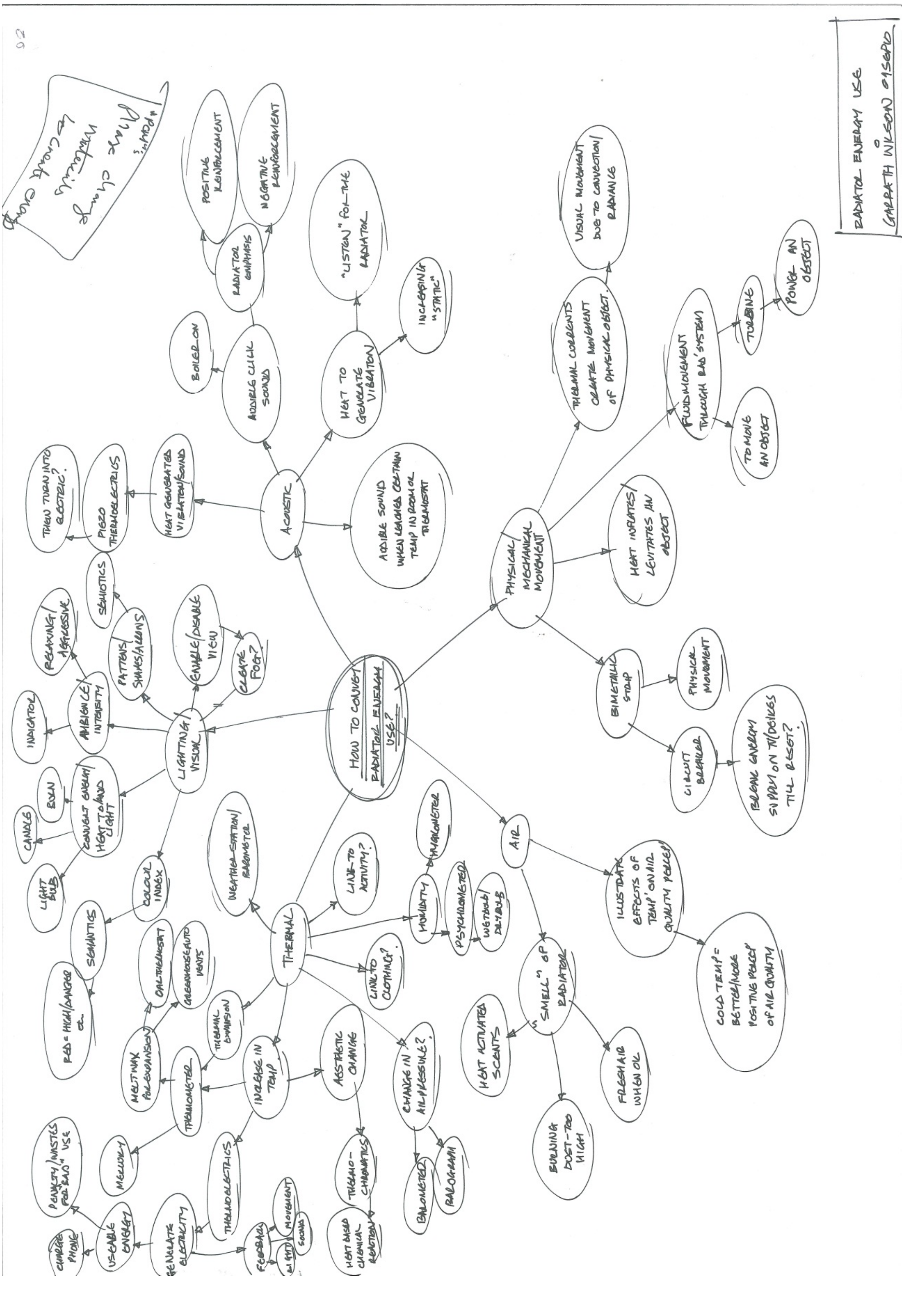

...better enable technically illiterate tenants to conduct their own appropriate DIY?
...help the tenants to locate draught sources?
...prevent tenant abuse of required vents?
...control domestic air quality without creating air flow?
...control air quality without negatively affecting thermal desirability?
...provide better control of vents?
...provide less energy intensive air movement (fans)?
...change the nature of draughts into a more accepted form (from piercing stream to large air movement)?
...better distinguish to the tenant required draughts (vents) and non required draughts?
...improve the tenant's acceptation of required vents?
...link controlled and uncontrolled air flows?
G
Investigate how the control between indoor and outdoor temperatures can be controlled through either user or technologically agentive methods.
H
Consider how the primary heating system controls may be synergised with the practices related to the attainment of fresh air and required ventilation, in order to provide an overall reduction in domestic energy consumption.
H
Explore how the attainment of fresh air and air quality can be quantified and used to inform the tenant to make intelligent decisions with regards the use of windows; to realise a saving in domestic energy consumption whilst maintaining tenant comfort.
C
J
Investigate ways by which the air flow required by housing standards can be implemented or changed to reduce the negative affects imposed upon a tenants comfort.
F
Recognising that fans may form part of a tenants comfort routine, redesign or incorporate the fan into existing products so that the domestic energy requirement is lowered, whilst maintaining the tenants comfort.
Investigate how the system of venting currently required by housing standards can be synergised with practices related to the attainment of fresh air and air quality, in order to realise an overall decrease in domestic energy consumption, whilst maintaining tenant comfort.
F
Redesign the current venting system required by housing standards to generate the required air flow whilst improving tenants understanding and control of the system, and preventing abuse and unacceptable closures.
F
J
Alter the tenants clothing behaviour through a re-contextualising of the relationship between domestic clothing and energy use; to reduce domestic energy consumption whilst maintaining comfort.
D
Incorporate secondary artefacts, such as blankets and clothing, into the primary heating system; providing contextual feedback as to appropriate action or combinations in order to reduce domestic energy consumption whilst maintaining comfort.
Through the use of new or existing low energy comfort artefacts, generate a new tenant routine that will reduce the tenants domestic energy expenditure; whilst also considering gender and health related issues and parameters.
E
Encourage the use of a new or existing comfort artefact through aesthetic (re)design, in order to generate a new tenant routine that will reduce domestic energy consumption whilst maintaining the tenants expected comfort levels.
E
I
Reduce the amount of domestic energy consumed when the tenant has visitors, whilst maintaining expected comfort levels set by the tenant.
...lower energy expenditure on heating systems through translation into personal artefacts?
...reduce thermal requirements and energy through the use of aesthetics?
...make personal thermal artefacts for larger groups?
...better accommodate gender specific differences (such as menopause)?
...encourage the use of low energy comfort devices?
...incorporate throws, blankets, and other personal artefacts into the primary heating system?
...change or create low energy clothing routines?
...incorporate clothing into the primary heating system?
Recognising that the consumable cost and aesthetics of efficient lighting products can be beyond what the tenant is willing to endure, investigate ways by which this cost can be lowered, or the aesthetics of the lower cost consumable's improved.



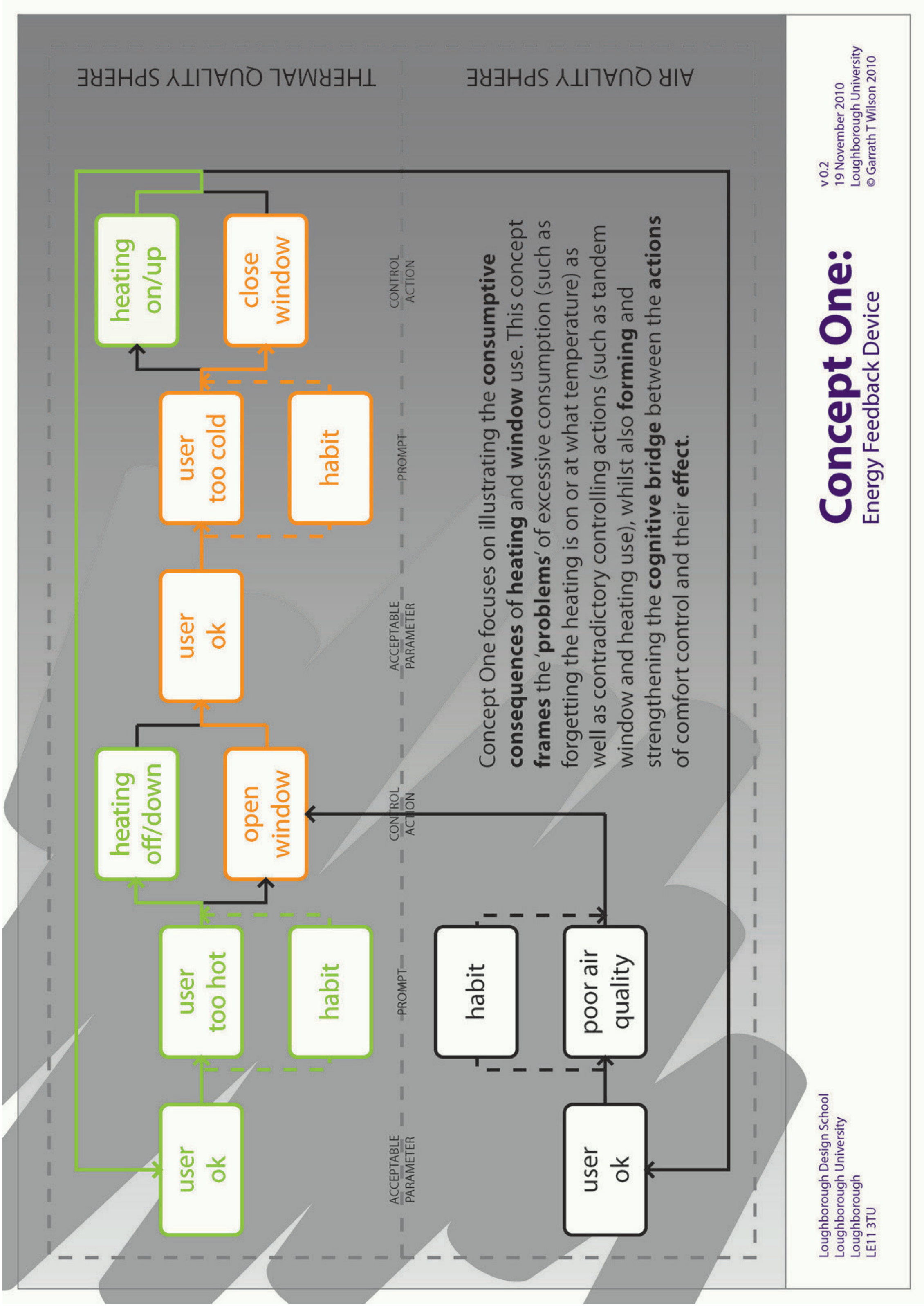
the control
and outdoor
an be controlled
ser or
agentive
H
Explore mechanisms by which to inform the tenant of the link between air movement, temperature and physical action in order to reduce domestic energy consumption.
...provide a modern day barometer?
...integrate air movement and temperature with a physical action (e.g. housework)?
...control the balance of indoor and outdoor temperatures?
...display to the tenant comparisons between the use of windows and alternatives (e.g. fans)?
...alter expectations of the effects from opening windows?
...display/link health to 'open window' action (e.g. health to air quality or temperature)?
...provide fresh air without opening windows?
...make apparent the link between window use and energy?
...control the air flow across the entire house?
...stop the tenant from going from one extreme (open windows) to other extreme (heating on)?
...reduce or quantify to the tenants the 'actual' need for fresh air?
...control humidity/mould without opening windows?
Explore how the attainment of fresh air and air quality can be quantified and used to inform the tenant to make intelligent decisions with regards the use of windows; to realise a saving in domestic energy consumption whilst maintaining tenant comfort.
C
Explore how energy consuming practices related to the attainment of fresh air and air quality can be quantified and used to inform the tenant as to the effects of action, in order to reduce domestic energy consumption.
C
Investigate the use of alternatives to opening windows in order to provide the tenants requirements for fresh air, and to realise a saving in domestic energy consumption.
F
...simplify the control of the heating system?
...improve user confidence in technology in general?
...simplify the control of room temperature?
...facilitate experiential learning?
...remind users as to how the system operates (controls)?
...change perceptions to accept lack of control?
...facilitate better understanding of room control systems?
...facilitate better understanding of system controls?
...provide temperature control in a room without TRV's?
Through the tenants understanding and mental model of heating systems, either change the heating system of operation to a more familiar and understood system type, or change the tenants mental model to accept the existing system.
BA
Alter the tenants temporal thermal expectations and respective clothing behaviour through a re-contextualising of the relationship between domestic clothing and indoor/outdoor temperature; to reduce domestic energy consumption whilst maintaining comfort.
D
D
Develop a new control system so to afford a better understanding of the heating system and consequences of choice by the tenant in order to reduce domestic energy consumption whilst maintaining tenant comfort.
B
Working within the constraints of the current heating system, develop a means by which to facilitate a greater understanding by the tenant of the system and its controls, in order to maximise comfort whilst reducing domestic energy consumption.
Same system, better understanding of control
A
Provide a retrofitted localised radiator control solution in order to realise a saving in domestic energy consumption, as part of the tenants wider domestic energy control behaviour.
...change or create low energy clothing routines?
...encourage the tenant to use clothes in relation to thermal comfort and reduce heating system burden?
...disrupt the expectation of indoor thermal monotony in line with outdoor climate?
...incorporate clothing into the primary heating system?
...bring the reasoning behind dressing for the outdoors (uncontrollable comfort zone) into the domestic indoors (controllable comfort zone)?
...re-contextualise the bottom end of the clothes to temperature parameters (how cold before clothing is not enough and the heating system must go on)?

