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TOWARDS SUSTAINABLE USE: DESIGN BEHAVIOUR INTERVENTION TO REDUCE HOUSEHOLD ENVIRONMENTAL IMPACT

By

TANG TANG

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

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ABSTRACT

The use of electrical products has a significant environmental impact, mainly determined by user behaviour, which has overridden the energy efficiency gains in the household from technological and educational solutions. Designers are identifiably in a position to plan and shape the way in which consumption occurs and to fill the gap between values and everyday user actions. Despite this, the literature demonstrates that the use phase of the product life cycle is often neglected in sustainable design. Few attempts have been made to change user behaviour through design-led interventions to limit its environmental burdens. In addition, there is a lack of understanding of users’ perceptions of environmental issues with reference to the specific context: actual use, habits and fundamental needs of the product as well as the behaviour changing products. This makes creating sustainable use of the household appliance lessen the significance of its original purpose.

The aim of this research is to seek the role that design could play in influencing more sustainable actions to reduce environmental household impacts. Based on a comprehensive literature review in diverse disciplinary fields of enquiry, a Design Behaviour Intervention Model has been established to bridge the social-psychological theories of behaviour and the behaviour intervention approaches. To inform this enquiry, a single product type (household cold appliance) was chosen as a case study to explore the capacity of a qualitative behaviour study to identify unsustainable aspects of product use. Two design activities were carried out: one examining the designer’s ability to respond to the design brief and the other applying the findings that emerged from the in-depth behaviour analysis and the model into the design process. The selected outcomes from the design study are evaluated by a focus group to uncover the users’ acceptance level of these concepts and the behaviour intervention approaches applied.

The collective findings are discussed along with the usefulness and effectiveness of the Design Behaviour Intervention Model in Design for Sustainable Behaviour. This research highlights that a detailed user study is not only the first step for improving energy efficiency in product use but also the origin of innovative design concepts to tap the market by providing better and greener use experiences. Useful insights on primary findings have emerged: the effectiveness of applying the social-psychological theory in the Sustainable Design domain; principles of improving effectiveness and acceptability of the behaviour interventions; and a guide for Design for Sustainable Behaviour.
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1 INTRODUCTION

This chapter introduces the background to this research and describes the focus and the objectives of the inquiry. It also raises the research problems and defines the thesis scope. The chapter ends by outlining the thesis structure and each chapter.

1.1 Background to the Research

Between 1970 and 2006, the growth in total energy demand was almost 7% whilst domestic energy consumption increased by 24% (BERR, 2007). The residential sector makes up around 30% of total UK energy demand (BERR, 2007) and 27% of end-user carbon dioxide emissions (DEFRA, 2007a). These trends have caused wide concern about the environmental impact from the domestic sector.

Many efforts, driven by legislative requirements, have focused on technological improvement and green materials investment during manufacturing and disposal phases and increasing market share of the products with energy labels and efficiency ratings. However, although the efficiency of buildings, heating systems and household appliances has improved by around 2% year on year since 1970 (Energy Saving Trust, 2006b), the energy use per household has remained unchanged and electricity use by domestic lights and appliances has increased by 70% (Environmental Change Institute, 2005). It is argued that improving the technical efficiency of appliances and manufacturing has not achieved the reduction needed in domestic energy consumption. As shown in Figure 1.1 until 2004 household energy consumption continued to rise, as improvements in energy efficiency did not outweigh the user demand pressures. Household energy consumption reduced between 2004 and 2007, but it still remained 8% higher in 2007 than in 1990 (Figure 1.1). It was admitted (House of Commons - Public Accounts Committee, 2009) that this fall could not be maintained as household energy consumption is continuously boosted by the need for more housing, the multiplied demands for more electrical goods and appliances and, in particular, the unsustainable manner of user’s interaction with the products, e.g. the increased standby power usage, and a liking for warmer houses.
In modern society, increasing levels of affluence, rapid technology development and specialised trends in product design provide people with the opportunity to own what they want to own. This leads users towards more individualistic (Sanne, 2002; Jackson, 2005) and hedonistic lifestyles (Buchholz, 1998; Vergragt, 1998). Multi social-psychological motivators behind consumption behaviour impel people to consume insatiable quantities of products and services. Environmental benefits of the wider global community, compared with the individual desires, are not strong enough to motivate a different lifestyle. In addition, user behaviour and operational decisions have contributed significantly to environmental impact (Environmental Change Unit, 1997; Sherwin and Bhamra, 1998; Lilley et al., 2005). In studies from the United States, the Netherlands and the UK, cited by Wood and Newborough (2003), it is estimated that householder behaviour is responsible for 26–36% of in-home energy use. Governments have continued to seek active participation from users in the environmental debate through a range of information campaigns. Literature suggests that these measures have largely been ineffective in creating sustained long term change in the majority of user behaviour (Jackson, 2005). Users have to make the link between the information, their own behaviour and the environmental and social impacts, and this makes it difficult to motivate a change in the majority of users. However, the UK Government’s Stern Review (2007) identified behaviour change as a priority for reducing the environmental impact of household energy consumption, with the Department of Energy and Climate Change recognising that “to change behaviour through helping people understand what they need to do and helping them to do it” was the hardest task (House of Commons - Public Accounts Committee, 2009, p. 10).
Designers have great potential to decrease environmental impact by considering the use phase of the product life cycle. However, this stage of the life cycle is often not considered in detail. Products, as the interface between users and consumption activities, can give immediate and direct responses to users’ operations, i.e., how it is perceived, learned, and used. Product manufacturers and designers are ideally placed to plan and to shape the way in which operation occurs and determine the compound impacts of the user use and interaction.

Recent research has started to investigate design-led approaches to behaviour change in both theoretical (Elias et al., 2008b; Elias et al., 2008c; Lockton et al., 2008; Pettersen and Boks, 2008; Pettersen, 2009) and practical dimensions; however these are mostly at the conceptual stage, such as research by Thompson and Sherwin (2001), van de Velden (2003b), Rodriguez and Boks (2005), Design Council (2006) and Lilley (2007) as well as the prototyping stage, such as the Static! Project by Interactive Institute (2004) and the Tyranny of the Plug Kitchen Machines (Van Hoff, 2003). To date, few of the current design concepts or studies have taken the underlying behavioural determinants into consideration during the design process. There is a lack of data on the users’ responses and effectiveness of the sustainable designed concepts.

The research outlined in this thesis was motivated by the fact that our empirical understanding of what users do with, and how they interact with products as well as the hidden factors behind the daily decision-making process is very limited. This research therefore aimed at gaining comprehension of user behaviour and ensuring an in-depth exploration of practical theory and effective strategy for Design for Sustainable Behaviour to reduce the household environmental impact.

1.2 Research Aim, Objectives and Questions

This section details the aim and objectives of the study and the research questions that are answered in this thesis.

1.2.1 Research aim

The overall aim of the study is to investigate how designers can influence user behaviour strategically through design interventions, in order to reduce the environmental impact of household appliances during use.
1.2.2 Research objectives

On the basis of the aim of the research, six objectives have been identified below:

1. To critically review substantial literatures and the secondary sources in relation to:
   - the driving forces of consumption and household energy consumption;
   - the barriers and enablers to pro-environmental behaviour;
   - the determinants of behavioural change in social psychological theory;
   - the current methods of moderating user behaviour;
   - the behavioural change determinants for application in a design context.

2. To investigate the potential design interventions for sustainable behaviour, linking existing theories and behaviour models to the sustainable product design domain;

3. To identify the relationship between household appliance consumption and its environmental impact, selecting a household appliance group as a case for further exploration;

4. To examine environmental impact resulting from the use of the selected case (household cold appliance) and to explore the capacity of a designer-conducted user study to identify environmental problems of product use;

5. To redesign the selected case, the fridge, to explore how design behaviour intervention could influence user behaviour to reduce the environmental impact of use through:
   - Investigating the effects of the more detailed observational methods on the design outcomes;
   - Exploring the effects of the more detailed behaviour intervention approaches on designing behavioural change;
   - Evaluating the effectiveness and the acceptance of the selected design concepts on behavioural change with target users;
   - Documenting the design process, techniques adopted and design outcomes for the subsequent analysis and generating the design case as illustrative examples of how design behaviour interventions could reduce the use impacts on environment;

6. To develop guidance to assist designers in implementing Design for Sustainable Behaviour strategically in future design processes.
1.2.3 Research questions

Four research questions will guide the research activities and ensure that the research aim and objectives can be achieved:

1. Why do householders use energy in an unsustainable way?
2. How do people use energy-consuming household appliances?
3. How can sustainable product design change user behaviour and habits?
4. How do users evaluate the improved design concepts (their acceptance and perceived effectiveness of applying design-led interventions to decrease environmental impact of household energy consumption)?

1.3 Scope and Direction

This design-led research into behavioural change targeted industrial user product designers with a common interest in sustainable product design. The intention of this study was to explore the potential of Design for Sustainable Behaviour to change user behaviour through design-led solutions towards more pro-environmental household consumption practices. This provided clear boundary conditions for this research. Firstly, it narrowed the scope by focusing on the environmental problems resulting from direct household energy consumption, particularly household appliance use where individual user behaviour was a significant factor. Secondly, a broad overview of Design for Sustainable Behaviour was built by reviewing a comprehensive range of literature from diverse disciplinary fields and providing illustrative examples of redesigned household appliances. It was also felt that this research would benefit more by having a broader scope, contributing to evolving the seven design approaches for behavioural change on the “design-behaviour” website (Lilley 2008) which was specifically developed to support designers and engineers not only to tackle the environmental but also the social impacts of products during use.

The purpose of the Pilot Studies was to investigate the feasibility of conducting the in-depth user research for unsustainable usage patterns of household cold appliance. A small sample was involved in this phase with the correct research focus in order to prepare for the Main Study. Data was collected by multiple research methods from a wide variety of sources so as to provide a robust body of data. The scope of this phase was necessarily broad to ensure both a broad and deep understanding of the interaction and use processes. Two design activities were carried out: one examining the designer’s ability to respond to the design brief and the other applying the findings that emerged from the in-depth behaviour analysis and the model into the design process. The
selected outcomes from the design study were evaluated by a focus group to uncover the users' acceptance level of these concepts and the behaviour intervention approaches applied. Finally, it was emphasised that the design outcomes developed focuses on the possible effects of the Design for Sustainable Behaviour in combination with conceptual design rather than on technological feasibility. Theoretical and practical aspects of both energy and technology have also been taken into consideration during the whole research and design processes.

1.4 Thesis Structure

This thesis consists of a further nine chapters:

**Chapter 2 – Literature Review**
This chapter explores the literature surrounding consumption, household energy consumption and theories of changing user behaviour in order to form the basis for this research inquiry and gaps in existing knowledge. Finally, four research questions are identified that will be addressed throughout the research to investigate design for sustainable behaviour.

**Chapter 3 – Research Methodology**
This chapter explains the selection and justification of the methodology used for this research, in terms of the six elements: “paradigm”, “purpose”, “strategy”, “type”, “data collection techniques” and “analysis”. It discusses the establishment of the validity and reliability of the data gathered and presents an overview of the research study design.

**Chapter 4 – Changing Behaviour and Design Intervention**
Based on comprehensive literature in diverse disciplinary fields of enquiry, the Design Behaviour Intervention Model is established to bridge the social-psychological theories of behaviour and the behaviour intervention approaches. Seven potential approaches for influencing user behaviour through product design are proposed. A range of design concepts as the examples are identified to explain what the approach is and how to apply it within design.

**Chapter 5 – Case Study Product Selection**
This chapter presents a review of household appliances and the relationship between domestic product use and its environmental impact. A literature review is also conducted to explore the environmental problems associated with the increased use of selected test products.
Chapter 6 – Pilot studies
The pilot studies test the effectiveness of the data collection methods employed in user study, which aim to gain users’ perceptions of environmental issues and to explore mundane practice and routine related to the use of selected case, fridge and/or freezer.

Chapter 7 – Main study
This chapter describes the findings that emerged from the data analysis of the main user study, providing an insight into the type of information required by designers to reduce energy consumption in use. The research techniques designed for the pilot studies in Chapter 6 were used to collect information about the “actual” and “assumed” needs, the diversity in use context, the unsustainable and sustainable use patterns and the hidden factors behind the usage across a broader sample in the main study. It exemplified methods and processes for extracting design oriented information from the behaviour study in the early phases of energy efficient product development. The final section discussed the implications for the future design of household cold appliances.

Chapter 8 – Design and Testing
Two design studies aiming to reduce the environmental impact of the household fridge use are outlined in this chapter. Design Study 1 investigates how designers tackle designing for sustainable behaviour by applying user centred research techniques. Design Study 2 is a more detailed design project. It describes how the findings from the specific behaviour study and the Design Behaviour Intervention Model could offer design solutions with the aim of reducing use impacts. By holding a focus group, the outcomes from Design Study 2 are evaluated in order to investigate the users’ acceptance of these concepts as well as the behavioural interventions applied. These studies present the evidence to suggest feasible solutions for making a difference to user behaviour.

Chapter 9 – Discussion
The collective findings are discussed along with the usefulness and effectiveness of the Design Behaviour Intervention Model in Design for Sustainable Behaviour. Referring back to the substantial literatures, useful insights on primary findings have emerged: understanding users as a resource for carrying out a sustainable behaviour design project; the effectiveness of applying the social-psychological theory in the Sustainable Design domain; principles of improving effectiveness and acceptability of the behaviour interventions; and a guide for undertaking Design for Sustainable Behaviour.
Chapter 10 – Conclusion and Future Work

This chapter provides a brief summary of the research findings. It shows that the research aim and objectives have been met and reflects upon the limitations of this research and the contrition to knowledge made by this study. In view of this, areas for future research are identified.

On the following page, Figure 1.2 outlines the aims and outcomes of each chapter and gives a schematic overview of this thesis.
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Figure 1:2: Aims and outcomes of each chapter
2 LITERATURE REVIEW

This chapter reviews substantial literature to form the basis for this research inquiry and the gaps in existing knowledge are highlighted.

2.1 Introduction

This chapter explores the literature surrounding the consumption, household energy consumption and theories of changing user behaviour in order to answer Research Question 1: Why do householders use energy in an unsustainable way? As shown in Figure 2.1, the relevant literature spreads across many different fields.
It begins by introducing consumption and domestic energy consumption and uncovers the driving forces of consumption and the barriers to sustainable energy consumption behaviour. Then the theories are then compiled into behaviour and habit models in order to learn the psychological factors behind household energy consumption. Based on comprehensive literature in diverse disciplinary fields of enquiry, links between current knowledge of underlying behavioural determinants for application in a design context are recognised. Finally, this chapter identifies four research questions that will be addressed throughout the research to investigate Design for Sustainable Behaviour.

2.2 Consumption

Many theorists have indicated that simply emphasising economic success and using GDP as the indicator of quality of life, has caused the pleasure-seeking trends in the culture and society. Because of the prevailing ethos of individualism, consumerism and the construction of false needs, the world’s people have consumed as many goods and services since 1950 as all previous generations put together (Buchholz, 1998). The threat of the exhaustion of natural resources (Boyle, 1996; UNEP, 2002; Cooper, 2005), inequalities - a widening gap between the rich and poor and between countries and within countries (UNEP, 2002; Moll et al., 2005; Sustainable Consumption Roundtable, 2006) as well as globalised trends of consumption (Shove and Warde, 1998; Bergh et al., 2000; UNEP, 2002) have been widely debated in the general critique of user societies.

Consumption is not only purchasing, but developing routines and rituals of use and modifying the product concretely or symbolically. It involves the selection, purchase, use, maintenance, repair, disposal and recycling of any product or service, as opposed to their design, production and marketing (Koskijoki, 1997). The consumption patterns not only embody a concentrated reflection on the contemporary society that values and shapes the user behaviour but also discloses the complex relationship to material goods and services. Some of the social macro- and individual micro- levels driving forces for the increase in consumption are outlined below.

2.2.1 Factors driving consumption and life change

Increasing levels of affluence, rapid technology development and specialised and systemic trends in product design provide people sufficient abilities and opportunities to own what they want to own, leading users towards a more individualistic (Sanne, 2002; Jackson, 2005) and more hedonistic lifestyle (Vergragt, 1998; Buchholz, 1998).
Today, more people have the financial, temporal, spatial and physical abilities to procure goods and service (Gatersleben and Velk, 1998). This, coupled with demographic development, has multiplied consumption.