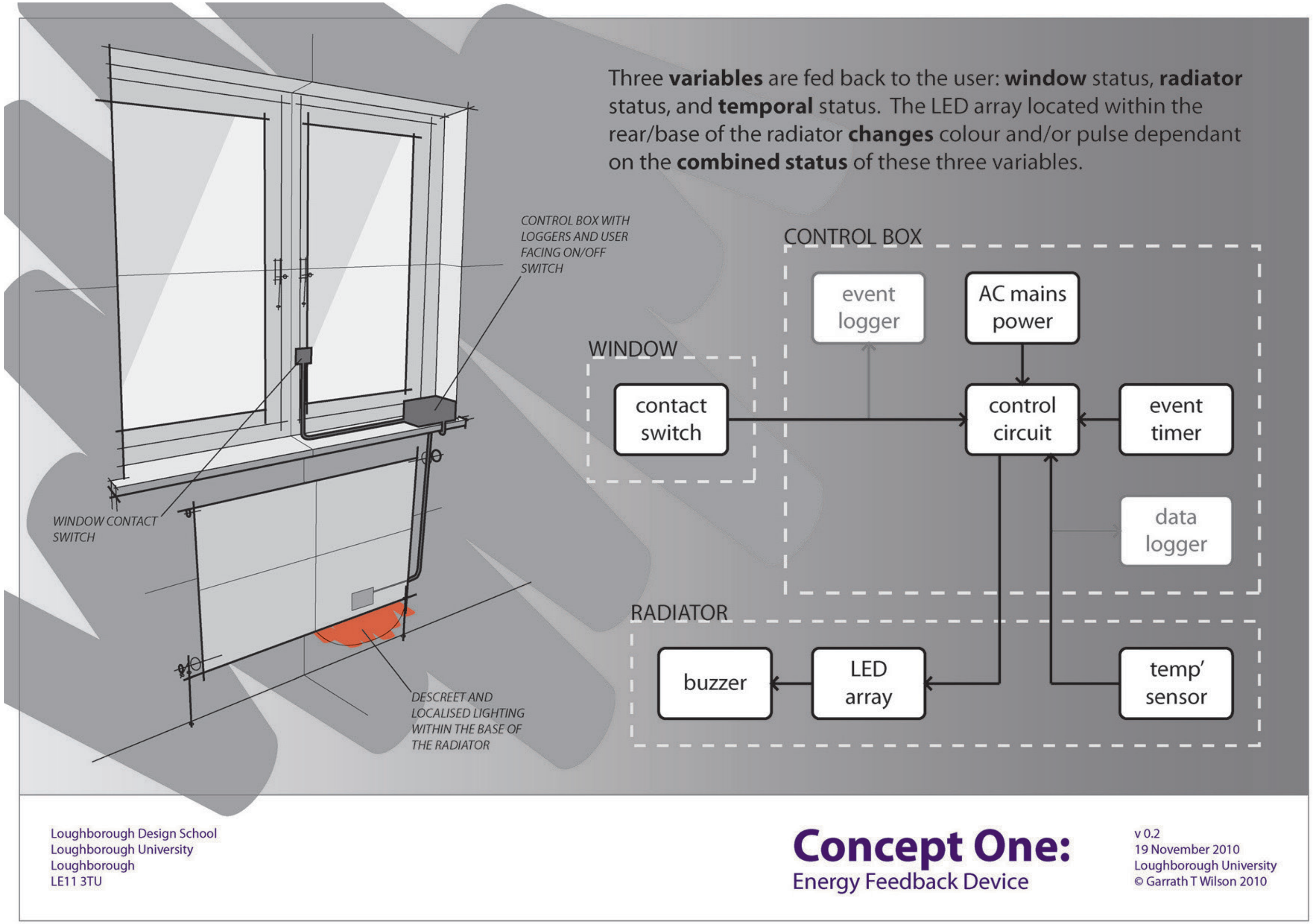
Appendix J. Initial Brainstorming Activity

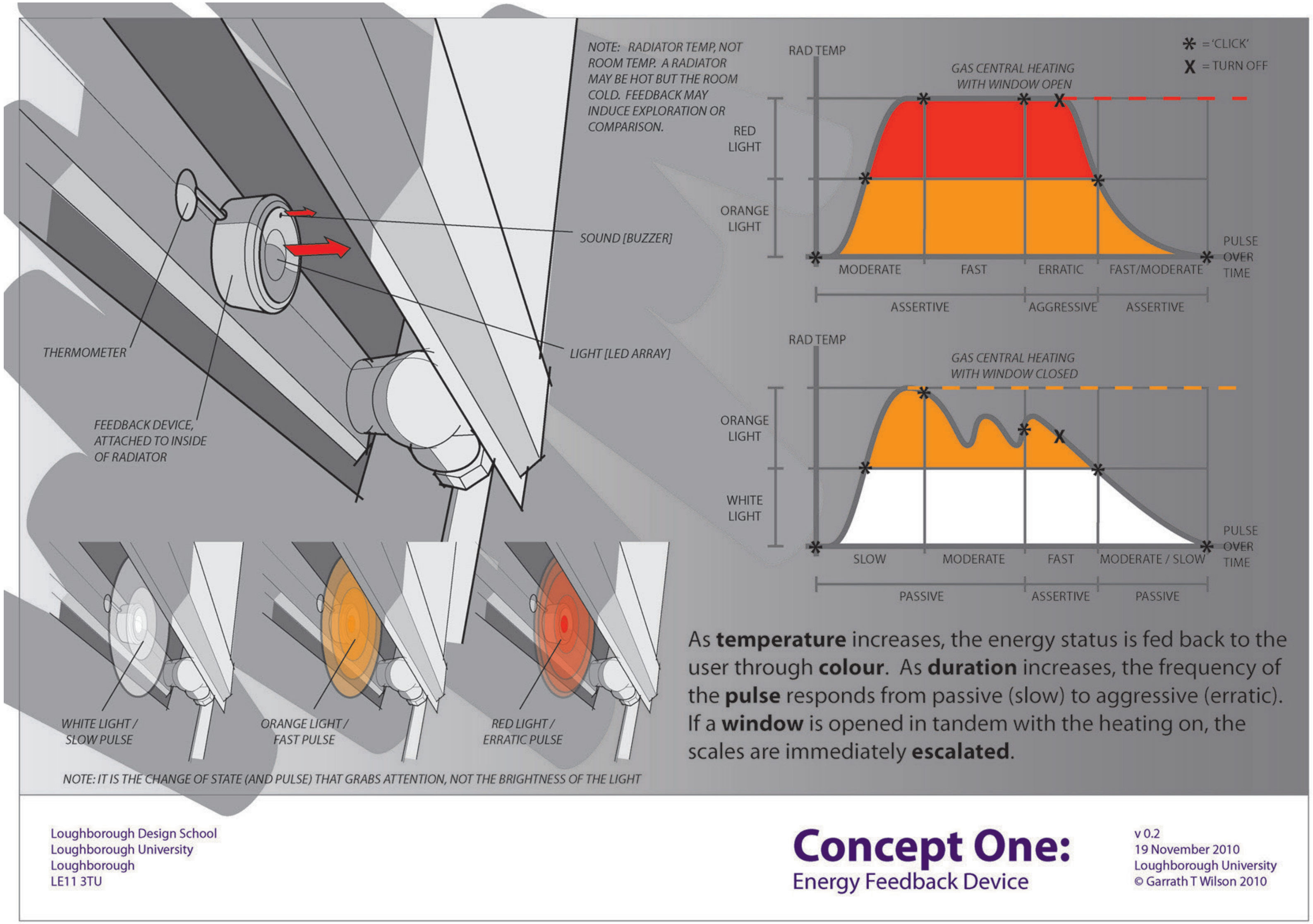


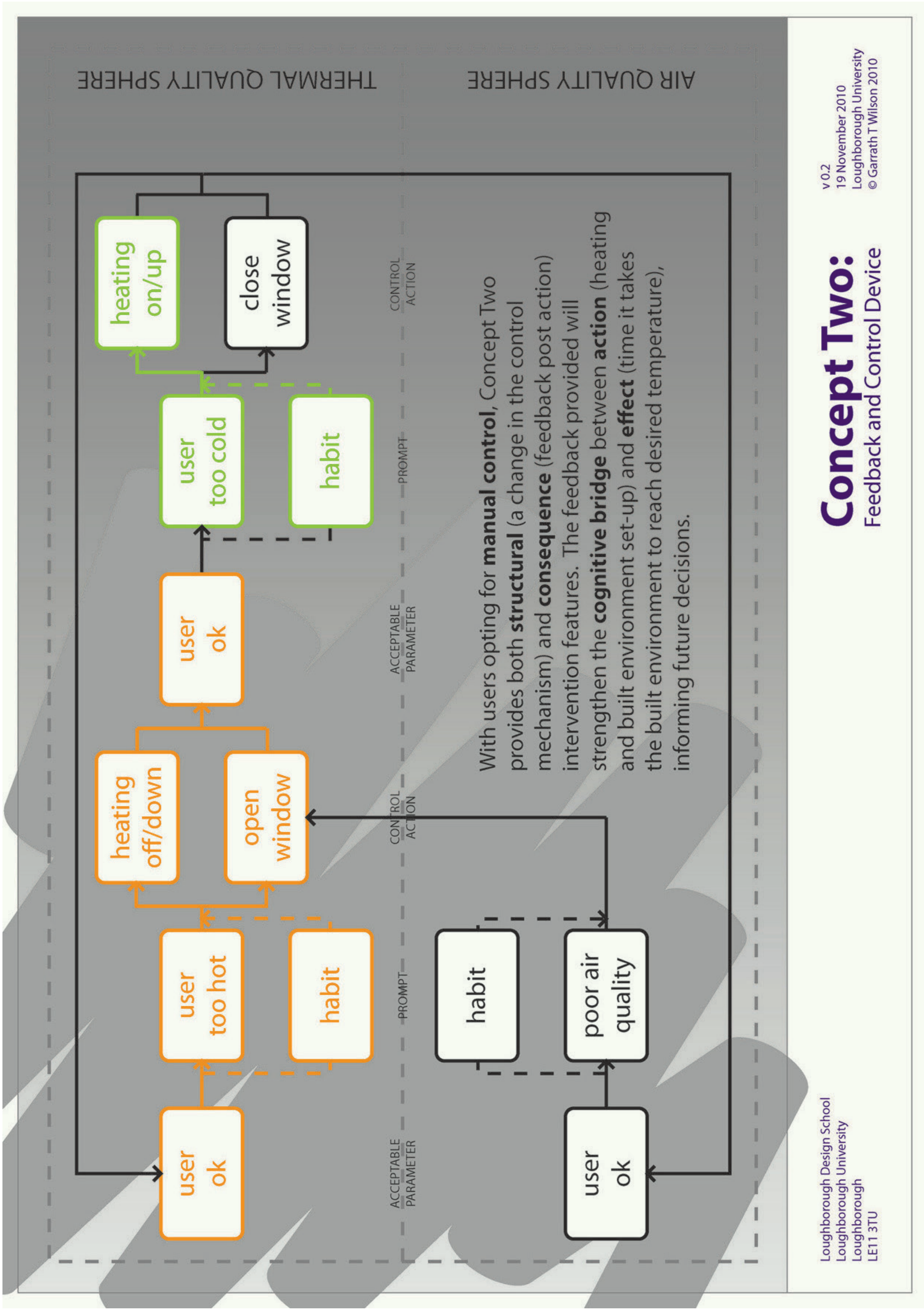

RADIATOR ENERGY USE
HOW TO CONVEY RADIATOR ENERGY USE?
ACOUSTIC
LIGHTING/ VISUAL
THERMAL
AIR
PHYSICAL/ MECHANICAL MOVEMENT
THERMOMETER
BAROMETER
BAROGRAPH
HUMIDITY
PSYCHROMETER
BIMETALLIC STRIP
CIRCUIT BREAKER
TURBINE
POWER AN OBJECT
TO MOVE AN OBJECT
SEMANTICS
SEMIOTICS
COLOUR INDEX
LIGHT BULB
CANDLE
INDICATOR
THERMOELECTRICS
GENERATE ELECTRICITY
USEABLE ENERGY
CHARGE PHONE
MELODY
AESTHETIC CHANGE
INCREASE IN TEMP
LINK TO CLOTHING?
LINK TO ACTIVITY?
"LISTEN" FOR THE RADIATOR
BOILER ON
POSITIVE REINFORCEMENT
NEGATIVE REINFORCEMENT
HEAT ACTIVATED SCENTS
FRESH AIR WHEN OK

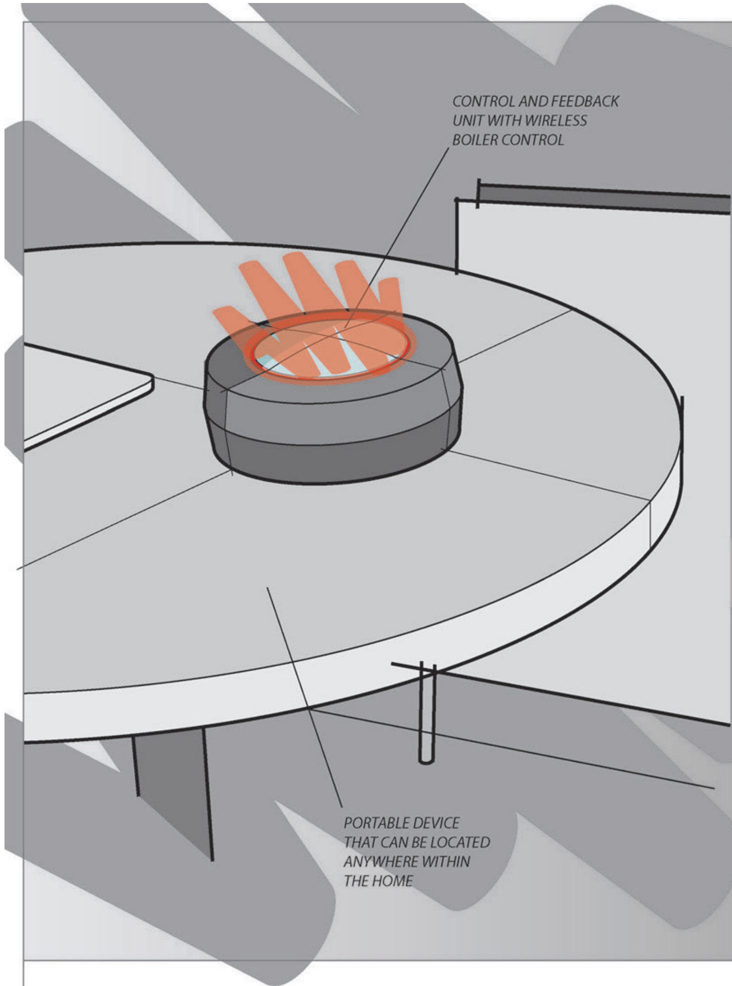
Appendix K. Advanced Concepts



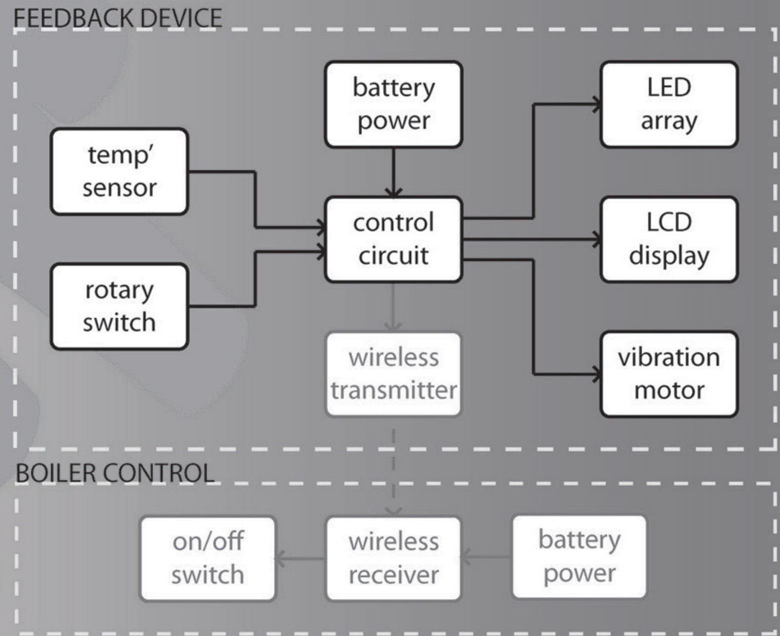

Three **variables** are fed back to the user: **window** status, **radiator** status, and **temporal** status. The LED array located within the rear/base of the radiator **changes** colour and/or pulse dependant on the **combined status** of these three variables.
CONTROL BOX WITH LOGGERS AND USER FACING ON/OFF SWITCH
WINDOW CONTACT SWITCH
DESCREET AND LOCALISED LIGHTING WITHIN THE BASE OF THE RADIATOR
CONTROL BOX
event logger
AC mains power
control circuit
event timer
data logger
WINDOW
contact switch
RADIATOR
buzzer
LED array
temp' sensor
Loughborough Design School
Loughborough University
Loughborough
LE11 3TU
Concept One:
Energy Feedback Device
v 0.2
19 November 2010
Loughborough University
© Garrath T Wilson 2010


NOTE: RADIATOR TEMP, NOT ROOM TEMP. A RADIATOR MAY BE HOT BUT THE ROOM COLD. FEEDBACK MAY INDUCE EXPLORATION OR COMPARISON.
SOUND [BUZZER]
LIGHT [LED ARRAY]
THERMOMETER
FEEDBACK DEVICE, ATTACHED TO INSIDE OF RADIATOR
WHITE LIGHT / SLOW PULSE
ORANGE LIGHT / FAST PULSE
RED LIGHT / ERRATIC PULSE
NOTE: IT IS THE CHANGE OF STATE (AND PULSE) THAT GRABS ATTENTION, NOT THE BRIGHTNESS OF THE LIGHT
* = 'CLICK'
X = TURN OFF
RAD TEMP
GAS CENTRAL HEATING WITH WINDOW OPEN
RED LIGHT
ORANGE LIGHT
MODERATE
FAST
ERRATIC
FAST/MODERATE
PULSE OVER TIME
ASSERTIVE
AGGRESSIVE
ASSERTIVE
RAD TEMP
GAS CENTRAL HEATING WITH WINDOW CLOSED
ORANGE LIGHT
WHITE LIGHT
SLOW
MODERATE
FAST
MODERATE / SLOW
PULSE OVER TIME
PASSIVE
ASSERTIVE
PASSIVE
As **temperature** increases, the energy status is fed back to the user through **colour**. As **duration** increases, the frequency of the **pulse** responds from passive (slow) to aggressive (erratic). If a **window** is opened in tandem with the heating on, the scales are immediately **escalated**.
Loughborough Design School
Loughborough University
Loughborough
LE11 3TU
Concept One:
Energy Feedback Device
v 0.2
19 November 2010
Loughborough University
© Garrath T Wilson 2010


THERMAL QUALITY SPHERE
AIR QUALITY SPHERE
ACCEPTABLE PARAMETER
PROMPT
CONTROL ACTION
ACCEPTABLE PARAMETER
PROMPT
CONTROL ACTION
user ok
user too hot
habit
heating off/down
open window
user ok
user too cold
habit
heating on/up
close window
user ok
poor air quality
habit
With users opting for **manual control**, Concept Two provides both **structural** (a change in the control mechanism) and **consequence** (feedback post action) intervention features. The feedback provided will strengthen the **cognitive bridge** between **action** (heating and built environment set-up) and **effect** (time it takes the built environment to reach desired temperature), informing future decisions.
Concept Two:
Feedback and Control Device
v 0.2
19 November 2010
Loughborough University
© Garrath T Wilson 2010
Loughborough Design School
Loughborough University
Loughborough
LE11 3TU



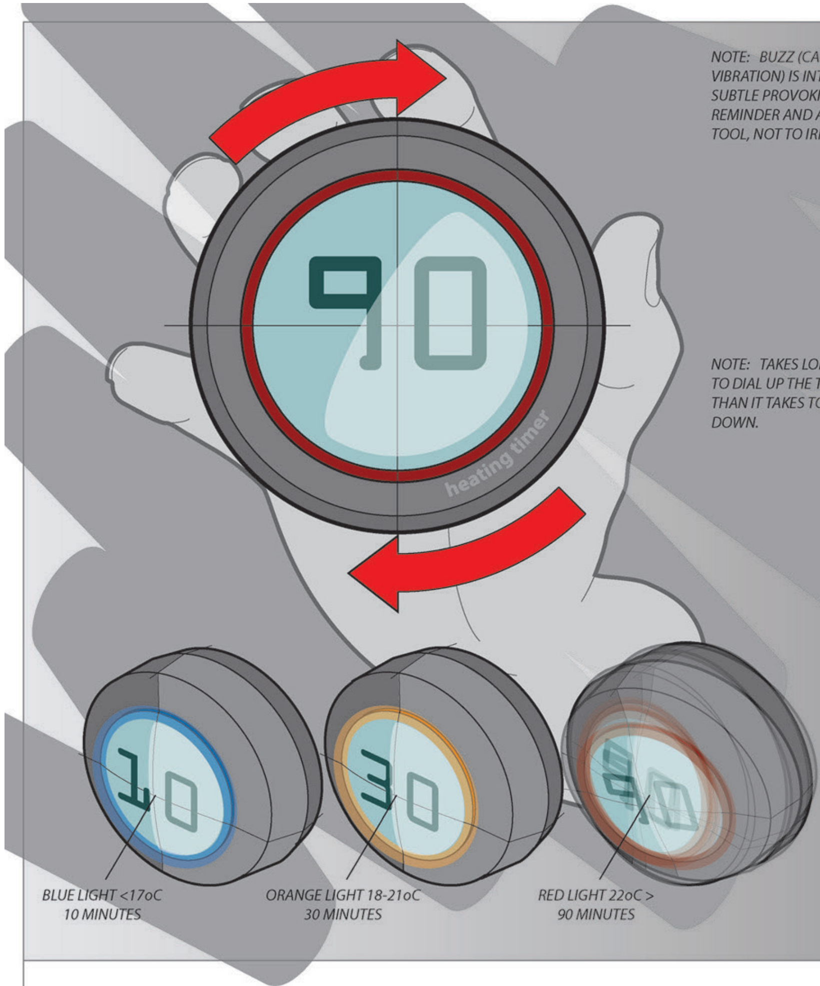
Two **variables** are fed back to the user: **duration** of heating, and the room **temperature**. The LCD display counts up the minutes that the unit has been **active**, with vibrations indicating **milestone** timings. Room temperature is reflected by **colour change** through the ringed LED array.