2.2.1.1 Economic development and levels of affluence

The gross national product (GNP) is widely seen as the single progress or welfare indicator of a country (Buchholz, 1998; Van der Wal and Noorman, 1998), although it has been questioned by many theoretical and empirical studies (e.g. Bergh et al., 2000) for not taking the environmental effects of economic activity into account. Rise in user purchases which makes up about two-thirds of GNP, or its equivalent, is considered as the principle measure of success (Sanne, 2002). To ensure economic progress, many Western governments have taken multiple measures to expand international trade, support technological development as well as guide users’ demands.

The growth in levels of affluence of users also greatly acts upon consumption (Van der Wal and Noorman, 1998). The real increases in incomes have developed into personal independence and individualisation that result in a steep increase in the number of the single households and the ownership of appliances, such as a TV, computer or telephone per household (Sanne, 2002).

2.2.1.2 Technological development and mass production

The consumption of devices and systems has accomplished the “democratising” transition (Manzini, 2002) from the luxury of the upper class to the normal for the common people. Mass production and technological efficiency have not only brought the reduction in the cost of manufacturing, the energy services, materials and labour to industry, but also the availability and accessibility of goods and services. People’s actual abilities and opportunities have improved through increases in productivity and falling prices (Buchholz, 1998; Gatersleben and Velk, 1998; Hertwich, 2005). It demonstrates the “metamorphoses of novelties from ‘toys’ to ‘instruments’, from ‘luxuries’ to ‘necessities’, from ‘pleasure’ to ‘comfort’ or from ‘sensation’ to ‘routine’” (Pantzar, 1999, 2005, p. 3).

Cheap mass production and rapid technological improvement, however, diminishes emotional attachment and labour value embedded in the products (Warde, 2002), resulting in a rebound effect (Sanne, 2002) or a psychological obsolescence (Cooper, 2004). People no longer cherish these items (Verbeek and Kockelkoren, 1997; Cooper,
The short life span and the high turnover through rapid innovation have accelerated resource and energy consumption.

### 2.2.1.3 Changes in product design

500-1000 new devices are estimated to emerge on the global market each day (Pantzar, 2005). The market is packed with specialised designed products, such as kitchen utensils, power tools and sporting goods. More and more items are designed for each application and no longer interchangeable (Shove and Warde, 1998). In addition, rapid technological improvements have forced product obsolescence. The household’s communication requirement and water and electricity consumption which rely on advances in innovation and technology is often systemic (Sanne, 2002). Firstly, replacement of older devices encourages the further acquisition and use of associated products (Shove and Warde, 1997; 1998), since it is important to ensure various interconnected products or components in a technical system work compatibly. Also, technological advancements place durable goods in an embarrassing position, since it may be more economical to replace older machines by newer ones.

Furthermore, consumer products integrate firmly with each other due to psychological and cultural needs as well as requirements of physical structure. Nowadays, a lot of commodities and their use have shifted from luxuries and conscious choices to a daily necessity. A single commodity becomes a component in larger systems of goods within lifestyles, homes, or neighbourhoods (Pantzar, 1999). Because of the systematic characteristics of consumer goods, the purchase and use behaviour of the product and its paraphernalia (by force) in daily life are losing their spontaneity and transforming initiative into passivity. For example, advances in technology have led to displacement of “old” with “new” technologies, records to CD’s and more recently analogue to digital TV. Replacement of the item (record to CD) requires replacement of other paraphernalia (players) thereby increasing the use of resources and curbing the life of the original product by forcing obsolescence. This leads to larger numbers of appliances purchased, used and discarded.

### 2.2.1.4 Changes in culture

Nowadays, owning a product seems not only a matter of using its function, but fulfilling the symbolic demands. In the competitive market, products do not stand out among other brands purely by providing superior functionality, since some of the symbolic actions have overridden basic needs (Jensen, 2008). As defined as "economy of
symbolic goods” by Bourdieu (1998), business is stepping up its efforts to improve sales by various product market strategies, such as advertising, promotion, intricate packaging and high added value.

The enrichment of material consumption has influenced individual expectations, desires, preferences and life values. Compared with the last generation, changes in culture of young adults are very much shaped by the instant mode of payment, mass media as well as government contribution. Since 1950s, the traditional ethic of self-denial and deferred gratification has changed into one of instant gratification (Buchholz, 1998). The availability of credit and loans encourages people to satisfy their desire immediately rather than wait (Buchholz, 1998; Gatersleben and Velk, 1998). Without saving-up money to by the goods, the emotional value of material goods has decreased (Walker, 2002). Consequently, the use of goods related to entertainment and personal development (Gatersleben and Velk, 1998) as well as the number of households have increased. User behaviour is becoming more individualised and more independent (Van Diepen, 1998; Sanne, 2002). In addition, culture changes are stimulated by business and mass media, such as commercial television, radio and magazines (Bergh et al., 2000; Sustainable Consumption Roundtable, 2006), which have made the definition of the typical happy family: owning a nice house in the suburbs with two cars and all the latest kitchen appliances. People eagerly embraced the opportunity to go into debt and enjoy the pleasure these goods and services could bring immediately (Buchholz, 1998). However, there seems to be no limit to people’s pursuit of comfort and enjoyment. It is argued that although the real user expenditure has more than doubled in the last 30 years, reported life-satisfaction has remained unchanged (Jackson, 2005).

2.2.1.5 Population size and demographic changes

The number of households has increased much more rapidly than the population. The divergence between the growth in the population and the number of household indicates that the average size of household decreased from 3.0 in 1961 to 2.4 in 2004 (Jefferies, 2005) and 2.3 in 2005 (Environmental Change Institute, 2005). In the UK, family life changing due to greater fragmentation (Mintel, 2007a) because of the high divorce rate and increasing number of “non-traditional” families. Only 7% of households in the UK contained more than four people in 2002, compared to 14% in 1971 (NS2004b in: Environmental Change Institute 2005). And the proportion of single-occupancy dwellings rose from 12% to 29 % over the period from 1961 to 2004.
(Jefferies, 2005). The demographic change and family dilution are assumed to have boosted consumption by multiplying the demands for kitchens, bathrooms, white and brown goods, etc. that each household requires (Sanne, 2002; Environmental Change Institute, 2005).

2.2.2 Motivation for consumption

Environmental benefits for the wider global community, compared with the individual desires and preferences, are not strong enough to motivate a different lifestyle (Jensen, 2008). The models discussed below may offer an explanation why a high proportion of users express a strong preference for eco-friendly goods and services, but there is still a gap between environmental values and user everyday action and locked-in occurrence (Sustainable Consumption Roundtable, 2006).

Multiple sociological and psychological motivators behind the consumption behaviour, such as seeking new pleasures and satisfactions, expressing self-identity, marking social status, hunting symbolic meanings of profession and more things besides, impel people to consume insatiable quantities of products and services. The theories about consumption are compiled into four models (Appendix 1, Table 1) in order to learn the psychological motivators behind consumption behaviour: Consumption as Well-being; Consumption as Social Classification; Consumption as Identity; Consumption as Meaning. The roles of material artefacts, such as cars, houses, fashions, gifts, trophies, photographs, not only include their purely functional values in satisfying needs for food, housing, transport, recreation and leisure, but also comprise the symbolic actions. These roles cause a range of complex, deeply engrained “social conversations” about status, identity, social cohesion, group norms and the pursuit of personal and cultural meaning as well as hedonic “dreaming” (Jackson, 2005; Sustainable Consumption Roundtable, 2006).

Some recent work in sociology suggests that a great deal of consumption in fact takes place inconspicuously as a part of the ordinary, everyday decision-making of individual consumers (Shove and Warde, 1998; Shove, 2004). Ordinary consumption (Appendix 1, Table 2) is not oriented particularly towards individual display or status seeking, but it is about convenience, habit, practice and individual responses to social norms and institutional contexts (Shove and Warde, 1998; Shove, 2003; Jackson, 2005). With the development of sociotechnical systems, the attention has been paid to the resources and resource (energy) efficiencies than to overall consumption. The relation of energy
consumption and the normal and ordinary practice and interaction with the products and service and technology will be discussed further in section 2.6.2.

The motives and needs behind habitual and conspicuous consumption are somehow transformed and promoted internationally in the process of consumption and the demand for energy and resources. Acquisition, novelty and the social significance of conspicuous consumption (Campbell, 1994), i.e. rational economic model, social classification model; self identity model, consumption as meaning, together with the ordinary consumption (Shove and Warde, 1998) escalate the level of consumption of commodities and create a larger environmental impact.

2.2.3 Progress towards sustainable behaviour

Sustainable consumption emerges from the concept of sustainable development, as defined in the Brundtland Report (World Commission on Environment and Development, 1987). The definition of sustainable consumption has been, and continues to be, interpreted in many different ways. But all imply the relationship not only between the human and the environment, but between the current and future generation, and their responsibility and contribution to the environment, the future and ourselves. As UNEP (2002, p. 18) stressed, “sustainable consumption is not about consuming less, but consuming differently, consuming efficiently and having an improved quality of life”. It emphasises that the efficiency could be gained from limiting the environmental impact of consumption and the way those goods and services are produced and delivered whilst enabling consumers to sustain current lifestyles. Although how sustainable consumption should be implemented in practice has yet come to a consensus (Jackson, 2004), the literature revealed a progress towards the sustainable change in consumer behaviour.

There is a wealth of evidences in the literature about public perceptions of climate change, demonstrating a near universal awareness of the issue. For example, only 2% of the English public have not heard of either “climate change”, “global warming” or the “greenhouse effect” (Co-operative Bank, 2005). Indeed, 7 out of 10 participants pointed out the main causes of climate change is due to human activities (DEFRA, 2002). The public have become more confident of their influence as consumers. 54% of people in 2004 agreed with the statement: “as a consumer, I can make a difference to how responsibly a company behaves” the study of Co-operative Bank (2005, p. 5).
In relation to people’s actual actions, people are increasingly willing to engage in the green consumerism and recycling. The market share for ethical products has grown by almost 40% in the past 5 years and the most significant growth in sales of energy efficient household appliances topped 50% of market share in 2003 (Co-operative Bank, 2004; Design Council, 2005); in 2007, approximately three quarters of the population regularly recycles household rubbish (DEFRA, 2007b). A high percentage of recycling is found than energy reduction behaviour (Whitmarsh, 2009). Of the minority of people who conserve energy, most do so for financial and health reasons rather than for environmental ones (DEFRA, 2002). More than a quarter of people could not link their behaviour and everyday lifestyle to climate change (DEFRA, 2007b) and 52% of people believe that climate change will have little or no effect on their personal life (BBC, 2004).

2.3 Household Energy Requirements

This section outlines the direct and indirect demand for household energy use and, further identifies some of the determinants of the household energy requirement and analyses the past changes in direct energy use of the residential sector at European level.

2.3.1 Household metabolic flows

Household metabolism is associated with the requirement for natural resources and the supply of materials and energy indirectly needed to accomplish these flows (Wilting and Biesiot, 1998). According to the study by Moll et al. (2005) which examines the average energy requirement of households in the Netherlands, the UK, Norway and Sweden, it is estimated that 70–80% of national energy use and greenhouse gas emissions may be related either to household activities directly or to activities required to deliver goods and services to households and to manage the waste flow they generate. To achieve sustainability, it is vital to balance the exploitation of natural resources, the generation of waste and the degradation of an increasing number of ecological functions (Van der Wal and Noorman, 1998).

Overall household energy consumption refers to both the direct and indirect demand for energy that determines the household metabolism (Moll et al., 2005). Figure 2.2 places the direct and indirect household energy requirements in the metabolism framework. The physical flows are summarised and numbered as follows (Van der Wal and Noorman, 1998, p. 37):
1. Direct energy consumption, i.e., the energy consumed directly in or by households (natural gas, electricity, motor fuel);
2. Indirect energy consumption, i.e., the energy embodied in consumer goods and services;
3. CO2 emissions related to direct and indirect energy consumption;
4. Domestic water consumption; and
5. Solid waste flows from households

Figure 2:2: Direct and indirect energy requirements of households and the household metabolism concept (flows 1-5 are described in the text) (adapted from Van der Wal and Noorman, 1998; Wilting and Biesiot, 1998; Moll et al., 2005).
2.3.2 Determinates of energy demand in the household

Household activities consume energy in both direct and indirect ways. There are three forms of household direct energy consumption: electricity for the use of white goods appliance and lights (lighting, cooling, washing, etc); natural gas (or electricity) for space heating, heating water, and cooking; and motor fuel for transport (Van der Wal and Noorman, 1998). Indirect energy use is related to the purchase of goods and services, which is the direct energy used by economic production sectors for production and delivery of these goods and service (Wilting and Biesiot, 1998). Table 2-1 presents the development and determinants of direct energy demand including heat and electricity in the UK since the 1970s which this research focuses on.

Table 2-1: Direct energy demand included heat and electricity since 1970s

<table>
<thead>
<tr>
<th>Energy carriers</th>
<th>Space heating</th>
<th>Water heating</th>
<th>Appliances and Lights</th>
<th>Data source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal, oil, coal gas</td>
<td>1950, 90% of UK’s total primary energy was supplied by coal; 2003, 80% of homes used natural gas as heating fuel</td>
<td>Natural gas</td>
<td>Van der Wal and Noorman, 1998</td>
<td></td>
</tr>
<tr>
<td>1950, 90% of UK’s total primary energy was supplied by coal; 2003, 80% of homes used natural gas as heating fuel</td>
<td>DTI 2004 in: Environmental Change Institute, 2005</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Percentage of residential delivered energy consumption (electricity &amp; gas)</th>
<th>77%</th>
<th>23%</th>
<th>Environmental Change Institute, 2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>60%</td>
<td>20%</td>
<td>20%</td>
<td>Design Council, 2005</td>
</tr>
<tr>
<td>59%</td>
<td>24%</td>
<td>17%</td>
<td>DTI 2002 in: Energy Saving Trust, 2006b</td>
</tr>
</tbody>
</table>

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<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Per household</td>
<td>Remained stable (1970-2001)</td>
<td>Increasing number of households; Increasing income; Low energy prices; Low electricity price; Availability of central heating system; Availability &amp; purchase of domestic appliances; Insulation installed in dwellings; Energy use of per appliance; Higher indoor temperature; Use patterns</td>
<td>Environmental Change Unit, 1997; Van der Wal and Noorman, 1998</td>
<td></td>
</tr>
</tbody>
</table>
2.3.3 Household energy use since 1970s

After entering the 21st century the residential sector, together with industry and transport, is one of the largest contributors in the UK to the man-made climate change. Table 2-2 below shows the key facts about global atmosphere carbon dioxide emissions by the end user during 1970-2004 in the UK (DEFRA 2006). The domestic sector makes up around 30% of total UK energy demand (BERR, 2007), 29% of electricity use (DEFRA, 2006; Energy Saving Trust, 2006b) and more than a quarter (27%) of end-user carbon dioxide emissions (DEFRA, 2007a). At the household level, the efficiency of buildings, heating systems and household appliances use has improved by around 2% year on year since 1970 (Energy Saving Trust, 2006b). However, the increased use of appliances (section 5.2) and a liking for warmer houses has swallowed up the hard-won energy gains. As shown in Figure 2.3, the energy use in the residential sector has increased by 32% and electricity consumed by household domestic appliances and lights has increased by 70% (Environmental Change Institute, 2005) and is anticipated to rise by a further 12% by 2010 (Energy Saving Trust, 2006b). Due to this steady rise in energy consumption and apparent lack of public participation, the UK government announced in 2004 that it would not achieve its the national target of the Kyoto commitment – to reduce 20% of 1990 carbon dioxide emissions by 2010 (Environmental Change Institute, 2005) while the achievements in energy conservation of a number of other EU countries also fall short of their targets (European Environment Agency, 2006).