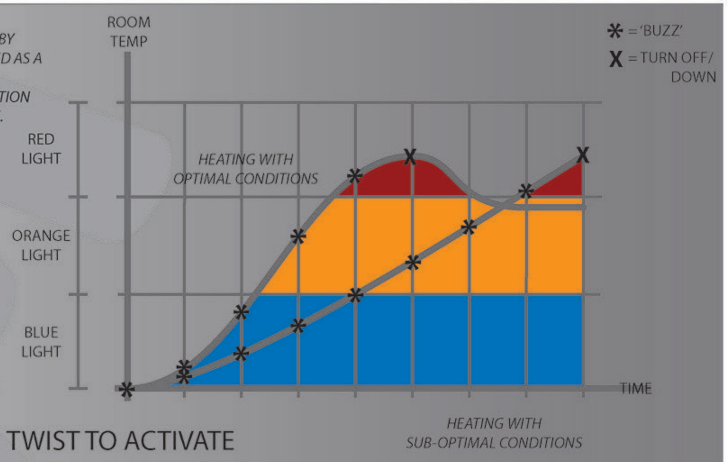


Loughborough Design School
Loughborough University
Loughborough
LE11 3TU

Concept Two:
Feedback and Control Device

v 0.2
19 November 2010
Loughborough University





1. TWIST TO ACTIVATE
2. TWIST TO SET TIMER
3. COUNT UP IN MINUTE UNITS
4. COLOUR CHANGE WITH TEMPERATURE
5. BUZZ EVERY 15MIN
6. BUZZ AT FINISH
7. AUTO SHUT DOWN OF BOILER
8. OR TO CONTINUE, RE-TWIST

The user must **determine** the length of **time** they wish the heating to be on for, enacted through the **structural change** of operation. As room **temperature** increases, the status is fed back to the user through **colour**. Through a **combination** of the upwards counting temporal and temperature feedback mechanisms, **awareness is increased**.

Loughborough Design School
Loughborough University
Loughborough
LE11 3TU

Concept Two:
Feedback and Control Device

v 0.2
19 November 2010
Loughborough University

Appendix L. Feedback Usability and Function Evaluation Questions

Frequency and Duration of the Feedback	1. Is the latest update of feedback presented when the user performs the activity? 2. Is the latest update presented when the user chooses to acknowledge the feedback pertaining to their activity? 3. Does the frequency of the feedback update match that required by the user and their activity? 4. Is the speed of feedback delivery after the user's activity appropriate? 5. Is the feedback device used 'hot' by the user (the feedback is acknowledged in real time by the user to reflect upon and guide the activity)? 6. Is the frequency and duration of the feedback appropriate to the requirements of a localised or centralised feedback location?
Accuracy of the Feedback	7. Is the feedback presented to the user appropriately accurate for the activity? 8. Is the feedback presented to the user appropriately accurate for the user? 9. Is the feedback based on actual or estimated activity?
Feedback Metrics	10. Does the feedback metric quantify energy, monetary, environmental or behavioural units? 11. How does the user comprehend the feedback metric? 12. Is the feedback metric relevantly framed in line with the user's motivations and norms? 13. Can the user relate the feedback metric back to the enacted activity? 14. Is the feedback metric trusted by the user? 15. Is the metric dependant on factors external to the user and the activity? 16. Does the feedback device require the users input to calibrate the units?
Breakdown of the Feedback	17. Is the feedback presented by granulated or systemic activity? 18. Is the feedback presented by granularity of activity appropriate for the user? 19. Does the feedback presented by granularity of activity affect the users understanding of individual activities? 20. Does the feedback presented by granularity of activity affect the users understanding of an individual activity in comparison to other activities?

	21. Does the feedback presented by granularity of activity affect the users understanding of an individual activity within a system? 22. Does the feedback presented by granularity of activity stimulate the user to explore their activity patterns?
Feedback Presentation Medium	23. How does the user comprehend the feedback presentation medium? 24. Is the feedback presentation medium relevantly framed in line with the user's motivations and norms? 25. Is the feedback presentation medium relevantly framed within the capabilities of the user (education level, technical ability, or free time)? 26. Can the user relate the feedback presentation medium back to the enacted activity? 27. Is the feedback presentation medium trusted by the user? 28. Is the feedback presentation medium dependant on factors external to the user and the activity? 29. Does the feedback presentation medium require the users input to access the feedback?
Feedback Presentation Mode	30. Is the feedback presentation mode clear and unambiguous? 31. How does the user comprehend the feedback presentation mode? 32. Is the feedback presentation mode relevantly framed in line with the user's motivations and norms? 33. Is the feedback presentation mode relevantly framed within the capabilities of the user (education level, technical ability, or free time)? 34. Can the user relate the feedback presentation mode back to the enacted activity? 35. Is the feedback presentation mode trusted by the user? 36. Is the feedback presentation mode appropriate to the requirements of a localised or centralised feedback location? 37. Does the choice of feedback presentation mode suite the frequency of the feedback update? 38. Does the feedback presentation medium require the users input to understand the feedback?
Feedback Ambience Features	39. Does the feedback ambience feature have distinguishable characteristics? 40. Is the feedback ambience feature clear and unambiguous? 41. Is the feedback ambience feature relevantly framed within the cognitive capabilities of the user? 42. Is the feedback ambience feature appropriate to the requirements

	of a localised or centralised feedback location? 43. Is the feedback ambience feature relevantly framed in line with the user's motivations and norms? 44. Can the user relate the feedback ambience feature back to the enacted activity? 45. Is the feedback ambience feature trusted by the user?
Location of the Feedback Device	46. Is the feedback device positioned in a localised or centralised feedback location? 47. Can the user relate the feedback devices location back to the enacted activity? 48. Does the location of the feedback device provide a suitable location for the user to explore localised feedback? 49. Does the location of the feedback device provide a suitable location for the user to explore centralised feedback? 50. Does the feedback device fit aesthetically within its location? 51. If the feedback devices location is transient, is it correctly designed to be so? 52. Is the feedback devices location dependant on factors external to the user and the activity?
Technical Expectations of the Feedback Device	53. Is the feedback device framed within the motivational and normative expectations of the user? 54. Is the feedback device framed within the capabilities of the user (education level, technical ability, or free time)? 55. Is the feedback device perceived to have been installed correctly by the user? 56. Does the feedback device perceive to be operating correctly by the user?
Feedback Comparisons	57. Is the feedback compared to historic or normative activity? 58. Is the feedback compared to granulated or systemic activity? 59. Is the feedback presented by comparison of activity appropriate for the user? 60. Does the feedback presented by comparison of activity affect the users understanding of an individual activity? 61. Does the feedback presented by comparison of activity affect the users understanding of an individual activity within a system? 62. Does the feedback presented by comparison of activity stimulate the user to explore their activity patterns?
Additional Information, Goals and	63. Has the use of supplementary information influenced how the user responds to the feedback? 64. Has the use of goal setting or anchoring bias influenced how the

Rewards	user responds to the feedback? 65. Has the use of incentives (energy, monetary, environmental or behavioural rewards) influenced how the user responds to the feedback? 66. Is the supplementary information, goals set, or incentive schemes offered tailored to the user? 67. Does the user require further information or instruments external to the user, the activity or the feedback device to understand or act upon the feedback provided?
The Rebound Effect and Other Challenges	68. Does the feedback increase the activity of the user? 69. Is the activity that the device provides feedback upon deemed to be necessary by the user? 70. Does the feedback increase stress and concerns pertaining to the activity of the user? 71. Does the feedback distort or conflict with the user's motivations and norms? 72. Does the feedback distort or conflict with the user's activity patterns and temporal rhythms?

Appendix M. Focus Group Pilot, Invitation Flyer

Carbon, Control and Comfort

Loughborough University

Would you like to give your views on exciting new products?

We are looking for 25 participants who are prepared to give us some of their time to be part of a Consumer Focus Group that will be asked to evaluate our new products and to complete a simple questionnaire.

CCC CONSUMER FOCUS GROUP

We would like to invite you to take part in this study for the CCC project, a collaborative research project between several UK Universities[1]. The aim of the project is to reduce the amount of energy we use in the home whilst remaining comfortable. To achieve this, we have designed several products based on our research so far. This Focus Group activity that you are being invited to take part in will help us to evaluate these products. There are no right or wrong answers, we are just after your views. Your comments are important to us and we will improve our designs based on your suggestions.

1. Questionnaire: Firstly, we will send you a short questionnaire by post prior to the Focus Group. The questionnaire contains general questions about how you use your heating, how you keep comfortable at home and who you are. Please fill the questionnaire and bring it along to the Focus Group meeting.

2. Focus Group: The Focus Group will involve you talking with several other participants and two researchers about four product ideas. For each product, we will start with a short energy and comfort story, follow by a product-in-use demo video and finally, a real discussion about how the design may be improved. The Focus Group will last two hours in total.

We will run the Focus Group from 10:00 a.m. to 12:00 a.m. on the 17th (Monday) October. Refreshments will be provided during the discussion and you will receive a gift voucher to compensate you for time. The venue for the Focus Groups will be at Loughborough Library (Granby Street, Loughborough, Leics, LE11 3DZ).

Confidentiality

Any individual information you provided will be considered strictly confidential and not disclosed to any third party. It will only be used in the development of design concepts to achieve the objectives of CCC project.

If you are interested in taking part and your property is owned by Charnwood Neighbourhood Housing, please speak to Dr. Tang Tang (via T.Tang@lboro.ac.uk or 07576614467) and Garrath Wilson (via G.T.Wilson@lboro.ac.uk or 07709497308) to ask for the questionnaire and information sheet and confirm arrangements for the Focus Group.

Many thanks for your help.

[1] Carbon, Control and Comfort: User-centred control systems for comfort, carbon saving and energy management project. Partners are Loughborough University, University College London, Kings College London, Leeds Metropolitan University, Cardiff University, De Montfort University and University of Greenwich

Appendix N. Focus Group Pilot, Information Sheet

Carbon, Control and Comfort

Loughborough University

CCC FOCUS GROUP INFORMATION SHEET

Please read this information carefully before deciding to take part in this research project.

We would like to invite you to take part in this study for the CCC project (Carbon, Control and Comfort: User-centred control systems for comfort, carbon saving and energy management project) a collaborative research project between several UK Universities[1].

Before you decide whether or not you want to take part, it is important for you to understand why the research is being done and what your participation will involve. Please take time to read the following information carefully, including the accompanying Consent Form, and discuss it with others if you wish. Ask us if there is anything that is not clear, or if you would like more information before deciding to take part.

The aim of the project is to reduce the amount of energy we use in the home whilst remaining comfortable. To achieve this, we have designed several products based on our research so far. This Focus Group activity that you are being invited to take part in will help us to evaluate these products. There are no right or wrong answers, we are just after your views. Your comments are important to us and we will improve our designs based on your suggestions.

1. Questionnaire: Firstly, we would like you to fill in the provided questionnaire prior to the Focus Group. The questionnaire contains general questions about how you use your heating, how you keep comfortable at home and who you are. Please bring it along to the Focus Group meeting.

2. Focus Group: The Focus Group will involve you talking with several other participants and two researchers about four product ideas. For each product, we will start with a short energy and comfort story, follow by a product-in-use demo video and finally, a real discussion about how the design may be improved. The Focus Group will last two hours in total. The aim of each discussion is to get your perspective on the prototypes. We are very keen to get your thoughts and opinions, both positive and negative.

With your permission, we would like to record this Focus Group using a video camera. At the same time, a second researcher will make a note of your responses.

[1] Carbon, Control and Comfort: User-centred control systems for comfort, carbon saving and energy management project. Partners are Loughborough University, University College London, Kings College London, Leeds Metropolitan University, Cardiff University, De Montfort University and University of Greenwich

Carbon, Control and Comfort

Loughborough University

Confidentiality
The information provided during this study will remain anonymous and confidential; names and addresses will not be used in any written reports for the research. Any identifying personal details obtained will only be available to those directly carrying out the research and will be stored securely.

Your involvement in all elements of the project is entirely voluntary. Please note that you have the right to withdraw from the study at any point, without having to give a reason.

Date, Venue and Compensation for Your Time
We would like to attend one out of three possible Focus Groups during the day on the 15th (Saturday) and16th (Sunday) October (time to be confirmed) and would ask you to select time slot that suits you. Refreshments will be provided during the discussion and you will receive a £15 gift voucher to compensate you for attending the Focus Group. The venue for the Focus Groups will be at Loughborough Library (Granby Street, Loughborough, Leics, LE11 3DZ).

What to Do Next
If you feel happy to take part in the study described above, please now read the Focus Group Consent form then sign and date at the bottom of the form. We will contact you to confirm arrangements for the Focus Group. **Please bring the completed questionnaire and signed consent form along to the Focus Group meeting.**

For further information or assistance, please feel free to contact us with any questions. You can contact us via the following:

Researchers:

Name	Dr Tang Tang	Garrath Wilson
Email	T.Tang@lboro.ac.uk	G.T.Wilson@lboro.ac.uk
Telephone	01509 223599	01509 226961

Lead Researchers:

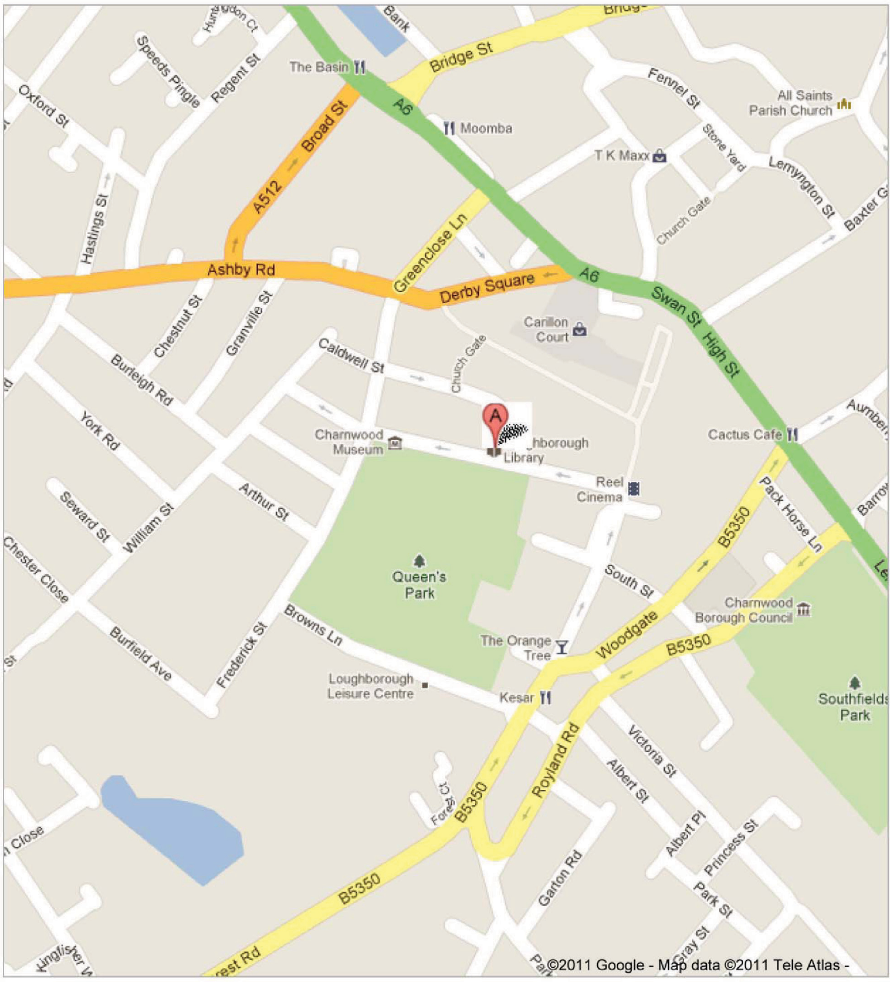
Name	Prof. Tracy Bhamra	Mrs Victoria Haines
Email	T.Bhamra@lboro.ac.uk	V.J.Haines@lboro.ac.uk
Telephone	01509 228 316	01509 226915

Address: Loughborough Design School, East Park Design Centre
Loughborough University
Loughborough, LE11 3TU, UK

Carbon, Control and Comfort

Loughborough University

The venue for the Focus Groups will be at Loughborough Library, Granby Street, Loughborough, Leics, LE11 3DZ.



Appendix O. Focus Group, Consent Form

Carbon, Control and Comfort

Loughborough University

CCC FOCUS GROUP CONSENT FORM

I have been given a copy of the Information Sheet and I have read and understood it. I have had the opportunity to consider the information and ask any questions to my satisfaction.

I understand that my participation is voluntary and that I have the right to withdraw from part or all of the study, at any time, without giving reason. I understand that if I withdraw my participation my information may still be included in the results, but it will not be possible to identify me in any way.

I understand that the information I provide will be anonymous and confidential. I agree to photographic, video and audio recording equipment being used for research purposes (e.g. written reports) and understand that no personally identifiable features (e.g. anything with your face, name or address on it) will be included in any research outputs.

I agree to the processing of my personal information for the purposes explained to me. I understand that this information will be treated in accordance with the terms of the Data Protection Act 1998.

I agree to participate in the study, as outlined in the Information Sheet.

Print Name : ______________________________

Signed: ____________________ **Date:** ___/___/_____

Researchers Name: ______________________________

Signed: ____________________ **Date:** ___/___/_____

Appendix P. Focus Group Pilot, Questionnaire

Carbon, Control and Comfort

Loughborough University

CCC FOCUS GROUP – QUESTIONNAIRE

Section A: About You
The following questions will give us information about you. Please mark the response applicable to you with "X" .

	Question		Response		X
1	Name				
2	Gender	Male		Female	
3	Age	8-12		35-44	
		13-17		45-54	
		18-24		55-64	
		25-34		65+	

Section B: The following questions will give us information about your house, heating and your energy and comfort practice. You do not have to answer every question, but ideally we would like you to complete as many of them as possible.

Household Composition

1. How many adults are in your household? ....

2. Do you have any children living with you in your household? ....

If 'YES', how old are they? ....

3. Relationship between household members (e.g. mother/husband, etc)?

....

....

4. How long have you lived here? ....

5. What do you do during the day (work/retired/housework, etc)?

....

Carbon, Control and Comfort

Loughborough University

Heating system

6. What is your heating system type? (e.g. gas back boiler/ gas combi/ electric storage, etc)? ……………………..………………..……….

7. How do you control your heating system? (e.g. using thermostat / programmer / Radiator Valve, etc)? …………………..……..………..…..

………………………...………………..….

8. How do you pay your energy bills (e.g. prepay/monthly direct debit/ etc)?

…………..…………………………….…

9. Do you keep an eye on your meters? …...………………………………

If 'YES', how often do you read the meters? ....……………………………

Comfort and Energy Practice

10. When you are at home, what kinds of things do you do to feel comfortable? Why? ……………………………………...……………………………

11. What is the most comfortable space/room? Why? ...…………………..…

………....………………………………………………………….…..….…

12. What is the least comfortable space/room? Why? ...…………………..….…

………....………………………………………………………….…..….…

13. Do you do anything to try to use less energy? Why? ...……………………

………....………………………………………………………….…..…..…

14. Do you use mood lights? (e.g. side lights/ fireplace lights/candles, etc)?

………....………………………………………………………….…..…..…

Appendix Q. Focus Group, Facilitator's Guide

FOCUS GROUP INFORMATION:

Date of the Focus Group...

17 October 2011, 10:30am-12:30pm

Location of the Focus Group...

Loughborough Library

Description of the Participants...

Moderator Name...

Garrath T Wilson

Asst. Moderator Name...

Dr. Tang Tang

Prototype Description...

Radiator / Window Device

Focus Group Order Number...

Prototype Number 4.

FOCUS GROUP ROUTE:

- Welcome
  - Good morning, thanks for taking the time...
  - Reintroduce myself...Garrath, Lboro
- Overview of the Topic
  - Investigate energy use and comfort in the home.
  - Heating system, window and energy use.
  - YOUR knowledge, experiences and opinions.
- Ground Rules
  - No right or wrong
  - confidentiality
  - please talk to each other
  - refreshments, toilet etc
- Questions to Participants
  - Scenario Video
  - Intervention Video
  - Intervention Prototype
  - First, video of an event we have seen in research.
  - Second, video with intervention...YOUR OPINIONS
- Summary

GENERAL INFORMATION / NOTES:

INTRODUCTION QUESTION

1. Who are you and why are you taking part in this focus group?

...get all to answer!

SCENARIO VIDEO QUESTIONS	BRIEF SUMMARY AND KEY POINTS / QUOTES / COMMENTS / OBSERVATIONS
VIDEO DESCRIPTION cold touch radiator thermostat up time passes warm up time passes gets hot time passes may forget heatings on air room / too stuff open window TRANSITION QUESTIONS 2. Thinking back to how you use your heating and open windows, in what ways does this video story feel familiar? 3. Are there any ways in which it is not familiar? Anything that you may do differently? What makes you touch it? How do you feel about touching it? What makes you open windows? Do you consider the heating when opening windows? ...could you explain? ...could you give an example? ...describe what you mean by...?	

INTERVENTION VIDEO QUESTIONS	BRIEF SUMMARY AND KEY POINTS / QUOTES / COMMENTS / OBSERVATIONS
VIDEO DESCRIPTION cold look at radiator thermostat up time passes light on time passes light on - click time passes may forget the heatings on open window light on - click close window...turn off heating? light on - click KEY QUESTIONS Thinking about how you use your windows and heating... 4. ... what are your first impressions? 5. ...what do you think this device is trying to achieve? 6. ...how do you think this device would affect your heating and window use? 7 ...what do you think the lights and colours mean? <play video> ...does anyone have a diff' point of view? ...has anyone had diff' experiences?	

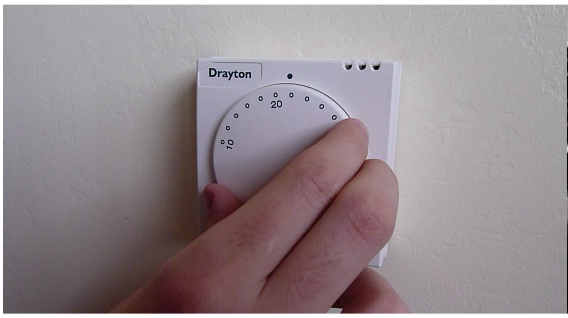
INTERVENTION PROTOTYPE QUESTIONS	BRIEF SUMMARY AND KEY POINTS / QUOTES / COMMENTS / OBSERVATIONS
PHYSICAL PROTOTYPE show prototype hold sensor light on open window sensor light on - click ...have a play! ENDING QUESTIONS 8. Any further impressions or comments? 9. What would you change to help you to better understand your heating and energy use?	

FURTHER / ENDING QUESTIONS	BRIEF SUMMARY AND KEY POINTS / QUOTES / COMMENTS / OBSERVATIONS
ENDING QUESTIONS cont. 10. Is there anything you wanted to say or ask but didn't have the opportunity? 11. Would you be happy to use this device as it stands? SUMMARY!	