<table>
<thead>
<tr>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry</td>
<td>83</td>
<td>60</td>
<td>52</td>
<td>43</td>
<td>44</td>
<td>41</td>
<td>42</td>
<td>43</td>
</tr>
<tr>
<td>Domestic</td>
<td>54</td>
<td>48</td>
<td>42</td>
<td>40</td>
<td>42</td>
<td>41</td>
<td>42</td>
<td>42</td>
</tr>
<tr>
<td>Transport</td>
<td>21</td>
<td>28</td>
<td>38</td>
<td>41</td>
<td>41</td>
<td>42</td>
<td>43</td>
<td>43</td>
</tr>
<tr>
<td>Other</td>
<td>29</td>
<td>29</td>
<td>29</td>
<td>25</td>
<td>26</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Total</td>
<td>178</td>
<td>166</td>
<td>161</td>
<td>149</td>
<td>153</td>
<td>149</td>
<td>152</td>
<td>152</td>
</tr>
</tbody>
</table>

‘Other’ mostly consists of emissions from commercial and public sector
2.4 Factors Influencing Domestic Energy Consumption

This section provides a short review of trends in society, technology and product design that contributed the constant rise of household energy use over last 30 years.

2.4.1 Household numbers and size

The trend in household numbers and size is a key factor of energy consumption in the UK (Van der Wal and Noorman, 1998; Van Diepen, 1998; Environmental Change Institute, 2005; Moll et al., 2005). Due to the growth in disposable income and the emergence of the welfare state, there are more people choosing to live on their own rather than live as part of a family (Sanne 2002, Mintel 2007a). There are more single-generation and small households because of the individualised and independent trend in current culture. Evidence showed in Table 2-3 suggests that living together is much more economical and environmental friendly. For similar living standards the per capita demands in a two-person household are estimated to be two thirds of what a single person requires (Sanne, 2002; Moll et al., 2005).
Table 2-3: Overview of results for different household types in the UK (Moll et al., 2005)

<table>
<thead>
<tr>
<th></th>
<th>One pensioner</th>
<th>Two pensioner</th>
<th>single</th>
<th>Two adults</th>
<th>One adult &amp; children</th>
<th>Two adults &amp; children</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total energy intensity (MJ/Euro)</strong></td>
<td>14.4</td>
<td>14.4</td>
<td>11.9</td>
<td>12.1</td>
<td>14.1</td>
<td>12.1</td>
</tr>
<tr>
<td><strong>Total indirect energy intensity (MJ/Euro)</strong></td>
<td>7.7</td>
<td>8.7</td>
<td>7.5</td>
<td>8.3</td>
<td>7.9</td>
<td>7.9</td>
</tr>
<tr>
<td><strong>Total energy requirement per household (GJ)</strong></td>
<td>150</td>
<td>246</td>
<td>217</td>
<td>406</td>
<td>237</td>
<td>426</td>
</tr>
<tr>
<td><strong>Household size (persons)</strong></td>
<td>1.0</td>
<td>2.0</td>
<td>1.0</td>
<td>2.0</td>
<td>2.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.8&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Total energy requirement per person (GJ)</strong></td>
<td>150</td>
<td>123</td>
<td>217</td>
<td>203</td>
<td>85</td>
<td>112</td>
</tr>
</tbody>
</table>

Note: one megajoule (MJ) =10<sup>6</sup> joules (J, SI) =239 kilocalories (kcal)=948 British thermal units (Btu). One gigajoule (GJ) =10<sup>9</sup> joules.

<sup>a</sup>Data on household sizes of these samples were not available. The household size is based on the fact that the average number of children in the United Kingdom is 1.8.

2.4.2 Technical innovations and changes of usage pattern

Since 1970, our homes and products have become more energy efficient. But the increasing numbers of products and the advanced technological innovation they contain have brought a particularly sharp rise in domestic energy consumption. According to the data from Environmental Change Institute, UK residential electricity demand doubled from 44 to 89TWh over between 1972 and 2002 (Energy Saving Trust, 2006b). Many items that were luxuries for only a few in the 1970s are now very common. Ownership of home computer has increased from 0% in 1981 to 67% in 2005 (Market Transformation Programme, 2006). Daily use of the TV increased by 13% between 1995 and 2005 (Boyny, 2006).

The scientific and technological development and product design has also affected the trivial scenarios of our lives and our ways of using products. For example, today people who have air-conditioning often keep the windows shut in the summer. They keep cool in private rather than spending time outdoors on verandas or porches (Shove, 2003).

What is more, the rebound effect occurs when saving energy or natural resources per unit of production and consumption results in lower costs which encourage increased consumption (Sanne, 2002). Advanced technologies make household activities more efficient, offering people the opportunities to enjoy a more comfortable life. Many
Housekeeping tasks (heating, laundry, bathing and cooking) have become easier and less time-consuming with the help of these time-saving products (Gatersleben and Velk, 1998). However, people consume more energy because they think that the equipment that they are using is more energy efficient, thereby using it more often and for longer periods of time (Manzini, 2002; van de Velden, 2003b; 2003a). The modern lifestyle has the characteristics of high speed and unlimited space which add to energy consumption (UNEP, 2002). This inconspicuous trend in the product use stage constitutes a significant environmental problem (Shove and Warde, 1997; Shove, 2003) that will be further discussed in section 5.2.

2.4.3 Product design and rise of household energy consumption

Specialised products have replaced multipurpose items (Sanne, 2002). In the past, one simple product was employed for many purposes, while nowadays different products are available for different uses. Items such as kitchen utensils, power tools, are designed for each application and “no longer interchangeable” (Shove and Warde 1998, p. 7). These trends stimulate a bulk purchase of specialised designed items and the direct energy use in the household. Lack of clear design regarding use has also resulted in the continuing demands for energy. Shove and Warde (1998) identified that it is essential to learn the conventions and habits of users and to understand the methods that influence the user behaviour, such as the ways in which central heating systems are used, or the frequency with which washing machines whirr. The proper design, such as providing the “affordances” (concerning the way that a designer uses the physical characteristics of a product to prescribe a desired behaviour), “constraints” (concerning the way that a designer uses to limit the behaviour to the perceived operation of a device) (Norman, 1998) may influence the use patterns and encourage the "proper" use of gadgets, objects or services in order to reverse this current situation.

2.5 Barriers to Efficient Energy Consumption

Having examined some trends in society, technology and culture and the factors for continued energy demand in the household, it is important to find out what the more specific causes are that may prevent energy-conscious practices taking place.

2.5.1 Invisible nature of energy and resource

People often only care about the performance of products (Verbeek and Kockelkoren, 1997; Linscheidt, 1999) rather than the energy and the resources that it takes to operate
the products. Borgamn, as discussed in Verbeek and Kockelkoren (1997, p. 114), identifies two elements of products: “machinery - the device as a physical object and commodity-the result it produces when it functions”. The consumables including the energy, resources and associated products should be considered as the third element of the product. Figure 2.4 demonstrates the relationship between three elements of products and the designers and the user. Designers make efforts into improving the results of the object, service and system to meet “insatiable” expectations of users. Products do not invoke the users’ emotional engagement with them as visible physical objects. The invisible nature of energy (gas and electricity) supplied for functioning the equipment not only leads to users’ disregard of use but also curbs more circumspect research or creative design concepts to improve efficiency of energy.

![Figure 2.4: Relationship between designers, users and three elements of products](image)

The attention towards invisible consumption of consumables should not only be built for users to reflect on their use but for designers to limit the environmental impact of product at the conceptualising stage.

### 2.5.2 Unawareness of the link between energy use and its environmental impact

User understanding of the exact causes and manifestations of climate change is far too limited to make a link to their daily lives and energy use in the home (Holdsworth, 2003; Co-operative Bank, 2005; Sustainable Consumption Roundtable, 2006). To build the bridge between effects and use habits, it is important to provide information to describe what action would negatively lead to environmental consequences (Holdsworth, 2003; van de Velden, 2003b; Stuart, 2006). It has been proven in recent projects (Boardman, 1995 and Vowels, 2000 in: Environmental Change Institute,
2005; Moll et al., 2005; Stuart, 2006) that energy saving can be gained by providing information and feedback through electricity bills and energy display meters. When people were made aware of their situation, they took action.

2.5.3 Careless attitudes towards energy

According to the report from Energy Saving Trust (2006a), 86% of users feel guilty about the amount of energy they use, but 42% cite laziness rather than lack of awareness as the main reason for their bad energy habits. Verplanken (Verplanken, 2005) analyses this as users’ being simply forgetful. However, the appropriate short-run rewards and incentives need be reinforced to encourage the long term changes to careless attitudes towards energy.

2.5.4 Disempowerment of big change

It is hard to take practical action if users do not believe individuals can make a difference. The government has been finding ways to reduce user environmental impact through cause-related information campaigns. However, the public has been flooded with “global level” messages which have failed to significantly change behaviour (Jackson, 2005). The issues are too large and too complex and users do not think that they can make a difference at an individual level (ESRC Global Environmental Change Programme, 2000, Dawnay and Shah, 2005).

2.5.5 Lack of trust

Clear and reliable information should be provided for people to access adequately and equally (Jackson, 2005). Users “are confused by current information and options and lack trust in information providers” for some cases (Design Council, 2005). With regard to energy labels for domestic appliances for example, there are three “good” categories in the current market. However, instead of reclassifying the categories, two further categories, A+ and A++, are added and of the original category A, left in place. This weakens the effect of the label and is also confusing for users (Environmental Change Institute, 2005).

2.5.6 Lock in lifestyle

Theoretically, new domestic appliances with efficient technological improvements could reduce energy consumption, but increased efficiency may not mean a reduction in consumption. The core problem is how they use the energy efficient appliances
(Shove and Warde, 1998, Shove, 2004). As discussed in sections 2.2.1 and 2.2.2, translating the excessive consumption pattern into daily life becomes the invisible and inconspicuous energy use habit. Although technical researchers have gone to considerable lengths to record domestic energy consumption, they are generally concerned with the end result, rather than the process. This leaves a real gap in our understanding of how best to influence user behaviour when undertaking domestic activities through product design.

2.6 Understanding User Behaviour and Habits

Focusing on individual behaviour, a number of theories try to answer the question: what factors contribute to behavioural change.

By analyzing some selected behaviour models, intention, habits and controls are considered important to antecedents of behavioural change (section 2.6.1). This study is followed by a more comprehensive survey into the use behaviour of energy-consuming products and services (section 2.6.2). Literature suggests that most of the practices ingrained in our life patterns associated with the operation of the household appliances exhibit a habitual and routine nature. Strategies for fostering behavioural change in social-psychological theories are discussed in section 2.6.3. UK policies and programmes that have been enforced to reduce domestic energy consumption are reviewed in section 2.6.4. By comparison, relatively little attention of the current measures has been paid to the habitual nature of use behaviour of products and services. In addition, policy measures and technological improvements may be not sufficient to affect and sustain the change in the routine use and interaction with the household appliances, in order to deliver a reduction in the domestic energy consumption.

2.6.1 Behaviour models

It is challenging to get to grips with the driving forces of user behaviour (Jackson, 2005; Sustainable Consumption Roundtable, 2006) related to a complex set of underlying factors which are often contradictory. This section cites a number of conceptual models to help understand what motivates user behaviour, drives behavioural change and provides heuristic frameworks for exploring and conceptualizing user behaviour to identify points of design-led intervention.
The literature review in social sciences revealed two perspectives in the debate of motivating the consumption behaviour change - external and internal elements. Jackson concludes internal antecedents of behaviour as being: values, attitudes, intentions, habits and personal norm; external factors as being: fiscal and regulatory incentives, institutional constraints, social practices and cultural order (Jackson 2005). The core question is: are users free to make decisions about their own actions or are they restricted by forces outside their control?

Sanne (2002, p. 275) proposes that “in the discipline of economics, consumption is an individual choice among different ways of acting to optimise one’s benefits”. Cogoy (1999, p. 386 in: Shove, 2003, p. 3) emphasises the internal determinants of consumption behaviour, since it is “the way in which individuals organise their lives”. In this theory, user behaviour is regarded as the “important contributions to the enjoyment of their lives”, which is “not a law of nature, but a cultural phenomenon”. Yet others have observed that peoples' routines and expectations are not freely chosen but institutionally determined or guided by external influences (Moisander, 1997a; UNEP, 2002; Jackson, 2004). Non-stop society forces users to adopt lifestyles which are unsustainable (Reisch 2001 in: Shove, 2003). Individual behaviours are deeply guided by what others around us say and do (Sustainable Consumption Roundtable, 2006). Jackson (2005) ascribes that there is a gallery of more than fifteen different influences for “locked-in” occurrence; however, it implies that to understand behaviour we should take a multi-dimensional view incorporating both external and internal perspectives.

A number of theories attempt to construct integrated models. In 1984, Giddens’ “structuration theory” presents (Figure 2.5) the relationship between the human agency (how people act) and social structure (the social and institutional context). This theory draws a distinction between “practical” consciousness - the everyday knowledge that people have about how to do things and “discursive” consciousness - social conditions of the action. It is evident that the intentional or goal-oriented behaviours require elaboration in discursive consciousness (Jackson, 2005) and this distinction helps understand social psychological factors behind routines and habits.
In Figure 2.6, the theory of planned behaviour (Ajzen, 1991; 2006), an extension of the theory of reasoned action (Ajzen and Fishbein, 1980), illustrates beliefs, attitudes, the subjective norm together with perceived behavioural control as explanatory factors of human behaviour. Also, the actual behavioural control received by individuals, as the external elements affect the ease or difficulty of performing the particular behavioural. However, some key elements in the social psychology of behaviour are still left out, such as affective (emotional) and cognitive (e.g. habitual) dimensions of people’s behaviour (Jackson, 2005).

Triandis (1977) proposes an integrated model of interpersonal behaviour (Figure 2.7). It not only includes social factors and emotions in forming intentions but also highlights the importance of habits as a mediated factor of behavioural change. Bagozzi and Warshaw (1990) develop the theory of “trying” (Figure 2.8) to demonstrate “trying” as being mediated by the intention to try and to explain user behaviour which includes both the “frequency and recency of past behaviours” (Dawnay and Shah, 2005;
Jackson, 2005, p.100). For the behaviours that are expensive or difficult, contextual and personal capabilities such as the knowledge and skills, are likely to account for more of the causes (Stern, 2000) of attitudinal changes. When attitudes and intentions become less predictive of future behaviour (Verplanken and Faes, 1999; Verplanken, 2005), habits become the main driving force of behaviour. When behaviour is challenged by motives or other driving forces, the accomplishment of wishes and desires which attitudes and intentions are aimed at might be interfered (Verplanken and Faes, 1999). Figure 2.10 demonstrates that behavioural change involves the discursive process of habit formation and change developed by Dahlstrand and Biel (1997 in: Jackson, 2005).

Figures 2.8, 2.9 and 2.10 present that the understanding of behaviour formation and disintegration are established on the basis of the theories of Triandis (1977 in: Jackson 2005), Ajzen (2006), Sten (2000), Bagozzi and Warshaw (1990 in: Jackson 2005) and Dahlstrand and Biel (1997 in: Jackson 2005). As is shown, intention, habits and controls are considered important immediate and mediate antecedents of behaviour change.
Figure 2:8: Bagozzi and Warshaw’s theory of trying (in: Jackson, 2005)

Figure 2:9: Compiled behaviour model of Triandis’ theory of interpersonal behaviour, Ajzen’s theory of planned behaviour and Stern’s causal variables influencing environmental significant behaviour

Figure 2:10: Habit formation and change (Dahlstrand and Biel, 1997 in: Jackson, 2005)
2.6.2 Habits - environmentally significant consumption behaviour

Energy Saving Trust (2006b) indicates that although users express strong concern about the environmental impact of their activities in the household, their actions do not reflect their concerns.

In reality, the practices ingrained in our life patterns, which are “highly automated” (Jackson, 2005), performed with a minimum of deliberation or little cognitive effort and often only limited awareness (Verplanken and Faes, 1999; Warde, 2002), become habitual. Meanwhile, attitudes, norms and perceived behavioural control become less useful for changing specific behaviour and people attend less to contextual information (Verplanken and Wood, 2006). Therefore, ordinary consumption is not display or status oriented but about convenience, habit, practice, and individual responses to social norms and institutional contexts (Jackson, 2005). As the studies of Verplanken and Wood (2006, p. 20) showed, “approximately 45% of respondents’ everyday actions were habits in the sense that they were performed almost daily and usually in the same location”.