Appendix R. Focus Group, Scenario Video Storyboard

cold

touch radiator



thermostat up

time passes

warming up

time passes

gets hot

time passes

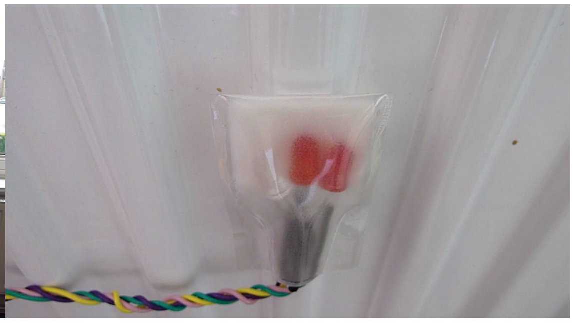
air room?

open window

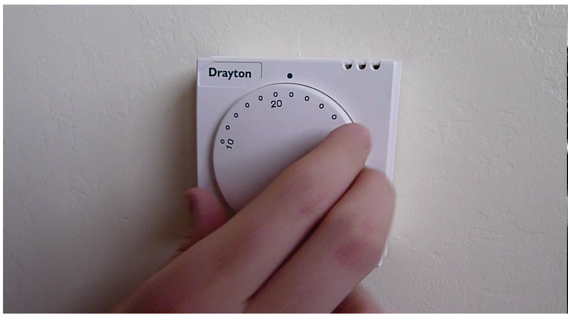
time passes

Appendix S. Focus Group, Intervention Video Storyboard

cold

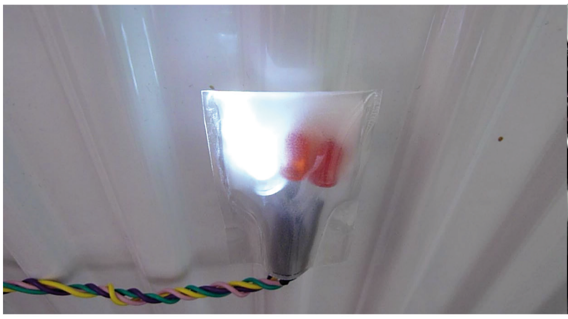


look at radiator



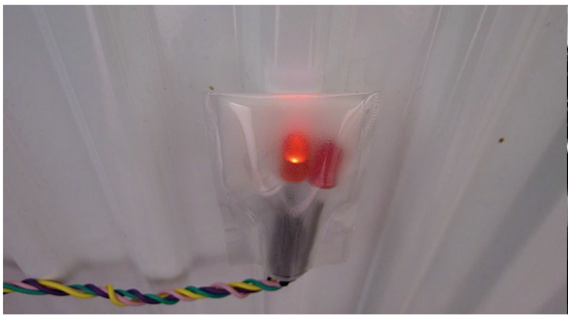
thermostat up

time passes



warming up - light on

time passes

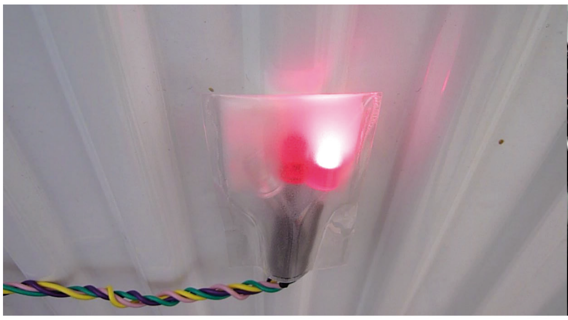


gets hot - light on - click

time passes

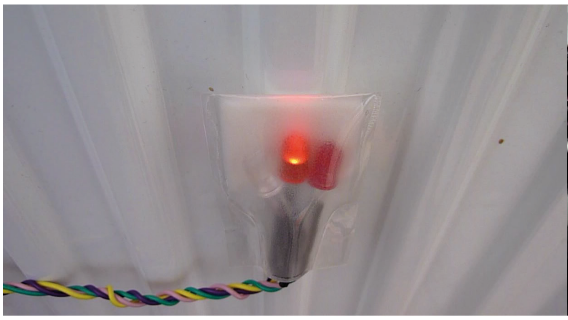
air room?

open window



energy conflict - light on - click

close window



conflict resolved, hot - light on - click

time passes

Appendix T. Focus Group, Information Sheet

Carbon, Control and Comfort

Loughborough University

CCC FOCUS GROUP INFORMATION SHEET

Please read this information carefully before deciding to take part in this research project.

We would like to invite you to take part in this study for the CCC project (Carbon, Control and Comfort: User-centred control systems for comfort, carbon saving and energy management project) a collaborative research project between several UK Universities[1].

Before you decide whether or not you want to take part, it is important for you to understand why the research is being done and what your participation will involve. Please take time to read the following information carefully, including the accompanying Consent Form, and discuss it with others if you wish. Ask us if there is anything that is not clear, or if you would like more information before deciding to take part.

The aim of the project is to reduce the amount of energy we use in the home whilst remaining comfortable. To achieve this, we have designed several products based on our research so far. This Focus Group activity that you are being invited to take part in will help us to evaluate one of these products. There are no right or wrong answers, we are just after your views. Your comments are important to us and we will improve our designs based on your suggestions.

1. Questionnaire: Firstly, we would like you to fill in the provided questionnaire. The questionnaire contains general questions about how you use your heating, how you keep comfortable at home and who you are.

2. Focus Group: The Focus Group will involve you talking with several other participants and a researcher about one of our product ideas. We will start with a short energy and comfort story, follow by a product-in-use demo video and finally, a real discussion about how the design may be improved. The Focus Group will last between an hour to two hours in total. The aim of this discussion is to get your perspective on the product. We are very keen to get your thoughts and opinions, both positive and negative.

With your permission, we would like to record this Focus Group using a video camera.

[1] Carbon, Control and Comfort: User-centred control systems for comfort, carbon saving and energy management project. Partners are Loughborough University, University College London, Kings College London, Leeds Metropolitan University, Cardiff University, De Montfort University and University of Greenwich

Carbon, Control and Comfort

Loughborough University

Confidentiality
The information provided during this study will remain anonymous and confidential; names and addresses will not be used in any written reports for the research. Any identifying personal details obtained will only be available to those directly carrying out the research and will be stored securely.

Your involvement in all elements of the project is entirely voluntary. Please note that you have the right to withdraw from the study at any point, without having to give a reason.

Compensation for Your Time
Refreshments will be provided during the discussion and you will receive a £15 gift voucher to compensate you for attending the Focus Group.

What to Do Next
If you feel happy to take part in the study described above, please now read the Focus Group Consent form then sign and date at the bottom of the form.

For further information or assistance, please feel free to contact us with any questions. You can contact us via the following:

Researcher:

Name	Garrath Wilson
Email	G.T.Wilson@lboro.ac.uk
Telephone	01509 226961

Lead Researchers:

Name	Prof. Tracy Bhamra	Mrs Victoria Haines
Email	T.Bhamra@lboro.ac.uk	V.J.Haines@lboro.ac.uk
Telephone	01509 228 316	01509 226915

Address: Loughborough Design School
Loughborough University
Loughborough, LE11 3TU, UK

Appendix U. Focus Group, Questionnaire

Carbon, Control and Comfort

Loughborough University

CCC FOCUS GROUP – QUESTIONNAIRE

Section A: About You
The following questions will give us information about you. Please mark the response applicable to you with "X" .

	Question		Response	X
1	Name			
2	Gender	Male	Female	
3	Age			

Section B: The following questions will give us information about your house, heating and your energy and comfort practice. You do not have to answer every question, but ideally we would like you to complete as many of them as possible.

Household Composition

1. How many adults are in your household? ....

2. Do you have any children living with you in your household? ....

 If 'YES', how old are they? ....

3. Relationship between household members (e.g. mother/husband, etc)?

 ....

4. How long have you lived here? ....

5. What style is your home (e.g. terraced/flat, etc)?

 ....

6. How old is your home (e.g. new build/Victorian, etc)?

 ....

7. What do you do during the day (e.g. work/retired/housework, etc)?

 ....

Carbon, Control and Comfort

Loughborough University

Heating system

8. What is your heating system type? (e.g. gas back boiler/ gas combi/ electric storage, etc)? ………………………..………………..……….

9. How do you control your heating system? (e.g. using thermostat/ programmer/radiator valve, etc)? ……………………..………..………..…..

………………………….....……………………..….

10. How do you pay your energy bills (e.g. prepay/monthly direct debit/ etc)?

…………....…………………………….…

11. Do you keep an eye on your meters? …....……………………………………

If 'YES', how often do you read the meters? ….……………………………

Comfort and Energy Practice

12. When you are at home, what kinds of things do you do to feel comfortable? Why? ………………………………………….....………………………………

13. What is the most comfortable space/room? Why? ..…………………….…

………......………………………………………………………………….…...….

14. What is the least comfortable space/room? Why? ..……………………..…

………......………………………………………………………………….…...….

15. Do you do anything to try to use less energy? Why? ..……………………

………......………………………………………………………………….…...…

16. Do you use mood lights? (e.g. side lights/ fireplace lights/candles, etc)?

………......………………………………………………………………….…...…

Appendix V. User Trial, Sampling Strategy

	rad/win ambient feedback of thermal and air managment	sticker re-framing the temp. range of a thermostat	feedback light rewarding on/off tree sidelight	distraction light temperature compensating comfort lights	WATTBOX De Montfort's technology agentive intervention
CA01 Solar water heater and gas combi boiler	1 living room window never used but lack of knowledge when heating is on via thermostat	1 understanding of newly installed thermostat is causing tenant problems	2* tenant has illustrated that ambient lighting in the living room improves comfort in the evening	2 tenant has illustrated that ambient lighting in the living room improves comfort in the evening	1 tenant has already opted out of installation
CA02 Gas combi boiler and electric living room fire	2* bedroom window open throughout the day and 'airing out' with regular heating conflicts	2 thermostat regularly changed by tenants for competing temperature control	2 tenant has illustrated that ambient lighting in the living room improves comfort in the evening	2 tenant has illustrated that ambient lighting in the living room improves comfort in the evening	2 competing comfort and health requirements would make for an interesting case study
CA03 Gas combi boiler and electric living room fire	0 system would be incompatible with current concept although dual window/heating shown	0 storage heater system does not have a thermostat	2 tenant has no control over heating output, only off/on, but sometimes supplements with halogen	2* tenant uses sidelights for reading and often finds heating system undesirably cooler in the evening	0 storage heater system would be incompatible with concept
CA04 Gas combi boiler and electric living room fire	2 daily window use for 'airing', and during cooking and smoking, and all night in bedroom (health)	2 thermostat regularly changed by tenants for competing temperature control	2 tenant has illustrated that ambient lighting in the living room improves comfort in the evening	2 tenant has illustrated that ambient lighting in the living room improves comfort in the evening	2* restrictive health and movement of one tenant would make for an interesting case study
CA05 Gas combi boiler and electric living room fire	2* daily kitchen and bedroom window use in spring, with ad hoc heating control (sometimes forgets its on)	2 thermostat usually kept at same temperature with ad hoc ammendments when desired	2 tenant has illustrated that ambient lighting in the living room improves comfort in the evening	2 tenant has illustrated that ambient lighting in the living room improves comfort in the evening	2 one tenant has regular daily routines whilst other may be working night shifts
CA06 Gas combi boiler	1 can't open living room window and has tight control and awareness of the heating	0 gas combi-boiler system does not have a thermostat	2 tenant has shown a desire for heating control (concept must be pet robust)	2 home may be without heating for days at a time (concept must be pet robust)	2* interesting if the device can save energy when a tenant has such tight control over the system
CA07 Gas combi boiler	2 ad hoc window use in spring and thermostat year-round (concept must be pet and child robust)	2* frequent ad hoc changes to thermostat settings (concept must be pet and child robust)	2 until recently has shown no desire for ambient lighting (concept must be pet and child robust)	2 until recently has had no desire for ambient lighting (concept must be pet and child robust)	2 having two young children would make for an interesting case study

0
0 = impossible, 1 = limited
2 = good, 2* = preferred,
red box = installed location

1
the grey box denotes prototypes or homes that are excluded from selection

2
the dashed line denotes that the prototype was installed for a month, then removed

Appendix W. User Trial, Information Sheet

CCC Study (Carbon, Comfort and Control)

INFORMATION SHEET

We would like to invite you and any other members of your household that would like to, to take part in a further part of the CCC project, following your earlier involvement. It is part of the series of activities that you have already been participating in, including the monitoring being undertaken by Cardiff University and the interviews that you participated in on two occasions last year. This study is independent from, but supported by, your housing association.