Levels of demand and patterns of consumption are the outcome of technical systems and practices (use of the products and services) (Shove, 2004). On one side, the daily routines and practices develop alongside the technological facilities and equipment on which they depended (Shove and Warde, 1997; 1998). On the other side, the design and use of the consumer goods and services influence the development of associated practices and patterns of demand. Routines, habits and conventions alter as new technologies and products are possessed and used. For example, the standards of cleanliness and conventions have been shaped by the popularisation of washing machine (Shove, 2003). On average, people use a washing machine 274 times a year per household in the UK (DETR, 2000).

Much of the literature (e.g. Margolin, 1997; Pantzar, 1999; Shove and Warde, 1999; ESRC Global Environmental Change Programme, 2000; Shove and Warde, 2002; Dawnay and Shah, 2005; Jackson, 2005; Energy Saving Trust, 2006a) argues that ordinary consumption has a significant environmental impact in terms of energy and resource consumption. It is argued that what users do with, and how they use, their electrical appliances is important (Shove and Warde, 1997). Habitual and routine behaviour contributes to the awareness - intention - behaviour gap between environmental values and everyday interaction with individual electrical appliances and locked-in occurrence in household energy consumption.
2.6.3 Fostering behavioural change

The following points explore and discuss some of the methods and theories developed by sociologists and psychologists to encourage pro-environmental user behaviour.

2.6.3.1 Information and persuasion

Three critical structural elements in the success of persuasion strategies are identified: the credibility of the source, the message and the thoughts/feelings of the receiver (Jackson, 2005). Information campaigns and education strategies have been commonly used by policy-makers to draw the public interest and to change either attitudes or behaviours in a pro-environmental direction (Jackson, 2005; Lorenzoni et al., 2007). These include informing users of the consequences of their actions and urging them to behave differently (Shove, 2003). However, in today’s message-dense environment, information often remains unclear to users what actually is the correct thing to do (Moisander, 1997c). Persuasion and exhortation probably result in higher knowledge levels (Abrahamse et al., 2005), but are difficult to ensure people’s long term engagement (Jackson, 2005) or energy savings.

2.6.3.2 Learning by ourselves

Learning from indirect experience by observing others (e.g. parents, peers) and direct experience from trial and error, as well as the consequence (e.g. punishment and reward), is considered as a more powerful avenue of behavioural change than information and awareness campaigns (Jackson, 2005). Firstly, there is a natural tendency to imitate behaviours of people around us (Sustainable Consumption Roundtable, 2006), particularly in more complex situations in which we are unfamiliar and within social groups which we belong to in order to communicate with others and identify ourselves (Dawnay and Shah, 2005). Specially, for altruistic actions (e.g. avoiding driving, recycling), an individual’s engagement is more reliant on conducive circumstances (Lorenzoni et al., 2007). Furthermore, learning by trial and error ourselves rather than pure imitation of others is applied commonly to induce users to adopt pro-environmental actions, such as the carrot and stick approach. It is argued that if the user is “punished for buying incandescent light-bulbs and rewarded for buying fluorescent ones”, he or she will “end up avoiding incandescents and buying fluorescents” (Jackson, 2005, p. 98).
2.6.3.3 Feeling in control and helplessness

When users feel in control, they can be highly motivated and effective in changing things for the better. People’s judgments of their capabilities to organise and execute the courses of action enact a powerful influence on engagement (Bandura, 1977, in: Dawnay and Shah, 2005). Therefore, it is important to offer them the necessary resources (ability) and opportunities (Moisander, 1997c) and adopt a participatory approach to keep the right balance of information and choice afforded (Dawnay and Shah, 2005). Either too much information or too many choices can lead to a feeling of helplessness and inaction. For example, it is impossible to foster engagement amongst the public by sending the information about climate change as “global level” messages as a distant threat in terms of time and space (Lorenzoni et al., 2007). A participatory approach was identified by Kaplan (1989, in: Jackson, 2005) to be more effective in encouraging behavioural change and making people happier to have a real sense of accomplishment of contribution to the environment. It was found that people are motivated when they:

- are aware of the reality and its causes;
- are engaged within the implementation of intervention or rule, e.g. to learn, discover and explore at their own pace and answer their own questions;
- participate and play a role in what is going on around them.

This implies that designers have the ability to enable or facilitate behaviour through providing the sustainable designed products as the external factors to do so. The questions posed by these findings are therefore: how designers can connect users to a level where they are stimulated to consider more than their own immediate world; how designers justify the degree of the power of control which is delegated to the product or is left to the user (Akrich, 1992).

2.6.3.4 Emotional motives

Specific emotions can serve as commitment devices (Jackson, 2005), such as feeling guilty for acting irresponsibly or being worried about the future wellbeing of his/her children. This functions as a psychological incentive which helps green users to resist the lures of “free-rider” behaviour and defensive denial of responsibility (Moisander, 1997b). In a design sense, materials, colours, textures and visual cues can and have been employed to evoke a sense of nature, but not responsibility or values relating to environment.
2.6.3.5 Breaking “bad” habits

Both from the literature and from most people’s personal experience – those counter-intentional habits are exceedingly hard to break (Linscheidt, 1999; Verplanken and Faes, 1999). Firstly, these ingrained behaviours are the process of routinisation of everyday behaviours which are less obvious to understand and less accessible to intervene in (Jackson, 2005). Secondly, habits are “automatic acts” which are operating outside awareness and are cognitively efficient (Verplanken and Faes, 1999).

Verplanken and Aarts defined (1999 in: Verplanken, 2004, p. 100) habits as “learned sequences of acts that have become automatic responses to specific cues, and are functional in obtaining certain goals or end-states”. Table 2-4 provides a closer look at some elements of the habits. The repeated behaviour need not be a habit (Ajzen 2002 in: Verplanken, 2004), since habit is in particular concerning the aspect of automaticity, i.e. the behaviour can be repeated but not “automatically”. “Frequency”, “automaticity” and “functionality” are the three aspects of habit structure which make habits too strong and durable to cope with (Verplanken, 2004).

Table 2-4: Definition of habits (based on Verplanken, 2004)

<table>
<thead>
<tr>
<th>Habits</th>
<th>Explanations of the feature as opportunities to break</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learned sequences of acts</td>
<td>A certain degree of practice is required for a habit to develop.</td>
</tr>
<tr>
<td>Automatic responses to specific cues</td>
<td>Habits have a history of repetition, whether this history is long and painful or short and easy.</td>
</tr>
<tr>
<td></td>
<td>Habitual acts are instigated as immediate responses to specific cues. Such cues can be anything, ranging from physical objects to time, geographical features, people, labels or internal cues like hunger or pain. Automaticity as a feature of habits is broken down into four possible components, i.e. a process or behaviour that: 1. occurs outside awareness 2. is difficult to control (but not impossible) 3. is mentally efficient (one can do other things in parallel), and 4. is unintentional (not so much in the sense of not being consciously planned, but rather in the sense of not being goal directed)</td>
</tr>
<tr>
<td>Functional in obtaining certain goals or end-states</td>
<td>Habits are developed to serve us and make our lives livable. Establishment and maintenance of behavior was a central theme.</td>
</tr>
<tr>
<td></td>
<td>Habits are created and maintained under the influence of reinforcement</td>
</tr>
<tr>
<td></td>
<td>Habits serve some goal</td>
</tr>
</tbody>
</table>

As discussed in 2.6.2 and 2.6.3, the rather linear model of persuasion has some significant limitations to bridging the intention - behaviour gap. One of many reasons for such a gap is that those who have developed strong habits are less likely to attend to
new information – “habituation leads to tunnel vision” (Verplanken, 2004, p. 103). This implies that it is important to understand the strength of habit and to design the interventions for each level of understanding and awareness. Table 2-5 presents a measurement instrument of habit strength developed by Verplanken and Orbell (2003 in: Verplanken, 2004). It is a 12-item scale called the Self-Report Habit Index (SRHI) and is used to monitor habit strength independently of actual behavioural frequency.

Table 2-5: The self-report habit index (Verplanken and Orbell 2003 in: Verplanken, 2004)

<table>
<thead>
<tr>
<th>(Behaviour X) is something:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1 I do frequently.</td>
<td>7</td>
</tr>
<tr>
<td>2 I do automatically.</td>
<td>8</td>
</tr>
<tr>
<td>3 I do without having to consciously remember.</td>
<td>9</td>
</tr>
<tr>
<td>4 That makes me feel weird if I do not do it.</td>
<td>10</td>
</tr>
<tr>
<td>5 I do without thinking.</td>
<td>11</td>
</tr>
<tr>
<td>6 I would require effort not to do it.</td>
<td>12</td>
</tr>
</tbody>
</table>

Responses can be given on seven-point scales anchored by agree – disagree. Some items may be adapted according to the nature of the behavior.

According to Lewin (1951 in: Jackson, 2005), the model of habitual change can be described in three levels - at the bottom level, existing “frozen” behaviours are unfrozen and shifted to a new level, and then a new behaviour is refrozen at the higher level. The model of habit formation and change created by Dahlstrand and Biel (1997 in: Jackson, 2005) echoes a similar sequence of processes and addresses specific factors - awareness of the need to change, consideration of alternatives and the evaluating of new behaviour (Dahlstrand and Biel 1997 in: Jackson, 2005). To encourage users to break old habits, two factors are suggested for consideration: repetition (how often the action is repeated) and reinforcement (the strength and frequency of the positive reinforcement received) (Dawnay and Shah, 2005; Jackson, 2005). Anderson (1982) identifies three stages in the formation of a new habit - the declarative stage, the knowledge compilation stage and final procedural stage. The cognitive script should be created for a new behaviour to develop and repeat so as to form a habit. Provision of the regular reinforcing reward as a consequence of a new behaviour is effective in reinforcing and solidifying the formation of the habit (Dawnay and Shah, 2005; Jackson, 2005; Sustainable Consumption Roundtable, 2006). Figure 2.11 was created to understand the process of habits formation. These principles could also be a useful starting point for interrogating the acceptability of interventions integrated in products aiming to change user behaviour towards more sustainable practices.
Figure 2:11: Breaking habits (inspired by Anderson, 1982; Verplanken, 2004; Jackson, 2005)
2.6.4 Current methods of influencing user behaviour

The people, business and government are responsible for players of a smarter, more sustainable change in the lifestyle. Figure 2.12 demonstrates the triangle of change. The methods and techniques applied by policy-makers and manufacturers to reduce the environmental damaging consumption are discussed below.

![Triangle of change: current UK policies and programmes affecting the residential sector](image)

2.6.4.1 Government Intervention

The Government has continued to seek active participation by consumers in the environmental debate through a range of information strategies. Users have to make the link between the information, their own behaviour and the environmental and social impacts. This makes it difficult to motivate a change in the majority of user behaviour. Whitmarsh’s research (2009) highlights the asymmetry of intentions and impacts, where exists a clear divergence between actions prescribed by policy-makers (i.e. energy conservation) and those taken by the public to mitigate climate change (e.g., recycling). The chosen government policy path has been ineffective in creating the long term behavioural shift needed to reduce the impacts of product use and has failed to deliver a reduction in carbon dioxide emissions in the residential sector.
Furthermore, to supervise the manufacturers, the government enacts policy strategies, such as regulation and legislation, to guarantee manufacturing processes more environmentally considered. Focusing a range of energy-using products, the policy measures are implemented to remove the least energy efficient appliances from the market (DEFRA, 2009). However, that efficiency is not carried into the use stage. Few policy actions address the responsibility of the manufacturers to regulate the appliance use behaviour after the point of sale. The information on the energy labels of energy-using products does not take the energy efficiency of user behaviour into consideration. The energy rating schemes themselves are partly responsible for the “rebound effect”. It is easier for manufacturers to achieve an ‘A’ rating by providing bigger appliances than smaller ones - a smaller appliance consuming the same amount of energy overall would have a higher kWh/litre value and receive a lower rating (UNEP, 2002; Environmental Change Institute, 2005; Parag and Darby, 2009).

2.6.4.2 Technological Innovation

There appears to be an acknowledgement that current efficient product design and technological innovation have gained some savings but will not be able to attain a reduction of energy and resource consumption and carbon dioxide emissions (Environmental Change Institute, 2005). Firstly, technological solutions, left out the declarative stage of the habit formation process demonstrated in Figure 2.11, are not enough to influence user awareness, relative social norms, values of consumption, and lifestyle aspirations and to create a profound change in energy intensive modes of consumption. Currently, energy efficiency is provided as one of the features of innovation. Users have to deliberately pick out the optimised settings from the numerous luxury options and they do not necessarily use them in an energy-efficient way. Take the eco-washing option on a washing machine for example, although it has been proved that new detergents produce the same quality of washing at lower temperatures (Unilever, 2000), 44% of people habitually wash clothes at 60 degree and 15% do at 90 degree (Energy Saving Trust, 2006a). Increasingly optional features and complex interfaces on household appliances cancel out intention of these designs. Are these functions created for providing “convenience” to the user, for offering energy efficiency “saving”, or really for suiting the assumed user “needs” and “taste”? The necessity of these functions needs to be taken in to the further research on usage patterns of household appliance.
Another problem with energy efficient inventions arises while technology is developing. Consumers often choose the “super” quality of performance rather than considering the secondary costs of the appliance, i.e. energy consumption and consumable prices, when they purchase the appliance. The relationship between the upgrade of TV sets and technology progress in televisions provides an interesting example. New technologies have made larger TVs a “must-have” product at home. The recent research by the Energy Saving Trust (2006b) shows that the rise in popularity of large plasma screens has contributed greatly to household energy consumption, as their on-mode consumption can be anything up to four times that of normal sized cathode ray tube (CRT) TV and six times of Liquid Crystal Display (LCD) TV (Environmental Change Institute, 2005). If half of British homes owned a plasma-screen TV, two nuclear power stations would have to be built for the extra energy demand (Smith and Jowit, 2006).

Pantzar (1999) argues that not only should environmentally harmful choices be averted from becoming routine, but unsustainable routines and practices which have already embedded in our lifestyle require de-stabilising. The review of behaviour models and theories for changing behaviour shows that relatively little attention of the current measures has been paid to the habitual nature of use behaviour of products and services. Policy measures and technological improvements may be not sufficient to affect and sustain the change in the routine use and interaction with the household appliances, delivering a reduction in the domestic energy consumption. The design of the products and services could play an important role in shaping the user perception, learning and interaction with the products and services. This affords the opportunity for the designer to affect the user behaviour and to challenge the habit formation. Through analysing the dynamics of consumer behaviour, behaviour changing interventions should be developed and classified into categories to respond to the three antecedents of behaviour change; intentions, habits and controls.

2.7 Changing User Behaviour through Sustainable Design

To begin to understand the ways in which the designers can change user behaviour, it is first necessary to understand how people understand, learn, use and interact with the energy-consuming products and services. This section discusses the significance and the potential way of engaging users in energy efficient product design. Section 2.7.1 presents a brief review of user centred design methods which the designers adopt to understand and deliver what the users want. By tackling the user behaviour to reduce the impacts of product use, it has been possible to broaden the scope of Sustainable
Design (section 2.7.2). An emerging field of Sustainable Design, Design for Sustainable Behaviour which aims to change user behaviour to reduce negative impact of use is introduced in section 2.7.2.1.

2.7.1 User centred design
In the 1980s, user centred design was firstly used in the area of human-computer interaction (Norman and Draper, 1986). This attempt places the needs and interests of users at the centre of the design process and focuses on the usability of computer design. With the emergent of user centred design, the field of design has shifted from designing static objects to designing user’s experiences and interactions with objects, environment and services (Fulton Suri, 2003). The recent discussions describe user centred design as a product design approach that involves users at every stage of the design process to enhance the usability of products and systems (Gulliksen et al., 2003; Abras et al., 2004).

User centred design approach concentrates highly on usability of the design outcomes in terms of the effectiveness, efficiency, safety of the designed products and the satisfaction of the users (Earthy et al., 2001). The users are actively involved in the design development process which includes stages of planning, understanding user requirements, specification of the context of use, generation of design solutions, testing and re-evaluating as required (ISO, 1999; Earthy et al., 2001). In this process, the designer acts as the facilitator and mediator and employs a range of innovative techniques, i.e. interview, observation, user trial, and scenario-of-use to identify “latent” user needs and to increase the use, success and performance of the designed product. According to Redström (2006, p124), the increasing popularity of ethnographic methods shows a need to have a better understanding of the users in order to create a “tight fit” between products and user’s experience and perceptions. The outcomes of the user centred design process enable users to use the products with minimum effort and complete the tasks with optimum efficiency.

2.7.2 Sustainable design
By the mid-1980s the term “green design” emerged (Madge, 1993) and focused on single issues of product environmental improvements rather than the overall environmental impact of a design (Lofthouse, 2001), such as the use of fewer materials or recycled materials (Verplanken and Faes, 1999). Ecodesign recognises as a more holistic approach which considers environmental issues at all stages of a product’s life.
cycle and encourages designers to think about new ways of doing things. Ecodesign was concerned with issues covered by Sustainable Design (Sherwin, 2000). Sustainable Design goes beyond consideration of environmental and economic issues all through the design process and also refers to the importance of considering social equality in design (Bhamra and Lofthouse, 2007).

Designers are in a position to shape the development of products and services which directly impact upon society and the environment (Papanek, 1971). The application of sustainable design can greatly reduce life cycle impacts of a product (Lewis et al., 2001). Literature indicates activities in the field have, to date, predominantly focused on reducing the impact of manufacturing and disposal. There appears to be a lack of conscious consideration on the role of design in affecting the inefficient product use.

2.7.2.1 Design for Sustainable Behaviour

Although behavioural patterns appear to be resistant to change, there is considerable evidence of radical technological and behavioural change in the uptake of product, such as mobile phones, plasma TVs, power showers, standby modes in electronic appliances and air conditioning in cars (Jackson, 2005). This highlights the potential for designers to influence and unlock environmentally harmful behaviours and habits and to promote a sustainable lifestyle.

Changing user behaviour through product and service design is a growing research area of concern. Some of the research focuses on sustainable scenarios and system-based solutions to help households move towards a sustainable development (Manzini and Jégou, 1998; Vergragt, 1998; Vergragt, 1999; Young et al., 2001; Manzini and Jégou, 2003). For example, Vergragt’s (1999) project - Strategies towards the Sustainable Household (1998-2000) - involved a broad range of society groups, such as the stakeholders, and was concerned about exploring strategies for creating a sustainable society through system design in three selected household functions, nutrition, clothing care and shelter. However, instead of designing for personal household appliances, these product-service system initiatives treat the household as the minimal unit, aiming to provide the public service to the whole community within the local area. As Vergragt (1999) states, the main part of these service-based provisions is to access user acceptance, since it is questioning that the service-based provisions may challenge the existing personal and societal values (Rodriguez, 2004) and cause more social problems. Other research on the application of individual owned product design for
sustainably behavioural change in both theoretical (Elías et al., 2008b; Elías et al., 2008c; Lockton et al., 2008; Pettersen and Boks, 2008; Pettersen, 2009) and practical dimensions are mostly at the conceptual stage. This includes research by Thompson and Sherwin (2001), van de Velden (2003b), Rodriguez and Boks (2005), Design Council (2006) and Lilley (2007) as well as the prototyping stage, such as the Static! Project by Interactive Institute (2004) and the Tyranny of the Plug Kitchen Machines (Van Hoff, 2003). However, few of the current design concepts or studies have taken the underlying behavioural determinants into consideration during the design processes. There is a lack of data on the users’ responses and effectiveness of the sustainable designed concepts.

The analysis of the literature reveals that the routinised use of energy remains both obscure and hard to describe. For example, it is difficult to articulate how often people take a shower without showing a damp towel and a less full bottle of shampoo or shower gel (Shove and Warde, 1998). Although technical researchers have gone to considerable lengths to record domestic energy consumption, they are generally concerned about the end result, not the process. The actual use of energy-consuming products and services is relatively unexplored by either social psychology studies or design research. This leaves a real gap in our understanding of environmentally significant practices of consumption (Shove and Warde, 1998; 2002) and sustainable design strategies that attempt to influence user behaviour during the use phase of a product, towards a more sustainable practice.

2.8 Conclusions

This chapter has reviewed literature in the fields that were found to be relevant to the general research topic, building up an understanding of the background and context of the research problems.

Firstly, the literature has partly answered Research Question 1 by positioning the energy use in the product life cycle and consumption. The life cycle of a product consists of resource extractor, manufacturing (design), distribution, sales, use and disposal or recycling. Consumption involves consumers’ selection, purchase, use, maintenance, repair, disposal and recycle of any product or service, as opposed to their design, production and marketing (Koskijoki, 1997). Consumers do make decisions conspicuously and inconspicuously when choosing or disposing of the appliances, attributed to the pursuit of wellbeing, social conversation, self-identity and symbolic meaning or even routinising habits. Ordinary inconspicuous practice is carried out
without conscious deliberation, regarding the energy consumption during the use phase for operating the device or using the service. The consumption of energy also belongs to the use stage in the life cycle of products which is largely determined by users’ behaviour (Environmental Change Unit, 1997; Sherwin and Bhamra, 1998; ESRC Global Environmental Change Programme, 2000; Rodriguez and Boks, 2005).

Increasing consumption of time-saving products has restructured people’s everyday life patterns through making housekeeping tasks easier, more comfortable and less time-consuming. The day to day invisible practices have shifted the meanings of comfort and the sense of well-being or normal standards, and changed the pace of life towards faster and more flexible. As a result, it increases the frequency of upgrade of the residential appliance and encourages “bad” habits and careless attitudes towards residential energy consumption constituting significant environmental stresses. Unlike other stages in the product life cycle and behaviours in the consumption the areas of household energy consumption, where users can make a significant contribution to sustainable consumption, are still largely unexplored (Shove and Warde, 1998; Lorek and Spangenberg, 2001).

According to the distinction between direct energy (the energy consumed for functioning the products and services) and indirect energy (the energy embodied in consumer products and services) consumed by the products and services (sections 2.3.1 and 2.3.2), Table 2-6 on the next page draws on the factors, consumption models, theories related to the use phase of household appliances in order to uncover the gaps in the existing theoretical research.

With the exception of the Environmental Change Unit (1997), Energy Saving Trust (2006a) and Elias et al. (2008b; 2008c), the effects of the use pattern on energy and resource consumption of household appliances have yet be tested and reported on publicly. In addition, excluding van de Velden (2003a; 2003b), Rodriguez and Boks (Rodriguez, 2004; Rodriguez and Boks, 2005) and the Static! Project (Interactive Institute, 2004), few design concepts have been created for changing users’ behaviour to reduce impacts of energy use in both theoretical and practical dimensions. In 2007, Lilley identified three approaches for design for sustainable behaviour, grounding this area which has drawn more recent attention (Elias et al., 2008b; 2008c; Lockton et al., 2008; Pettersen and Boks, 2008; Pettersen, 2009). However, design for sustainable behaviour is shown to be a new realm of sustainable design and the decision on how it is to be embedded in design processes needs to be made.
Table 2-6: Direct energy requirements in the household: influences, effects and relevant theories and design strategies

<table>
<thead>
<tr>
<th>Direct energy</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Macro-level factors</strong></td>
</tr>
<tr>
<td>Patterns of economic indicators; Demographic changes &amp; family dilution;</td>
</tr>
<tr>
<td>Disposable incomes; Ownership of appliances; Energy efficiency of products and services</td>
</tr>
<tr>
<td><strong>Micro-level factors</strong></td>
</tr>
<tr>
<td>Careless attitude towards energy, unawareness of the energy usage, lack of consideration of, lax attitude to energy saving, lock in lifestyle</td>
</tr>
<tr>
<td><strong>Consumption model</strong></td>
</tr>
<tr>
<td>Ordinary inconspicuous consumption</td>
</tr>
<tr>
<td><strong>Consumption behaviour</strong></td>
</tr>
<tr>
<td>Use</td>
</tr>
<tr>
<td><strong>Effect on the product life cycle</strong></td>
</tr>
<tr>
<td>Use phase</td>
</tr>
<tr>
<td><strong>Theory or report</strong></td>
</tr>
<tr>
<td>Habits of a lifetime(Energy Saving Trust, 2006a); 2MtC - DECADE: Domestic Equipment and Carbon Dioxide Emissions (Environmental Change Unit, 1997)</td>
</tr>
</tbody>
</table>

2.8.1 Informed research questions

The literature review addresses the gaps in current knowledge which have led to the development of the following research questions:

1. Why do householders use energy in an unsustainable way?
2. How do people use energy-consuming household appliances?
3. How can sustainable product design change user behaviour and habits?
4. How do users evaluate the improved design concepts (their acceptance and perceived effectiveness of applying design-led interventions to decrease environmental impact of household energy consumption)?

The literature has identified a number of reasons generally why unsustainable consumption occurs. In the following chapters the research will be taken further, by conducting a design case which will record the process of applying user centred research techniques to identify and reduce the negative environmental impact resulting from product. This ensures in-depth exploration of practical theory and effective strategy for Design for Sustainable Behaviour.
3 RESEARCH METHODOLOGY

This chapter outlines the methodological approaches and describes the selection and justification of the methodology for this research.

3.1 Introduction

Adopting an appropriate research methodology for an inquiry is crucial to the success of a research project. Methodology refers to the approach or paradigm that underpins the research (Blaxter et al., 2006), facilitating the most productive processes for achieving the stated aim and objectives. “Paradigm”, “purpose”, “strategy”, “type”, “data collection techniques” and “analysis” are the six key elements needed to be considered during the research design stage. Figure 3.1 refers to the elements taken into account when a research process is configured.

![Diagram of research design elements]

Assumptions adopted towards truth, reality, knowledge, and how knowledge is to be used

Research paradigm
- Positivism and Post positivism
- Constructivism / Interpretivism
- Critical Approaches Feminist and other Emancipatory approaches

Research Design

Research Purpose
- Exploratory
- Descriptive
- Explanatory
- Emancipatory

Motivations for carrying out a research study

Research Strategy
- Fixed research design;
- Flexible research design.
- Case study
- Ethnographic study
- Grounded theory study

Choices with respect to how research is to proceed

Research Type

Quantitative Research/ Data

Qualitative Research / Data

Data Collection
- Questionnaire;
- Interview;
- observation;
- Customer Diaries;
- Scenarios;
- Co-creation...

Data Analysis
- Data reduction
- Data display
- Conclusion Drawing
  /Verification

Techniques for the analysis of data

Figure 3.1: Elements constituted a research design (Hiles, 1999; Robson, 2002b).
This chapter reviews available research methodologies and justifies the approaches taken within the research project, in terms of the six elements listed above. It also details the establishment of the validity and reliability of the data gathered. The final section presents an overview of the research study design.

3.2 Research Paradigm

A research paradigm is a basic set of beliefs that guides action (Guba, 1990). All research follows a set of procedures that begin with a group of assumptions or a set of beliefs about the world and how it should be studied (Denzin and Lincoln, 2003). There are mainly three paradigms structuring research: Positivism and Post-positivism, Constructivism/Interpretivism and Critical Approaches (Feminist and other Emancipatory approaches) (Robson, 2002b). Table 3-1 summaries the understanding of these paradigms.

<table>
<thead>
<tr>
<th>Paradigm</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Positivism and Post-positivism</strong></td>
<td>This is the view that social research exists externally and objectively. The researcher and researched persons are independent of each other. The &quot;reality&quot; can be captured through the adoption of experimental, quasi-experimental, survey and rigorously defined qualitative methodologies.</td>
</tr>
<tr>
<td><strong>Criteria</strong></td>
<td><strong>Form of Theory</strong></td>
</tr>
<tr>
<td>Internal, external validity</td>
<td>Logical-deductive grounded</td>
</tr>
</tbody>
</table>

| **Constructivism/Interpretivism** | The reality is socially constructed and reproduced by people acting on their knowledge of it. The researcher focuses on understanding the multi-layered and complex realities, using a naturalistic set of research methods such as case studies, interviews and observation to acquire multiple perspectives. The research participants are viewed as helping to construct the "reality" with the researchers. Findings are usually presented in terms of the criteria of grounded theory or pattern theories. |
| **Criteria**                  | **Form of Theory**                                                                                                                                   | **Type of Narration** |
| Trustworthiness, credibility, transferability, conformability | Substantive-formal                                                                                                                                  | Interpretive case studies, ethnographic fiction |

| **Critical Approaches** | This view criticizes both the post-positivism and constructivism. The researchers are relatively powerful experts researching relatively powerless people and trying to find ways of over-coming this imbalance in power. Included in this category would be feminism, neo-Marxism, anti-racist and participatory approaches. |
| **Criteria**             | **Form of Theory**                                                                                                                                   | **Type of Narration** |
|                          |                                                                                                                                                |                        |
This research has largely involved the understanding of the individual’s values, attitudes, behaviour and motivation for behavioural change. Because of the complexity of behavioural phenomena, it would be difficult to find the “one reality” (Robson, 2002b, p.27) with controlled condition, observable in a scientific way, as the positivist and post-positivist approaches do. In addition, this research was centred on developing a design intervention strategy for sustainable behaviour, building a “conversation” between the researcher (designer as practitioner) and the research participants (users). The constructivist paradigm would be most appropriate, as it recognised that the knowledge is mutually created by the researcher and the participants, which would provide a more open room for both of them to co-construct the reality. The constructivist paradigm would be adopted in this study.

3.3 Research Purpose

Four motivations for carrying out a research study are classified as Exploratory; Descriptive; Explanatory (Robson, 2002b) and Emancipatory (Marshall and Rossman, 1999) (Table 3-2). Explanatory is particular related to an action perspective (Robson, 2002b).

<table>
<thead>
<tr>
<th>Exploratory</th>
<th>To find out what is happening, particularly in little-understood situations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>To seek new insights</td>
</tr>
<tr>
<td></td>
<td>To ask questions</td>
</tr>
<tr>
<td></td>
<td>To assess phenomena in a new light</td>
</tr>
<tr>
<td></td>
<td>To generate ideas and hypotheses for future research</td>
</tr>
<tr>
<td></td>
<td>Almost exclusively of flexible design</td>
</tr>
<tr>
<td>Descriptive</td>
<td>To portray an accurate profile of persons, events or situations</td>
</tr>
<tr>
<td></td>
<td>Requires extensive previous knowledge of the situation etc. to be researched or described, so that the appropriate aspects can be distinguished on which to gather information</td>
</tr>
<tr>
<td></td>
<td>Maybe be of flexible and/or fixed design.</td>
</tr>
<tr>
<td>Explanatory</td>
<td>Seeks an explanation of a situation or problem, traditionally but not necessarily in the form of causal relationship</td>
</tr>
<tr>
<td></td>
<td>To explain patterns relating to the phenomenon being researched</td>
</tr>
<tr>
<td></td>
<td>To identify relationships between aspects of the phenomenon</td>
</tr>
<tr>
<td></td>
<td>May be of flexible and/or fixed design.</td>
</tr>
<tr>
<td>Emancipatory</td>
<td>To create opportunities and the will to engage in social action</td>
</tr>
<tr>
<td></td>
<td>Almost exclusively of flexible design.</td>
</tr>
</tbody>
</table>
Design for sustainable behaviour is a relatively new area that has not yet been addressed in detail by either the social-psychological theories or by sustainable design research practically or theoretically. This research did not intend to prove or disprove the existing knowledge, but instead to build understanding about what is happening in order to develop and test a strategy that could assist designers to improve the current situation. Therefore, it was appropriate to adopt an exploratory research study, “to seek new insights, to ask questions, to generate ideas”, to create a theory based in the information collected (Robson, 2002b, p.59). This research was therefore exploratory in nature.

3.4 Research Strategy

Research strategy, the approach of putting “paradigms of interpretation into motion” (Denzin and Lincoln, 2003, p. 36), defines the framework of the project which decides how the inquiry is to proceed, including the way of gathering and analysing the empirical data (Yin, 1994).

The distinction between fixed and flexible research design offers an alternative way of thinking about basic research strategies. The main determinates that influences the choice is whether the research design can be pre-specified before the data collection stage (Robson, 2002b). In order to address the research aim and objectives, it is necessary to use a flexible research design, enabling the details of the research to evolve, develop and unfold as the research proceeds. The flexible research includes case study, ethnographic study and grounded theory study (Robson, 2002b), summarised in Table 3-3.