Before you decide whether or not you want to take part, it is important for you to understand why the research is being done and what your participation will involve. Please take time to read the following information carefully, including the accompanying Consent Form, and discuss it with others if you wish. Ask us if there is anything that is not clear, or if you would like more information before deciding to take part. You should only participate if you want to; choosing not to take part will not disadvantage you in any way.

Details of what to do if you are happy to take part, or if you have any questions about the study, are included at the end of this information sheet.

Study information

The CCC project involves several UK Universities[1]. The overall aim of the project is to find out how to reduce the amount of energy we use in the home whilst remaining comfortable. The activities you are being asked to take part in will help us to do this.

As you will remember, on the two previous occasions that we visited you last year we asked you about the ways you keep comfortable in your home, and how you use things like your heating and your windows to do this. This time, we would like to find out if there have been any changes in what you do or why you do it.

[1] King's College London, Cardiff University, University of Greenwich, Loughborough University, University College London, Leeds Metropolitan University and De Montfort University

We may ask you to trial a prototype of a new product that has been inspired by what you and other participants in this project have told us. Some households may not receive a prototype.

This interview will take around 1 hour. As before, with your permission, we would like to record our conversations during this visit with a digital audio recorder. We will also make a note of your responses.

<u>If you receive a prototype:</u>

If you agree to trial a prototype, then we would like you to live with this for three months and to agree to talk to us during spring 2012 to tell us about your experiences of living with it. You will be provided with an additional information and consent sheet specific to the intervention you receive, which you will be invited to consider before agreeing to trial the prototype.

<u>If you don't receive a prototype:</u>

Even if you don't receive a prototype to trial, we would still like to speak to you in spring 2012 to find out if there have been any changes to what you do.

<u>For everyone:</u>

During the final interview in spring 2012, we would like to thank you for your time by presenting you with a £25 supermarket gift card.

Confidentiality

- Your contributions will be made anonymous so that nobody will be able to associate what you have told us with you personally.

- Your personal information will be considered confidential and will not be shared. Names and addresses will not be used in any written reports for the research. Any identifying personal details obtained will only be available to those directly carrying out the research and will be stored securely.

- Your involvement in all elements of the project is entirely voluntary.

- You have the right to withdraw from the study at any point, without having to give a reason.

What to do next

If you feel happy to take part in the study described above, please now read the Consent Form then sign and date at the bottom of the form.

For further information or assistance, or if you have any concerns with the prototype at any point during the trial, please feel free to contact us – our contact details are provided below.

Researchers:		
Name:	Garrath Wilson	Dr Emma Hinton
Institution:	Loughborough University	King's College London
Email:	G.T.Wilson@lboro.ac.uk	Emma.Hinton@kcl.ac.uk
Telephone:	07709 497 308	07904 888 876
Lead Researchers:		
Name:	Prof. Tracy Bhamra	Dr Karen Bickerstaff
Institution:	Loughborough University	King's College London
Email:	T.Bhamra@lboro.ac.uk	Karen.Bickerstaff@kcl.ac.uk
Telephone:	01509 228 316	020 7848 2625

Appendix X. User Trial, Prototype Information Sheet

CCC Study (Carbon, Comfort and Control)

PROTOTYPE INFORMATION SHEET

The prototype that we are inviting your household to trial is one of the final parts of the CCC project, following on from the interviews and monitoring activities undertaken by King's College London, Loughborough University and Cardiff University over the past couple of years. This prototype has been specifically designed based on the information you and other participants in this project have told us, and is related to how you use energy and what you do to stay comfortable.

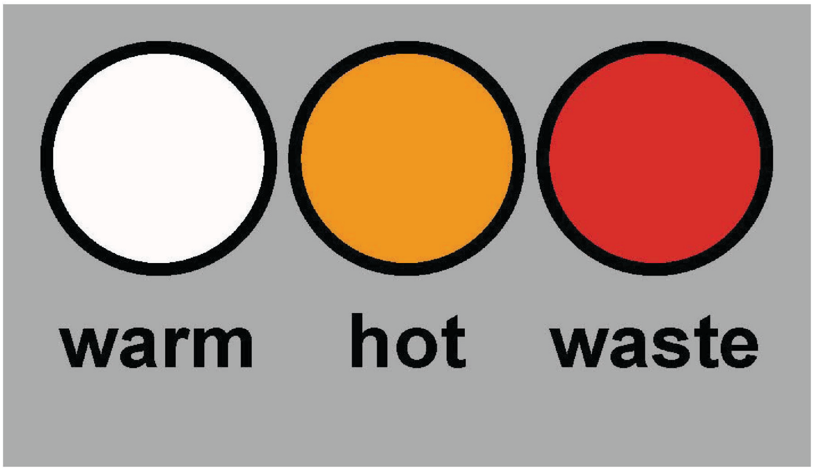
Before you decide whether or not you want to take part, it is important for you to understand why the research is being done and what your participation will involve. Please take time to read the following information carefully, including the accompanying Information Sheet, Consent Form and Prototype Consent Form, and discuss it with others if you wish. Ask us if there is anything that is not clear, or if you would like more information before deciding to take part. You should only participate if you want to; choosing not to take part will not disadvantage you in any way.

Details of what to do if you are happy to take part, or if you have any questions about the study, are included at the end of this information sheet.

Trial information

The aim of this prototype is to give you feedback to help you to understand and control your energy consumption, whilst remaining comfortable.

This battery operated device provides energy information through a series of lights to indicate the temperature of the radiator it is installed on. A white light indicates that the radiator is warm, an orange light indicates that the radiator is hot, and no lights indicate that the radiator is cold. If the window nearby to the radiator is opened whilst the radiator is warm or hot, the light changes to red, to indicate that the heat and energy from the radiator is escaping out of the window and is being wasted. The colour guide below helps to illustrate the above information, and will also be provided to you on magnets for you to stick on the radiator until you get the hang of things:



If you agree to take part in this part of the study, the prototype will be installed for three months. The installation of this prototype will be not permanent and will be easy to remove with no damage to your property. The prototype will also in no way affect the operation of your window or heating system; the device is purely there to give you information on what you already do, not to physically change or control what you do. The prototype has also been examined and passed all relevant safety checks, and should take less than ten minutes to install.

Following the prototype trial we would like to return during spring 2012 to ask you about your experiences of living with it. Following this final interview in spring, we would like to present you with a £25 supermarket gift card to thank you for your time.

Confidentiality

- Your contributions will be made anonymous so that nobody will be able to associate what you have told us with you personally.

- Your personal information will be considered confidential and will not be shared. Names and addresses will not be used in any written reports for the research. Any identifying personal details obtained will only be available to those directly carrying out the research and will be stored securely.

- Your involvement in all elements of the project is entirely voluntary.

- You have the right to withdraw from the study at any point, without having to give a reason.

What to do next

If you feel happy to take part in the study described above, please now read the Prototype Consent Form then sign and date at the bottom of the form.

For further information or assistance, or if you have any concerns with the prototype at any point during the trial, please feel free to contact us – our contact details are provided below.

Researchers:		
Name:	Garrath Wilson	Dr Emma Hinton
Institution:	Loughborough University	King's College London
Email:	G.T.Wilson@lboro.ac.uk	Emma.Hinton@kcl.ac.uk
Telephone:	07709 497 308	07904 888 876
Lead Researchers:		
Name:	Prof. Tracy Bhamra	Dr Karen Bickerstaff
Institution:	Loughborough University	King's College London
Email:	T.Bhamra@lboro.ac.uk	Karen.Bickerstaff@kcl.ac.uk
Telephone:	01509 228 316	020 7848 2625

Appendix Y. User Trial, Consent Form

CCC Study (Carbon, Comfort and Control)

CONSENT FORM

I have been given a copy of the Information Sheet and I have read and understood it. I have had the opportunity to consider the information and ask any questions to my satisfaction. I understand what taking part in this research involves.

I understand that my participation is voluntary and that I have the right to withdraw from part or all of the study, at any time, without giving reason. I understand that if I withdraw my participation my information may still be included in the results, but it will not be possible to identify me in any way.

I understand that the information I provide will be anonymous and confidential. I agree to photos being used for research purposes (e.g. written reports) and understand that no personally identifiable features (e.g. anything with your name or address on it) will be included in these images.

I agree to the processing of my personal information for the purposes explained to me. I understand that this information will be treated in accordance with the terms of the Data Protection Act 1998.

I agree to participate in the study, as outlined in the Information Sheet.

Signed:________________ Print name:________________ Date:________________

Researcher's statement:

I confirm that I have carefully explained the nature, demands and foreseeable risks (where applicable) of the proposed research to the volunteer.

Signed:________________ Print name:________________ Date:________________

Appendix Z. User Trial, Prototype Consent Form

KING'S College LONDON

Loughborough University

CCC Study (Carbon, Comfort and Control)

PROTOTYPE CONSENT FORM

I have been given a copy of the Prototype Information Sheet and I have read and understood it. I have had the opportunity to consider the information and ask any questions to my satisfaction. I understand what taking part in this research involves.

I understand that my participation is voluntary and that I have the right to withdraw from part or all of the study, at any time, without giving reason. I understand that if I withdraw my participation my information may still be included in the results, but it will not be possible to identify me in any way.

I understand that the information I provide will be anonymous and confidential. I agree to photos being used for research purposes (e.g. written reports) and understand that no personally identifiable features (e.g. anything with my name or address on it) will be included in these images.

I agree to take reasonable care of the Prototype and will immediately inform the Researchers as named on the Prototype Information Sheet should the device operate in any way that it was not intended.

I agree to the processing of my personal information for the purposes explained to me. I understand that this information will be treated in accordance with the terms of the Data Protection Act 1998.

I agree to participate in the study, as outlined in the Prototype Information Sheet.

Signed:________________ Print name:________________ Date:________________

<u>Researcher's statement:</u>

I confirm that I have carefully explained the nature, demands and foreseeable risks (where applicable) of the proposed research to the volunteer.

Signed:________________ Print name:________________ Date:________________

Appendix AA. User Trial, Facilitator's Guide

THIRD ROUND OF BASELINE DATA COLLECTION	Household:

- It's been a year since we last saw you – we'd like to find out if there has been any change in your household, or in your comfort, or in what you do to stay comfortable over that time
- [outline new info sheet and invite to sign new consent sheet]
- [check ok to record interview and take notes]

Notes:

When participants indicate that there has been a change, where relevant (e.g. Qs 3-8) explore this using the following questions as a guide:

i. *What does this change involve – e.g. heating controls, windows, other devices…*
ii. *When did you start doing this?*
iii. *Why did you start doing this? (What does doing it this way achieve?)*
iv. *What influenced you to start doing this? Did you find out by yourself, or hear about doing this, or did someone you know start doing this, or did someone suggest you start doing this?*
v. *Has it changed what others in your household do?*
vi. *What do you think about doing this – is it better or worse or just different than what you were doing before?*

GENERAL COMFORT (3 mins)	
1. How would you describe your experience of comfort in your home over the last year? (e.g. more/less comfortable; mostly/rarely comfortable; period of discomfort – and why – and what do you do in response?)	
BACKGROUND INFORMATION (3 mins)	
2. Have there been any changes to…	
(a) Your household?	
(b) Your building or heating system?	
(c) Other factors that might change how you use energy (e.g. new heater)	
WARMTH (3 mins)	
3. Since we were last here, has there been any changes in how you keep warm? (use of heating system (boiler, timer, thermostat, TRVs), additional heaters, clothing, curtains, draught management) Do you do anything differently in particular rooms?	