<table>
<thead>
<tr>
<th>Case Study</th>
<th>Development of detailed, intensive knowledge about a single “case”, or of a small number of related “cases”. An empirical inquiry that investigates a contemporary phenomenon within its real-life context using multiple sources of evidence. <strong>Typical features</strong>: selection of a single case (or a small number of related cases) of a situation, individual or group of interest or concern; study of the case in its context; collection of information via a range of data collection techniques including observation, interview and documentary analysis.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethnographic Study</td>
<td>Seek to capture, interpret and explain how a group, organization or community live, experience and make sense of their situation. <strong>Typical features</strong>: selection of a group, organization or community of interest or concern; immersion of the researcher in that setting; use of participant observation.</td>
</tr>
</tbody>
</table>
Grounded Theory Study

The central aim is to generate theory from data collected during the study. Particularly useful in new, applied areas where there is a lack of theory and concept to describe and explain what is going on. Data collection, analysis and theory development and testing are interspersed throughout the study.

**Typical features:** applicable to a wide variety of phenomena; commonly interview-based; a systematic but flexible research strategy which provides detailed prescriptions for data analysis and theory generation.

Grounded theory, a general methodology for developing theory, is grounded in data systematically gathered and analysed through the research process (Strauss and Corbin, 1994). Based on a comprehensive literature review in diverse disciplinary fields of enquiry, the Design Behaviour Intervention Model was developed by the researcher with the aim of assisting design to stimulate more sustainable actions. To identify the potential capability of design to change the energy use behaviour, an exploratory investigation of product use and its environmental impact was carried out through a case which generated a conceptual framework, hypothesising recommendations to improve the existing use patterns of the household cold appliance. Traditional (Design Study 1) and non-traditional (Design Study 2) design studies to reduce environmental impact of household fridge use were conducted, discussed and compared with an ultimate goal to form a body of theoretical knowledge. This research should not be simply seen as design research project (Schön, 1983; Scrivener, 2000), which emphasises gathering the relevant information from the practice-based design activity for theory generation. In Design Study 2, the researcher as practitioner took a subject stance and adopted the Design Behaviour Intervention model in the practical design processes. The practice helped the researcher as designer to frame the complex situation in identifying and solving some of the unforeseen problems that a design may have (Schön, 1983). The design process and its outcomes served as illustrative examples for the domain of design for sustainable behaviour. In this study, the researcher does not begin with a theory and then prove it but instead the area of study emerges from the most relevant themes (Strauss and Corbin, 1998). Therefore, the grounded theory approach, a flexible research design, was chosen as the research strategy used to collect and analyse the data, providing the framework for this project.

### 3.5 Research Type

Having decided the most appropriate research strategy for this project brief, the next consideration is to collect either quantitative and qualitative data, or a combination of the two. Table 3-4 sets out the perceived differences between the quantitative and qualitative research (Blaxter et al., 2006).
Table 3.4: Distinctions between quantitative and qualitative research (adapted from Oakley 1999, p. 156, cited in Blaxter et al., 2006, p. 65).

<table>
<thead>
<tr>
<th>Quantitative</th>
<th>Qualitative</th>
</tr>
</thead>
<tbody>
<tr>
<td>-Seek the facts/causes of social phenomena</td>
<td>-Concerned with understanding behaviour from actors’ own frames of reference</td>
</tr>
<tr>
<td>-Obtrusive and controlled measurement</td>
<td>-Naturalistic and uncontrolled observation</td>
</tr>
<tr>
<td>-Objective</td>
<td>-Subjective</td>
</tr>
<tr>
<td>-Removed from the data: the “outsider” perspective</td>
<td>-Close to the data: the “insider” perspective</td>
</tr>
<tr>
<td>-Ungrounded, verification oriented, reductionist, hypothetico-deductive</td>
<td>-Grounded, discovery oriented, exploratory, expansionist, descriptive, inductive</td>
</tr>
<tr>
<td>-Outcome-oriented</td>
<td>-Process-oriented</td>
</tr>
<tr>
<td>-Reliable: hard and replicable data</td>
<td>-Valid: real, rich, deep data</td>
</tr>
<tr>
<td>-Generalisable: multiple case studies</td>
<td>-Ungeneralisable: single case studies</td>
</tr>
<tr>
<td>-Particularistic</td>
<td>-Holistic</td>
</tr>
<tr>
<td>-Assumes a stable reality</td>
<td>-Assumes a dynamic reality</td>
</tr>
</tbody>
</table>

Quantitative research produces the findings that have been recorded numerically (Punch, 2005) by statistical procedures (Strauss and Corbin, 1998). Qualitative research is concerned with collecting and analysing information in many forms, chiefly non-numeric. Qualitative researchers are interested in the complexity of social interactions in daily life (Marshall and Rossman, 1999) and focuses on exploring smaller numbers of instances in detail with the aim of achieving depth rather than breadth (Blaxter et al., 2006).

To address the research objectives, in particular to examine environmental impact resulting from the use of the selected case (household cold appliance) and to explore the capacity of a designer-conducted user study to identify environmental problems of product use (section 1.2.2), it would be necessary to collect qualitative data. The intricate details of phenomena would be difficult to convey with quantitative methods (Strauss and Corbin, 1990) as they are generally distant from the data (Blaxter et al., 2006). Therefore, this research was qualitative.

### 3.6 Research Methods

In traditional social field studies, the rich data can be collected from multiple sources: questionnaires, observations, conversations, formal interviews, autobiographies, public records, organizational reports, respondents’ diaries and journals and the researchers’ tape-recorded reflections. For designing a product, user centred design methods are commonly used to gain information about users’ perceptions and their use experiences.
To identify suitable tools for this sustainable design research, all these methods for a qualitative inquiry and user centred research design are sorted into three groups; interview/survey based, observation based and scenario based.

The research was multi-disciplinary and multi-method. As the research proceeded, different research methods were applied in different research phases to meet each research objective. Objective 3 and 4 (section 1.2.2) aimed to understand the current situations and to seek for new insights. The Product-in-Use method (Evans et al., 2002) was used to approach data collection for the selected case. In the phase of design and testing, participative research methods were adopted to lay an empirical foundation for the theory. This enabled the researcher as practitioner to be involved in the improvement of the situation (Robson, 2002b) and contribute directly to the on-going practice (Scrivener, 2000). Having identified the problems of the real world, the results were used by the researcher engaged in the development of the design concepts, ensuring that the solutions could reflect the actual needs of the user. Responding to Objective 5 (section 1.2.2), the emerging concepts were tested by the target users and the feedback contributed to the validity of the theory for its wider applicability and effectiveness in reducing the household environmental impact. The user focus group brought out a richness of information which could compensate the absences from other research methods. A more relaxed atmosphere initiated more candid responses, and comments made by one participant often inspired ideas from others (Robson, 2002b). The chosen techniques for each research activity are to be detailed in later sections (observations, questionnaires and semi-structured interviews in sections 6.2 and 7.3; the focus group in section 8.3).

### 3.7 Data Analysis

The data analysis techniques adopted for this research were based on the grounded theory approach. An important element of grounded theory research is keeping a balance between science and creativity (Strauss and Corbin, 1998). Being scientific means to maintain a certain degree of rigour during the categorising and extracting the masses of unorganised raw data into an integrated and realistic scheme in a creative approach. Miles and Huberman (1984) provide a systematic framework for conceptualising and classifying qualitative data.

A variety of analysis methods facilitate interpreting the data and developing the conclusion of the body of the research. A brief summary of possible analysis methods are outlined in Table 3-5.
Data analysis occurred four times within the project. In general, coding, mapping and clustering were used to deal with the data from the Pilot Studies (Chapter 6), the Main Study (Chapter 7) and the user focus group (Chapter 8). Having completed the assessment sheet for Design Study 1 (Chapter 8), the raw data with similar patterns or characteristics was clustered to draw the conclusion. The procedures for analysing the four were described in detail in the relevant sections.

### 3.8 Sampling

The sampling plan varied in different phases of this research. Purposive sampling was used in the user studies and testing focus group. This method is based on the judgement of the researcher regarding the selection of subjects who represent the population being studied (Robson, 2002b). In the Pilot Studies (Chapter 6), participants were independently selected, who were the most suitable for representative participants and to satisfy the specific requirement in the household cold appliance study. For example, the location of the participant’s house, ownership of their household cold appliance and doing food cooking and shopping were the key considerations. Regarding the household type, less single person households were recruited in the Main Study (Chapter 7) in order to ensure the diversity in fridge and
freezer use behaviours, as shown in the Pilot Studies (Chapter 6). Thereafter, a snowballing sample technique (Strauss and Corbin, 1998) was employed to contact a group of people who may be useful for the research through the existing subjects (Robson, 2002b). The users representing different family sizes were recruited for the focus group to obtain representative results of the design concepts evolution. Convenience sampling (Robson, 2002b) was applied in the design studies. Rather than multidisciplinary design teams in industry, access to the students and academic designers was straightforward. The Industrial Design Masters students in the Department of Design and Technology at Loughborough University were considered as the most convenient and suitable persons to act as respondents for a useful and accessible trace of the idea generation process underlying the design concepts. In Design Study 2, the researcher, a experienced practitioner, engaged in the creative-production phase (Scrivener, 2000), as creator, intended to contribute directly to the on-going practice effecting sustainable change. Small sample sizes were used across all sets of participants as the quality and the richness of the information was paramount for more focused research (Mason, 2007).

3.9 Research Quality

The quality of the flexible, qualitative research is difficult to specify (Robson, 2002b; Corbin and Strauss, 2008). In fixed research studies, “validity” and “reliability” are the two terms often used to interpret the replication of flexible, qualitative research. A much cited definition of “validity” is that of Hammersley (1987, p. 69): “it represents accurately those features of the phenomena that it is intended to describe, explain, or theorise”, and reliability “refers to the degree of consistency with which instances are assigned to the same category by different observers or by the same observer on different occasions” (Hammersley, 1992, p. 67). Lincoln and Guba (1985) use the terms “credibility, transferability, dependability and conformability” to make a judgement. To Corbin and Strauss (Corbin and Strauss, 2008), the quality of the qualitative research is not only about validity and trustworthiness but also creativity. However, ensuring the quality of qualitative research relies on the researcher’s ability to be comprehensive, honest and objective and mindful to avoid bias during three main areas of the research conducted: description, interpretation and theory (Robson, 2002b).

To ensure the quality of data collected in the activities, a variety of methods were used to record responses, including video recording, note taking and the use of self-completion templates on which participants recorded data during the study, as
suggested by Robson (2002a). The use of self-completion questionnaires in Pilot Studies and Main Study, design logbooks (design diaries) in Design Study 1 and Design Study 2, as well as the assessment sheet for evaluating the design outcomes from Design Study 1, are considered as additional instruments to minimise the potential for bias.

The research adopted Miles and Huberman’s (1984) approach to systematically carry out three steps of data analysis: data reduction, data display and conclusion drawing/verification. To provide evidence and avoid bias in the data interpretation phase, all the raw data from the research activities was transcribed and transferred into a computer-based format, labelled with codes, displayed in matrices or maps and grouped into data threads. This refers to the identification of the regularities, patterns and configurations that can assist with the conclusion drawing process. The direct quotes from participants in user behaviour studies in Pilot Studies (Chapter 6) and Main Study (Chapter 7) and user focus group (Chapter 8) and images taken from the observational studies (Chapter 6 and 7) and the design studies (Chapter 8) support the thinking and analytical process in many ways. These quotes enhanced the richness and authenticity of the research (Robson, 2002b; Corbin and Strauss, 2008). The full records of data collected and the details of the coding and analysis were kept and stored on CD-ROM, as “audits trail” to reduce the threat of researcher bias.

The trustworthiness and rigour of research can be further enhanced by data triangulation. The triangulation of data from multiple sources in the study of the same research question helps the researcher to control bias and to reduce errors (Robson, 2002b). In the case of this research, the self-completion questionnaire and the semi-structured interview in the use behaviour study (Chapter 6 and 7) were used to collect basic information on users’ attitudes, intentions and knowledge about household energy consumption and their perceptions of their cold appliance usage patterns; whilst three observational studies collected more accurate data on their daily practices and routines. This multi-source strategy is especially suitable for human behaviour studies, since it provides two viewpoints for analysis and comparison, allowing for the gap between their intentions and real actions to be identified (Kelley and Littman, 2001; Schmid, 2006). There can be less respondent and research bias to establish valid propositions and converge among multiple and different sources of information to form themes in a study. Furthermore, maintaining the quality of each activity in the research is building up a solid foundation and paving the way for further progress. For example, the findings from the user behaviour studies in the Pilot Studies (Chapter 6) and the Main Study (Chapter 7) were triangulated with the literature reported in Chapter 2. The
design outcomes from Design Study 2 created using the results of the user behaviour studies were triangulated with the design outcomes from Design Study 1 and the existing design concepts presented in Chapter 5. Triangulating findings from separate studies strengthened the validity and reliability of the conclusion drawn from the data, therefore, improve the quality of the research.

3.10 Overview of Research Design

A grounded theory approach was chosen in the design of this exploratory, qualitative research. Figure 3.2 provides the illustration of research methodology and activities conducted for the overall research at a general level. A detailed account of how research methods and analysis techniques inform the development of the research will be explained for each phase in Chapters 6, 7 and 8.
Figure 3.2: Research design

Phase 1: Gap
- Literature Review
  - Understanding the background; identifying the research gap

Phase 2: Model
- Design Behaviour Intervention Model
  - Bridging social psychology theories to design interventions

Phase 3: Case
- Document Analysis
  - Selecting the case, household cold appliance, for detail study

Phase 4: Behaviour Studies
- Pilot Study 1
  - Data Collection: 3 Householders
  - User profile; Observation (use condition, unpacking and cooking); Questionnaire; Interview

- Pilot Study 2
  - Data Collection: 3 Householders
  - User profile; Observation (use condition, unpacking, 24h use record); Questionnaire; Interview; Explanation

Phase 5: Design
- Design Study 1
  - Traditional Design Task
  - User-centred research methods
  - Data Collection: 5 Designers
  - Logbooks & presentation

- Design Study 2
  - 10 Design Briefs emerged in Detailed Behaviour Studies
  - Data Collection: Researcher as Practitioner
  - Logbooks

Phase 6: Testing
- Data Analysis
  - Assessment sheet-- Clustering

- Consumer Testing
  - Data Collection: 8 Participants
  - Focus Group

Phase 7: Theory
- 10 Points for design for sustainable behaviour

Discussion and Comparison
- Design Study 1, 2 Literature

Discussion of Research Findings

Conclusion and Future Work

Chapter 3
- Select Research Technique
- Grounded Theory
- Select Research Type
- Qualitative

Chapter 3
- Select Research Strategy
- Exploratory

Chapter 3
- Select Data Collection Techniques
- Techniques
4 CHANGING BEHAVIOUR AND DESIGN INTERVENTION

In this chapter, the analysis of a range of existing design concepts results in the development of seven behaviour intervention approaches. Based on a comprehensive literature review in diverse disciplinary fields of enquiry, the Design Behaviour Intervention Model is established to bridge the social-psychological theories of behaviour and the behaviour intervention approaches.

4.1 Development of Design Behaviour Intervention Model

Social-psychological theories have been widely applied in many different areas in humanities and social science to explain the determinants of behavioural change. Few attempts have been made to link the social-psychological theories to the domain of sustainable design. With this background, a comprehensive literature (Chapter 2) in diverse disciplinary fields of enquiry was reviewed to uncover the social-psychological motivators behind consumer behaviour. The behaviour and habit models presented in Figures 2.8-2.10 (section 2.6.1) and Figure 2.11 (section 2.6.3.5) summarise the understanding of social, psychological and behavioural factors of behavioural change. However, it was not known what these models mean to designers when they deal with Design for Sustainable Behaviour tasks. In an attempt to address this question, a model was developed in which the behavioural change in product use, enabled through the design approaches at three levels, was explicitly expressed. It was expected to demonstrate how designers change user behaviour through influencing different factors of behavioural change.