WINDOWS (3 mins)	
4. Has there been any change in how you use your windows? (air out, fresh air, cooling, when doing something (cooking, bathing, smoking, washing, drying)) Do you do anything differently in particular rooms?	
LIGHTING (3 mins)	
5. Has there been any change in how you use natural and artificial light? (e.g. ceiling lights, side lights, candles, artificial fire, curtains, doors) Do you do anything differently in particular rooms?	
DIURNAL & SEASONAL DYNAMICS	
6. The lounge (3 mins) - Is it ever uncomfortable? Why? What do you do to make it comfortable? - How do you use it over the course of the day? What do you do to make it / you comfortable? - How do you use it over the course of the year? (spring, summer, autumn, winter) What do you do to make it / you comfortable? - Has there been any change in what you do since we last saw you a year ago?	

Appendix AB. User Trial, Installation Guide

1 Radiator / Window Prototype

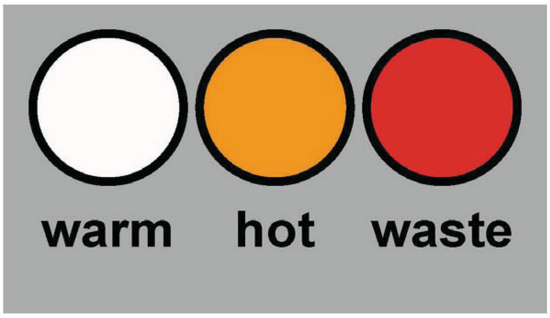
1.1 Introduce the Prototype to the Participant

The aim of this prototype is to give you feedback to help you to understand and control your energy consumption, whilst remaining comfortable. This prototype has been specifically designed based on the information you and other participants in this project have told us, and is related to how you use energy and what you do to stay comfortable.

SHOW THE PROTOTYPE AFTER THIS INTRO SECTION

The device we have designed for you is a battery operated device that provides energy information through a series of lights to indicate the temperature of the radiator it is installed on. A white light indicates that the radiator is warm, an orange light indicates that the radiator is hot, and no lights indicate that the radiator is cold. If the window nearby to the radiator is opened whilst the radiator is warm or hot, the light changes to red, to indicate that the heat and energy from the radiator is escaping out of the window and is being wasted.

INTRODUCE THE MAGNET



Moving between any of these light states produces a small 'click'.

WE WANT TO GIVE YOU THIS DEVICE TO SEE IF THE INFORMATION AFFECTS THE WAY YOU OR YOUR FAMILY USE ENERGY OR CONTROL YOUR COMFORT.

If you agree to take part in this part of the study, the prototype will be installed for three months. The installation of this prototype will be not permanent and will be easy to remove BY US with no damage to your property. The prototype will also in no way affect the operation or build of your window or heating system; the device is purely there to give you information on what you already do, not to physically change or control what you do. The prototype has also been examined and passed all relevant safety checks, and should take less than ten minutes to install.

I should also note, the device is not recording any data, so please don't think we are watching to see if you use it correctly, there are no right or wrong ways of using or interpreting the information.

Following the prototype trial we would like to return during spring 2012 to ask you about your experiences of living with it for this period, and any difference it has made to how you control your energy consumption or what you do to keep comfortable.

Following this final interview in spring, we would like to present you with a £25 supermarket gift card to thank you for your time.

RECAP DEVICE FUNCTIONS

BE PREPARED WITH AN ALTERNATIVE PROTOTYPE IF THIS ONE IS REJECTED!

Additional Prototype Information (only if asked by the participant)

Radiator Surface Temp. (on/off and °C/°F)	**Window Status (open/closed)**	**Light Status (off/white/orange/red)**
off	closed	off
on <25°C (<77°F)	closed	off
on 25-43°C (77-109°F)	closed	white
on >43°C (>109°F)	closed	orange
off	open	off
on <25°C(<77°F)	open	off
on 25-43°C(77-109°F)	open	red
on >43°C(>109°F)	open	red
		>43°C can produce burns after contact according to NHS guidelines

RED LIGHT COST: A CARBON TRUST energy efficiency calculation, combined with a prepayment meter energy cost:
A typical office window left open over night in winter may waste up to around £3.

1.2 First Impressions Question the participants over their first impressions of the device. • What are your first impressions? • What do you think about a device that reacts to the heating system being turning on/up? • What do you think about a device that reacts to the heating system being turned down/off? • What do you think about a device that reacts to a window being opened with the heating system on?	

2 OBSERVATION AND INSTALLATION

INTRODUCE PHYSICAL PROTOTYPE

Demonstrate and explain the features of the prototype, and how it is installed.

WINDOW INSTALLATION
RAD LIGHT INSTALLATION
TEMP SENSOR INSTALLATION

ARE YOU HAPPY FOR THIS TO BE INSTALLED?

Discuss with the participants the best location for installation. Once a location has been determined and agreed upon between the participants and the interviewer, INSTALL THE PROTOTYPE.

Whilst one researcher is installing the prototype, the second interviewer asks permission to take photos of the room that the prototype is to be installed in (points of interest as previously discussed, panoramic of the room, what the prototype looks like from various regular seating or standing locations). Following the taking of photos, the interviewer draws the layout of the room, location of the intervention and any other notes

DEMONSTRATE IN SITU, MAKE SURE IT IS CLEARLY UNDERSTOOD AND MAGNET PLACED

2.1 Installation Notes

Date:
Day:
Time:
Weather:

Participants:
Researchers:
Intervention prototype:

W	windows	S	sofa (suite)	TV	TV	FURTHER ITEMS:		
V	vents	C	chair (suite)	L1	table lamp			
H	add. heaters	T	coffee table	L2	ceiling light			
F	fireplace	Rg	rug	L3	floor lamp			
ID	internal door	DC	dining chair	L4	candles			
ED	external door	DT	dining table	L5	fireplace light			
R	radiator	B	bed	L6	halogen strip			
O	oven	WR	wardrobe	L7	extractor light			
CB	cupboard	DR	drawers	EF	extractor fan	★ INTERVENTION		

2.2 Further Impressions Once the prototype is installed, ask for further impressions: • What are your impressions? • What do you think about the installation of this prototype? (e.g. location of box, location of window sensor, location of temp sensor, location of lights) • ANY QUESTIONS?	

Appendix AC. User Trial, Extraction Guide

We'd like to find out if there has been any change in your household, or in your comfort, and how you feel about the 'product' we left with you in November

[outline new info sheet and invite to sign new consent sheet]

[check ok to record interview and take notes]

[compensation?]

[Notes:

When participants indicate that there has been a change, where relevant (e.g. Qs 3-8) explore this using the following questions as a guide:

i. Who tends to do this? Why you/this person?

ii. What does this change involve – e.g. heating controls, windows, other devices...

iii. When did you start doing this?

iv. Why did you start doing this? (What does doing it this way achieve?)

v. What influenced you to start doing this?

vi. How frequently do you/they do this?

vii. Has it changed what others in your household do?

viii. What do you think about doing this – is it better or worse or just different than what you were doing before?]

ix. Do you/they ever consider alternatives?

...if the participants start to discuss the prototype in response to the above questions, ask questions 2.1-2.4 concerning that 'topic' (e.g. the prototype in relation to the windows or kitchen etc) and then return back to question order.

1. **<u>General change</u>**

Since we last saw you, has there been any change in...

1.1. Your experience of comfort?

- E.g. more/less comfortable; mostly/rarely comfortable; period of discomfort
- Why?
- What do/did you do in response?

1.2. Your household? • E.g. who lives/stays here? • E.g. your building / heating system? • Other factors that might change how you use energy (e.g. new heater, being at home more/less, entertaining more/less, looking after others at home more/less)? **1.3. How you keep warm?** • E.g. in relation to various practices such as getting up in the morning, cooking, eating, cleaning, bathing, washing, drying • Do you do anything differently in particular rooms? • Do you do anything differently at particular times? **1.4. How you use your windows?** • E.g. in relation to various practices such as airing out, getting fresh air, cooling, cooking, bathing, smoking, washing, drying • Do you do anything differently in particular rooms? • Do you do anything differently at particular times? **1.5. How you use natural and artificial light?** • E.g. how you use ceiling lights, side lights, the fire light, candles, curtains when doing particular things • Do you do anything differently in particular rooms? • Do you do anything differently at particular times? **1.6. How comfortable you feel in the lounge?** Why? Has there been a change in how you use it over the course of the day? **1.7. How comfortable you feel in the kitchen?** Why? Has there been a change in how you use it over the course of the day?	

1.8. How comfortable you feel in the bedroom? Why? Has there been a change in how you use it over the course of the day? **1.9. How you use the heating?** Has there been any change over the course of the day / in different rooms / when different people are home?	
2. **<u>The Product</u>** **2.1.** What are your general impressions of the product? Have these changed since the product was first installed? If so, why? **2.2.** What did you understand the purpose of the product to be? Did it meet your expectations? **2.3.** Could you explain how you used it? • Do you think you used the product in a different way to the way it was intended to be used? Why? **2.4.** When did you notice the product (e.g. feedback information, automated control on)? What were you doing at the time? *...if the above have already been asked in relation to 'general change' continue with question 2.5/2.6 (depending on answers already given).* **2.5.** Did you do anything differently as a result of the product being there? Did this change over time (i.e. over the time that you have lived with the product)? • E.g. have you changed how you keep warm (heating, clothing, bedding, hot water bottles) / ventilate your house (windows, vents, doors)? • E.g. have you changed when you do particular things? • E.g. have you changed where you do particular things?	

2.6. Over the last 3 months, since you have lived with the product, have there been any changes to: • How much energy you use / how much you spend on energy (why do you think this is?) • Whether you monitor your energy use, or try to reduce it (why? How?) • How you pay for your energy (why?) • If nothing changed as a result of the product being installed, any thoughts as to why? • If there has been change, do you think this may continue when you no longer have the product? **2.7.** Did you set any targets, goals or rewards associated with the product? **2.8.** Has it made you think differently about your home energy (e.g. more control) and the way you use it (e.g. efficiency, responsibility)? **2.9.** Have you discussed the product with anybody? Who? Why? What did you talk about? What happened afterwards? **2.10.** Was the product easy to understand? • Can you tell me how you think it works? • What did the information the product provided represent to you? **2.11.** Was the product easy to use? How have you used it and has this changed at all? • Was the product flexible enough – enough control? • What do you think of where the product is position (within the house/room)? ○ Why do think that? (aesthetic / practical / information access reasons) ○ If you could move the product, where would you move it to? (within the house/room)	

2.12. What do you think about: • How the product operated – did you think it would work differently? Why? • The information provided by the product? What did you think about the type of information it provided (e.g. visual/aural/digital/paper)? Was the information interesting/useful? Was the information accurate? Was the information frequent enough? • The physical appearance of the product and its components (e.g. bulbs, boxes, batteries, cables)? • What have others in your household, or your family and friends, said they thought about it? Has this changed what you thought about the product, or how you used it? **2.13.** How do you think that this product could be improved to help you to manage your comfort and reduce your energy consumption? • Are there any changes that would make the product more useful to you / your household? ○ e.g. alternative energy use / cost / environmental units, or comparison of the information to other users / rooms / devices / historic data. • Do you think you would have benefited from any additional support or information about the product, or the information it provides? ○ E.g. interactions with others using the product, a manual, training **2.14.** Would you be interested in other efficiency or energy generation devices as a result of your involvement with this project? Why?	

3. <u>Final questions</u> **3.1.** Is there anything else you think we should know about how you keep comfortable at home, or about your experiences of living with the product? **3.2.** [Feedback section on qualitative analysis: a few brief summaries of key practices we have observed] **3.3.** Finally, we have some questions on what you thought about participating in this project over the last couple of years: • Could you tell us why you chose to participate, initially? What did you want to get out of participation? Do you think you got what you wanted to out of participation? • What did you think about the process – the interviews, the audio tour, the physical monitoring, the products? • Has participating in the project made you think differently about your home energy (e.g. more control) and the way you use energy (e.g. efficiency, responsibility)?	
[check ok to take photos of the product in situ] [uninstall the device, during 'final questions' if short on time?] [Any further project information and ask if they have any questions]	

This page has intentionally been left blank.