This chapter outlines the development of the multi-level model. The primary tasks were to investigate existing behaviour intervention approaches and how designers use them in different contexts. The analysis of the existing design cases identified the scale of interventions and resulted in the development of seven approaches to facilitate Design for Sustainable Behaviour (section 4.2). The discussion of the strengths and weaknesses of the different approaches enabled the researcher to uncover the alliance between the identified approaches and the behaviour theory. Seven behaviour intervention approaches were classified into three levels to correspond to the three main behavioural change elements (guide, ensure and maintain the change). Section 4.3 describes the Design Behaviour Intervention Model that potentially enables design to
change individual behaviour and habits. Figure 4.1 illustrates the three key steps of developing the theoretical model.

![Figure 4:1 Process of developing the Design Behaviour Intervention Model](image)

4.2 Existing Design Cases and Seven Design Approaches

Lilley (2007) proposed three potential approaches for influencing user behaviour through product design: eco-feedback (McCalley, 2004), behaviour steering (Akrich, 1992; Jelsma and Knot, 2002) and persuasive technology (Fogg, 2003). The author’s studies of the existing design cases have identified seven behaviour intervention approaches which can be applied within design to reduce the impacts of product use. The following tables describe each approach with the supportive theory and examples of their application in product design:

- Eco-information – design oriented education;
  1 - Visualizing energy / resource (Table 4-1);
  2 - Experiencing energy / resource (consumables) (Table 4-2);
- Eco-choice – design oriented empowerment (Table 4-3);
- Eco-feedback – design oriented links to environmentally or socially responsible action (Table 4-4);
- Eco-spur – design oriented rewarding incentive and penalty (Table 4-5);
- Eco-steer – design oriented affordances and constraints (Table 4-6);
- Eco-technical intervention – design oriented technical intervention (Table 4-7);
- Clever design (Table 4-8).
### Eco-information

**Aim:** to make consumables (e.g. energy) visible, understandable and accessible to inspire users to reflect upon their use of resources.

**Description:** 1. Product expresses the presence and consumption of resources e.g. water, energy etc.

**Theory:** Seeing is believing.
The invisible nature of energy is the most basic barrier to transforming the householder into an active manager of energy. It is impractical to manage something that cannot be seen or measured (Lockwood and Murray, 2005). Routinising energy (consumables) consumption can be understood when users can see the “evidence” of consuming with users’ own eyes. Transparency in product aesthetics has been linked to notions of natural and environmental “friendliness” (Tse and Yim, 2002). In terms of design for durability, the transparent product can extend the product life in a “psychological” sense, since “the sealed housing of many electronics products forbids repair when breakdown occurs” (Verbeek and Kockelkoren, 1997, p. 112).

Visualization of consumables and clear and transparent electronics products will allow users to continue their relation with the resources (water and energy) when they leave it on unnecessarily, in standby mode, for example, since its working state can be seen.

**Examples (Interactive Institute, 2004)**

**Power Aware Cord - Seeing personal energy consumption**

“The ‘Power-Aware Cord’ is a re-designed electrical power strip in which the cord is designed to visualize the energy rather than hiding it. The current use of electricity is represented through glowing pulses, flow, and intensity of light”. This enables the user to visualise and reflect on energy consumption of household devices of electrical devices in their home.

**Disappearing-Pattern Tiles - Expressing daily hot water routines**

The bathroom tiles are “decorated with patterns in a thermo-chromic ink that reacts to heat, fading away to reflect splashes and intensities of hot-water use. The longer the shower, the less decoration on the wall! The architectural surface acts as a subtle reminder of personal energy use over time, reflecting the duration and waste of water during a shower”.

**Heat Sensitive Lamp - Capturing energy as form**

Heat-Sensitive Lamp takes its shape as it is turned on for the first time, its material composition determined by the heat of light bulb. In this case, electricity (energy) as an essential material participates in the design of a lamp. Energy changes the aesthetic form of objects to express its existence.

**Appearing-Pattern Wallpaper - Exposing sunlight patterns over time**

“Appearing-Pattern Wallpaper” amplifies slow behaviours – “it comes in a solid color when purchased, but a pattern emerges over time as sunlight exposes textures printed with UV-sensitive ink. This is a poetic example of how the life-span of ordinary things and everyday life may be transformed in relation to existent energy conditions”.
Table 4-2: Eco-information - design oriented education -2

**Eco-information**

**Aim:** to make consumables (e.g. energy) visible, understandable and accessible to inspire users to reflect upon their use of resources.

**Description:** 2. Product expresses the presence and consumption of resources.

**Theory:** Verbeek and Kockelkoren (1997, p. 113) argue that “if we want our attachment to be directed towards objects”, we should “design them” to be “engaging” and that “products are engaging when they ask for our involvement”. Energy is invisible and intangible. We can only see, feel, hear and even smell its effects, but cannot really perceive it (Interactive Institute, 2004). Two methods to encourage users to interact with resource use and bridge the gap between energy (consumables) and the result:

- Experiencing the amounts of energy required by the electric products;
- Being involved in powering the product, e.g. human powered device. Powering devices manually provides users a good impression and reflection on the sources of the power and the amount of energy for operating appliances (van de Velden, 2003b).

**Examples:**

**Element - Feeling the heat and light of energy at home**

Element is a prototype that makes the heat escaping from radiators appreciable. It is made out of glass, metal and enough light bulbs to reach the same efficiency as an electric radiator, and the current energy level is visible at all times (Interactive Institute, 2004).

**Tyranny of the Plug Kitchen Machines –Being involved to power the product**

Van Hoff’s (2003) Tyranny of the Plug kitchen series include a blender, a mixer and lemon squeezer. The prototypes are powered by human energy rather than by electricity to inspire people to consider the generation of power. To operate the mixer, for example, the handle must be continuously rotated; to blend, the user must pull on the cord which turns the blade.

**Baygen wind-up clockwork radio**

eliminates the need for batteries by using an internal spring-driven generator powered by hand. 25 seconds turns of the handle power the radio for 30 minutes (Science & Society, 2004).

**Freeplay self powered LED windup torch**

does not need bulbs or replacement batteries and 60-second wind-up provides 1 hour of illumination (EcoHamster, 2007).

**Freeplay freecharge mobile phone charger**

provides emergency power to mobile phones and enables the user to make and receive calls at any time (Freeplay Energy, 2009).

**Muscle powered toothbrush**

The effect of an electric toothbrush is achieved by a wind-up mechanism in the shank of this toothbrush (Biothinker, 2000 in: Information/Inspirati on, 2005)
Table 4-3: Eco-choice - design oriented empowerment

<table>
<thead>
<tr>
<th>Eco-choice</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aim:</strong> to encourage users to think about their use behaviour and to take responsibility for their actions by providing them with sustainable options.</td>
</tr>
<tr>
<td><strong>Description:</strong> Users have a choice and the product enables sustainable use to take place.</td>
</tr>
<tr>
<td><strong>Theory:</strong> It is morally and ethically acceptable to provide users with sustainable alternatives. Products should assist and enable users to choose whether or not to be environmentally sound (van de Velden, 2003b). Blocking or forcing unsustainable use behaviour without raising users’ awareness would not offer the learning mechanism for users to take responsibility for their actions (ibid).</td>
</tr>
<tr>
<td><strong>Examples:</strong></td>
</tr>
<tr>
<td>Machine with ‘Eco - button’ - Individual product idea</td>
</tr>
<tr>
<td><img src="image1" alt="" /></td>
</tr>
<tr>
<td>Domestic Energy Display - Household system level concept</td>
</tr>
<tr>
<td><img src="image2" alt="" /></td>
</tr>
<tr>
<td>Home Monitoring - Household system level concept</td>
</tr>
<tr>
<td><img src="image3" alt="" /></td>
</tr>
</tbody>
</table>
Table 4-4: Eco-feedback – design oriented links to environmentally or socially responsible action

**Eco-feedback**

**Aim:** to inform users about their operating status and to facilitate users to make environmentally and socially responsible decisions through offering real-time feedback.

**Description:** The product provides tangible aural, visual, or tactile signs as reminders to inform users of resource use.

**Theory:** Product designers could raise the environmental awareness of users by providing immediate feedback information on user-product/system interaction: resource use, energy consumption and environmental impact (Sherwin et al., 2000; Thompson and Sherwin, 2001). Feedback, grounded in Feedback Intervention Theory (Kluger and DeNisi, 1996), is widely used as a safety measure in electronic household appliances and medical equipment to confirm an action performed correctly (Lockton, 2005a). The real-time feedback depends on communicating the right people with the right information, such as focusing on particular perceptions and life values of the target user group.

**Examples:**

**Standard feature used by electronic household appliances - Visual and aural feedback**

The feedback as a common feature is adopted by kettle design. The feedbacks provided are visual, when the kettle is working and aural-when the water is boiled.

- **Kambrook “Axis” Kettle** gives feedback on both the temperature and the amount of water in the kettle (Sweatman and Gertsakis, 1996). The observations revealed that the kettle was often overfilled and reboiled as the user left the room to do something else. The indicator on the handle could show when the water is still hot enough to use.

- **Russell Hobbs Thermocolour Iron - Visual feedback**

Thermocolour iron with new thermocolour technology uses visual feedback to tell the users what temperature it is safe to iron at. The LED lights located in the water tank change colour automatically according to the temperature. To ensure the different fabrics are ironed at the correct temperature with just one glance (Russell Hobbs, 2006).

- **Wattson - Visual feedback in numbers and colours shows how much electricity the whole house is using at any given moment**

Wattson (What Watts are On) (DIY Kyoto, 2005) is a wireless energy monitor. It aims to reduce energy consumption and costs by making users more aware of the real-time energy used by household devices. Information from the household electricity meter or fuse box is transferred directly to the Wattson which instantly displays usage in total kilowatts consumed and money in a simple graphic display and through graduated light - blue for low energy use, red for high. Its internal memory records up to 4-week energy use history which can be uploaded to the computer via a USB lead. The user can then access the data through “Holmes”, an energy monitoring program developed to accompany Wattson.
**Table 4-5: Eco-spur – design oriented rewarding incentive and penalty**

**Eco-spur**

**Aim:** to inspire users to explore more sustainable usage through providing rewards to “prompt” good behaviour or penalties to “punish” unsustainable usage.  

**Description:** The product shows the user the consequences of their actions through “rewarding incentives” and “penalties”.

**Theory:** To effectively link behaviour and consequence, users must be provided with real-time information about their energy use vividly (Darby, 2006). Availability of a rewarding or penalising consequence helps to increase public awareness, interest and curiosity in participation (McKenzie-Mhor and Smith, 1999). People learn what to do by experiencing positive (and negative) reinforcements (rewards or penalties) for their behaviours (Jackson, 2005). 

In terms of the form of incentives and disincentives, financial rewards can potentially lead to a diminished sense of responsibility (Nyborg, 2003). This deficiency could be made up with non-monetary incentives, such as increasing convenience, efficiency and comfort by redesigning a product and use experiences. Furthermore, rather than show up the consequence of the electricity use in bills, it is easily reduced to an abstract, invisible phenomenon whose only concrete representations are “two holes in the wall” (Interactive Institute, 2004). The appropriate short-run rewards need be reinforced to encourage the long term changes in both use habits and attitudes towards sustainable energy consumption.

**Examples:**

**Flower Lamp - Rewarding energy behaviour**

In the “Flower Lamp” example, its form reflects energy used in a household. The lamp “blooms” as a reward – changing its shape when power consumption has been low for some time. If too much electricity is used, it closes up again. “To make the lamp more beautiful, a change in behaviour is needed” (Interactive Institute, 2004).

**Energy Tree - Rewarding energy behaviour**

The Energy Tree (Arent, 2007) is a conceptual device which monitors household energy use and recycling practices. By drawing data from the electrical sockets and devices plugged into the supply, it provides visual feedback via an information display panel which details energy consumption. The Energy Tree as a strong incentive for behaviour change would encourage energy-efficient behaviour by creating an emotional bond between the user and a living tree embedded in the device. Its well-being would be dependent on how well the user utilise their energy supply. However, it is argued that immediate feedback is more effective than waiting for the real tree to respond to a behaviour change.

**Erratic Appliances - Experiencing Local Energy Levels**

Erratic Appliances are a series of objects that behave erratically when an individual is using too much power. For example, the Erratic Radio may “untune” as a kind of warning or punishment when there are too many objects in the room consuming energy. It visualises the consumption by its unexpected response and gives the direct feedback on the high quantity of energy being used at the exact moment (Interactive Institute, 2004).
Table 4-6: Eco-steer – design oriented affordances and constraints

<table>
<thead>
<tr>
<th>Eco-steer</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aim:</strong> to facilitate users to adopt more environmentally or socially desirable use habits through the prescriptions and/or constraints of use embedded in the product design</td>
</tr>
<tr>
<td><strong>Description:</strong> The product contains affordances and constraints which encourage users to adopt more sustainable use habits or reform existing unsustainable habits</td>
</tr>
<tr>
<td><strong>Theory:</strong> Affordances and constraints are assumed in product forms in terms of simple clues to limit behaviour to what is correct - forcing the correct usage (Norman, 1998). These two techniques could be strategically applied into the design to guide users through the most sustainable ways of use. Affordances inform the user how the product could be used and constraints place limitations on what actions can be performed. Two issues are worth noting in application: the uncertainty over how to avoid the restrictions which the design of control imposes and how much work is required to make a difference. Because of the invisible and intangible nature of the energy (consumables), it is difficult for the designer to adopt the “scripts” (Verbeek and Kockelkoren, 1997; Jelsma and Knot, 2002; Cooper, 2005) and “memes”(Blackmore, 2000) to instil energy (consumables) with “sustainable values”. However, these methods are widely supported by the literature review to build the appropriate emotional (Walker, 1997; 2005) or sentimental relationship between the user and the product, leading to better care and respect for the object and ensuring longer product lifetime.</td>
</tr>
<tr>
<td><strong>Examples:</strong></td>
</tr>
<tr>
<td><strong>The AWARE Puzzle Switch – Attracting to behave in the most sustainable way</strong></td>
</tr>
</tbody>
</table>

The AWARE Puzzle Switch (The AWARE project, 2007) is an on/off button. It encourages people to switch of the light by playing with people’s built-in desire for order. It gives much more feedback of its current state than a traditional switch. |
| **Unilever Powder Tablet – Counteracting excessive amounts of consumables consumption by prescribing correct dose** |

Users tended to use more washing powder than needed to ensure that clothes are clean. The Unilever powder tablet is designed to prescribe quantity to counteract this rebound effect. The simple formula of just one or two tablets reduces tendency of consumer to add a little bit extra to be sure of a good result (Unilever, 2000; 2001). |
| **Electric Shock Mobile – Modifying user behaviour to be less disruptive and social impacts.** |

The Electric Shock Mobile (IDEO, 2002) prototype attempts to reform mobile phone users who persistently disturb others with loud and intrusive conversations. It delivers a variable level of electric shock depending on how loudly the person on the other end of the line is speaking to encourage both parties to speak more quietly. |
Table 4-7: Eco-technical intervention – design oriented technical intervention

<table>
<thead>
<tr>
<th>Eco-technical intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aim:</strong> to restrain existing use habits and to persuade or control user behaviour automatically by design combined with advanced technology.</td>
</tr>
<tr>
<td><strong>Description:</strong> The product utilises advanced technology to persuade or control user behaviour automatically.</td>
</tr>
<tr>
<td><strong>Theory:</strong> Technological solutions address the limitations of the previous strategies by circumventing the decision making process, diminishing the potential for irresponsible environmental or social behaviour (Lilley et al., 2005). However, it is worth noting the long term effectiveness, ethical and moral issues of using technology (Jelsma, 1997; van de Velden, 2003b). Designing a few mundane artifacts doing their job cleverly and manipulating people for the environment silently, people may feel forced and directed by technology.</td>
</tr>
<tr>
<td><strong>Examples:</strong></td>
</tr>
<tr>
<td><strong>Power-peg – eliminating electricity wasted from mobile phone chargers left on</strong></td>
</tr>
<tr>
<td>Mobile phone, MP3 or camera charger that remains plugged in to the electrical socket continues to use electricity even when the device has been removed. The Power-peg (Belley, 2007) is designed to eliminate energy waste by automatically cutting off the power supply when the device has been fully charged. The user does not deliberately remember to unplug the charger.</td>
</tr>
<tr>
<td><strong>Honda’s integrated motor assist (IMA)</strong></td>
</tr>
<tr>
<td>Honda’s integrated motor assist (IMA) system automatically turns the engine off and on at traffic lights to save energy and reduce emissions. The IMA features are activated by in-built technology, the driver is not aware of the actions taken, nor is he/she consciously choosing that behaviour. This increases the performance coupled with a reduction in operating emissions, which is not reliant on user compliance, whilst passing the benefits on to the customer in the form of cost savings. Honda makes it clear that the action taken is controlled by the car and selling point is to help the user to “save money” without noticing a thing (Honda, 2004).</td>
</tr>
<tr>
<td><strong>‘Eyes off Road Time’ – Combating the behaviour of walking and using the phone via real time video streaming</strong></td>
</tr>
<tr>
<td>This concept was designed by Richard Miles as part of his Masters in Industrial Design at Loughborough University in 2005. The brief for this project was to identify and address a social issue resulting from the use of mobile phones in public space by redesigning the product to modify user behaviour. Richard (Miles, 2006) observed the consequences of what he called ‘eyes off road time’ i.e. sending or reading text messages, using an mp3 player, checking voice mail or entering numbers whilst walking. To combat this behaviour, he provided visual feedback to improve the user’s awareness of their surroundings and employed intelligent, persuasive technologies to encourage the user to move away from other pedestrians when using their phones. A handset featuring real time video streaming was devised. When the handset is open and in motion the forward view is projected as a screen saver behind any text improving awareness during eyes off road time.</td>
</tr>
</tbody>
</table>
Table 4-8: Clever design

**Clever design**

**Aim:** to induce an environmental and social friendly action purely through innovative product design, without raising awareness or changing user behaviour.

**Description:** The design solution decreases environmental impact without changing the user’s behaviour.

**Theory:** Clever design guarantees that the goal of alleviating environmental stresses could be achieved. However, users neither do not make a decision nor change anything during use of the clever designed products. The potential opportunity for creating sustainable values leading to long term lifestyle change will be wasted. Sparks and Shepherd (1992 in: Jackson, 2005) found that when individual takes some kind of green action, he/she likes to do another and when he/she regards him/herself as a “green” user he/she is motivated to do more. It is questioned that the “spillover effects” (Jackson, 2005) between one pro-environmental behaviour and another will be interrupted by making unsustainable actions impossible without raising user awareness.

**Examples:**

**Integration of toilet and washbasin**

In order to lower total bathroom water usage, Huib van Manen (in: van de Velden, 2003b) integrates toilet, hand basin and tap combination to use the waste water from the sink to flush the toilet.

**Integration of toilet and washing machine**

Similar concept from (Electrolux 2008b) integrates toilet and wash machine to decrease water use by re-using water for clothes-washing to flush the toilet.

By comparing the theories and the design concepts, it is possible to identify the advantages and disadvantages of these approaches.

Eco-information, Eco-choice and Eco-feedback are the persuasive design approaches to induce or solicit voluntary changes in behaviour. The informative products employing these approaches provoke the users’ reflection and construct the conservation goals through heuristics, “simple cues or cognitive signs” (Jackson, 2005, p.80), such as showing energy existence, providing options and feedback. Compared to the pure information and education campaigns (section 2.6.2.1), informative products are more straightforward interventions. Embedding sustainable informations and conversations into the products could give immediate responses to the user behaviour. This could
simplify the process of setting the priorities regarding the numerous areas of environmental concerns and the different elements of the user’s individual responsible consumption strategies. However, the results of these approaches to altering behaviour remain uncertain. The initiative to act rests with the user. Their individual interpretation of the interventions offered and their decision whether to take action or not, are crucial to the success of these approaches. Particularly, as it has been reported, when plenty of options and opportunities are provided, the users often do not choose the “best” way of using the products prescribed by the designers (Jelsma, 1997). One prominent example is the use patterns of the washing machine. A large number of people still habitually and culturally wash clothing at 60 degrees or 90 degrees rather than using the AA rated option, a 40 degree wash. The freedom given by open scripts and constraints permits more undermining behaviour than closed ones. Therefore, Eco-information, Eco-choice and Eco-feedback are considered as the approaches to guide the behavioural change.

To reinforce the long term changes, Eco-spur stimulates the maintenance of new behaviour by provision of incentives and penalties. Eco-steer prescribes a desired behaviour through designing the physical characteristic of the product. By using affordances (informing potential behaviours) and constraints (limiting potential behaviours) (Norman, 1998), the interventions steer the user’s interactions without force. These two approaches to maintaining the change could be placed in the centre of power for decision making between the user and product. On one hand, by concealing sustainability values inside other more desirable attributes, responsible actions might be rewarded and afforded through providing pleasure, convenience and useful functionality. On the other hand, the penalties and constraints might restrain the user behaviour and further decrease the user acceptance of interventions employing these approaches.

Eco-technical intervention and Clever design apparently address the disadvantages of persuasive design approaches. These coercive approaches control the user behaviour automatically or eradicate user engagements to ensure the pro-environmental change occurrences. The automated solutions may prove more efficient in altering behaviour without causing conflicts in people’s beliefs, values, preferences and modifications to the existing routines. In terms of innovation, developing markets and supporting policies, changing the product requires lower investments than changing the user (Jelsma, 1997). However, there are still big concerns about employing the Eco-technical intervention and Clever design:
- Lack of normative and intentional change and restriction of the “spillover effects” (Jackson, 2005) of the pro-environmental behaviour: they result in the short term behavioural change (Jelsma 1997) and are not enough to sustain a long-term change in lifestyle (van de Velden, 2003b);

- Rebound effects: as discussed in sections 2.2.1.2 and 2.4.2, these “easy” approaches may cause unpredictable behaviours and even more consumption that results from the increased efficiency and lower user costs;

- Low user acceptance: coercive interventions limit user behaviour and the user acceptance of these products is most likely to be low. They cannot be effective without people choosing to comply with the behaviour “controllers”;

- Ethical and moral issues of intelligent interventions (Gowri, 2004): by using these approaches, the behavioural change will creep upon the user silently when he/she is using the product every day. These changes Jelsma (1997) is concerned that the invisible blackbox, coercion may evoke irritation and increase users resistance.

Seven approaches enable designers to passively or actively influence user behaviour and assign the different rights to the user and the interventions (product/service/system) in the decision-making process. As illustrated in Figure 4.2, the degree of power for decision making may determine the success of the behaviour interventions, as such attaining a normative or motivational change (Abrahamse et al., 2005; Steg and Vlek, 2009), the user’s acceptance of interventions, the effect on the environmental impact of interventions.
4.3 Design Behaviour Intervention Model

By linking the design approaches with the social-psychological theories and behaviour models, the breakthrough points that potentially enable design to change the individual behaviour and habits are identified. A Design Behaviour Intervention Model is proposed (Figure 4.3). It illustrated the multiple factors in behaviour formation and the relationship between these factors and the approaches for Design for Sustainable Behaviour.
Figure 4.3: Design behaviour intervention model: linking antecedents of behavioural and habitual change with varying levels of behaviour intervention approaches
As highlighted in section 2.6, intention, habits and controls are considered important antecedents of behavioural change. The intention is affected by attitudinal, social and affective factors which relate to the knowledge and skills, the beliefs and evaluation of the outcomes, social norms, personal roles, self-concepts and emotional responses. When behaviour becomes an automatic act, it is subject to three stages of the habit formation (Anderson, 1982), which are determined by the repetition of the past behaviour and the strength and frequency of stimulators and interventions received.

Due to the complexity of motivations for shifting behaviour, different levels of interventions are made by linking the design approaches to the behavioural change elements accordingly to ensure behavioural and habitual change in energy and resource consumption. Seven behaviour intervention approaches could be applied within design to reduce the impacts of use (e.g. environmental and social) at three levels, including guiding the behavioural change through building the conversation, reinforcing the change with “Eco-spur” and/or “Eco-steer” and blocking or forcing the behaviour by making unsustainable action implausible. As demonstrated, design interventions are also classified by the degree of power for decision making between the user and design-led solutions from three design categories, whereby their daily practice could be shaped by sustainable product/service/system design. It is important to develop a balanced and ethical approach: weighing up determinates of behavioural and habitual change and designing the sustainable product/service/system to limit the impact of use.

4.4 Ethical Considerations for Design for Sustainable Behaviour

Using this Design Behaviour Intervention Model, designers may be able to passively or actively influence user behaviour with the resulting tension between choice and control raising ethical and moral considerations. Whilst several behaviour intervention approaches have been proposed, the criterion for selecting appropriate approaches is not defined. For instance, it is unclear how to assess the severity of consequences enacted by product use or misuse. Berdichevsky and Neuenschwander's (1999) principles of persuasive technology design (Table 4-9) provide interesting guidance for considering the ethical acceptability of behaviour interventions, however, they have not made a fully assessment of the designers’ role in promoting and facilitating behavioural changes, such as how the designers deal with unintended usage from a persuasive technology (Pettersen and Boks, 2008).
Table 4-9: Ethical principles of persuasive technology (Berdichevsky and Neuenschwander, 1999)

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.

4.5 Conclusion

This chapter brings theory and practice across disciplines and approaches together to build the model for Design Behaviour Intervention. Social psychological theories and behaviour models which inform and support Design for Sustainable Behaviour are introduced and seven approaches for design practice are defined with existing product and conceptual case studies. Additionally, the model demonstrated the consideration of user acceptance for implementing the behaviour interventions. More importantly, it highlights that the potential behaviour interventions should not be confined to the single product solution, but more sustainable benefits could be gained from the wider design categories, the service design and the system design which could involve various stakeholders to create radical behavioural change. This model is designed to give a snapshot of the possible drivers and the moderators of individual behaviour, directing the designers towards the applicable behaviour intervention approaches to tackle the problems more effectively and efficiently.
4.6 Next Step

The behaviour intervention approaches, whilst providing interesting considerations for designers, have not been widely applied and there is lack of real data on the effectiveness in both theoretical and practical dimensions. It is for this reason that empirical research will be conducted to understand further Design for Sustainable Behaviour. Through examining the consumption meanings and its consequences of each household appliance group (Chapter 5), a case will be selected to demonstrate the process of implementing the Design Behaviour Intervention Model in new product development from behaviour study (Chapter 6 and 7) to designing and testing the concepts with users (Chapter 8), in order to link the theory and the practice of Design for Sustainable Behaviour.
CASE STUDY PRODUCT SELECTION

Having identified the potential design intervention model for sustainable behaviour, one product or group of products needs to be selected in order to formulate a specific user focused study through analysis of the meanings and environmental impact of household appliance use.

5.1 Consumption Meaning of Household Appliance

Consumer goods play double roles in people’s daily life both functional and immaterial (Koskijoki, 1997; Jackson, 2005; Sustainable Consumption Roundtable, 2006). More and more artefacts are purchased and used to satisfy the needs beyond the functional, such as the aspirational, spiritual and emotional needs (Bruseberg and McDonagh-Philp, 2001b). The significance of material goods stems largely from the symbolic roles of the artefacts in communicating personal, social and cultural meaning (Jackson, 2005). Shove and Warde (1999; 2002) identified five social mechanisms to explain why people consume ever increasing quantities of goods and services and what the environmental consequences are of escalating demand. Consumption is endowed with five meanings:

- Social comparison: products and services are viewed as vessels of cultural and personal meanings which act to classify the social status of their consumers. Consumption is the process of emulation whereby lower classes seek to imitate the practices of their superiors;

- Creation of self-identity (Identity): people use goods to create and sustain a sense of self and personality and “define themselves through the messages they transmit to others through the goods and practices they possess and display” (Shove and Warde, 2002, p.5);

- Mental stimulation (Novelty): people seek new goods and services which could bring them new pleasures and experiences;

- Matching: items should match one another. People may constantly replace items to ensure everything is consonant, e.g. equally new or stylish;

- Specialisation: multipurpose products have been replaced with specialised ones (discussed in section 2.2.1.3). People now buy a pair of shoes for each kind of
activity, e.g. running, training, squash and tennis, “whereas the previous
generation just bought plimsoles” (Shove and Warde, 1998, p. 7).

Table 5-1 presents unsystematic reflections of how the five mechanisms might explain
the possessions of the household appliances.

Table 5-1: Consumption meaning of household appliance and environmental significant
consumption (adopted from Shove and Warde, 2002)

<table>
<thead>
<tr>
<th>Sector</th>
<th>Environmental significant consumption</th>
<th>Social Comparison</th>
<th>Identity</th>
<th>Novelty</th>
<th>Matching</th>
<th>Specialisation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total energy consumption</td>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>maybe</td>
</tr>
<tr>
<td>Total water consumption</td>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>maybe</td>
</tr>
<tr>
<td>Kitchen</td>
<td></td>
<td>√</td>
<td>√</td>
<td>maybe</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Space heating</td>
<td></td>
<td>√</td>
<td>x</td>
<td>Not now</td>
<td>√</td>
<td>×</td>
</tr>
<tr>
<td></td>
<td></td>
<td>×</td>
<td>×</td>
<td>Not now</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>Water heating</td>
<td></td>
<td>×</td>
<td>maybe</td>
<td>x</td>
<td>x</td>
<td>√</td>
</tr>
<tr>
<td>Cold</td>
<td></td>
<td>×</td>
<td>x</td>
<td>Not now</td>
<td>maybe</td>
<td>√</td>
</tr>
<tr>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
<td>×</td>
<td>x</td>
<td>×</td>
</tr>
<tr>
<td>Wet</td>
<td></td>
<td>×</td>
<td>×</td>
<td>Not now</td>
<td>x</td>
<td>√</td>
</tr>
<tr>
<td></td>
<td></td>
<td>x</td>
<td>maybe</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Cooking</td>
<td></td>
<td>×</td>
<td>maybe</td>
<td>x</td>
<td>maybe</td>
<td>√</td>
</tr>
<tr>
<td></td>
<td></td>
<td>√</td>
<td>√</td>
<td>maybe</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Lighting</td>
<td></td>
<td>×</td>
<td>×</td>
<td>Not now</td>
<td>x</td>
<td>√</td>
</tr>
<tr>
<td></td>
<td></td>
<td>√</td>
<td>√</td>
<td>×</td>
<td>√</td>
<td>√</td>
</tr>
</tbody>
</table>

The "no" and "maybe" responses relate to issues which are boringly normal, invisible and enmeshed in a
network of related practices and habits. Despite these qualities, such features change, often rapidly,
with instant and wide ranging environmental consequences.

It can be seen from the table that appliances and practices only communicate some
meaning, while display is a major consideration. With increased abilities and
opportunities for people to consume, many household appliances that were once
novelty items but become normalised and are now standard in a modern house. The
meanings of acquisition and use of the appliances are symbolically different (Shove and
Warde, 2002). For example, “identity” might not apply to cookers as objects, but what
people do with and how people use cookers might express their personal identity and
define who they are.

There is potential to embed sustainability values in a product, if appropriate and
effective value drives can be established. However, it seems that most of the meanings
do not apply to appliances when they are in use. The meaning of appliances as objects is
not explored further in this thesis, because it does not fit within the scope of this project. As defined in section 1.3, this thesis focuses on the environmental problems resulting from direct household energy consumption, particularly household appliance use where individual user behaviour was a significant factor.

5.2 Product Use and Environmental Impact

The distribution of end-uses of domestic energy consumption appears to follow a fairly consistent pattern: space heating or cooling generally accounts for the largest proportion, followed by consumer electronics, lighting, cold and other appliances, such as cooking, wet and miscellaneous appliances sectors. Table 5-2 provides a breakdown of energy usage in the home in the UK.

Table 5-2: Domestic energy usage broken down by sector in the UK (Environmental Change Institute data in: DTI, 2003, Energy Saving Trust, 2006b, P. 13-17)

<table>
<thead>
<tr>
<th>Sector</th>
<th>Per cent energy usage (%)</th>
<th>Per cent electricity usage (%)</th>
<th>Appliance</th>
<th>Penetration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space heating</td>
<td>59%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water heating</td>
<td>24%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cold</td>
<td>3%</td>
<td>18%</td>
<td>Fridge-freezer</td>
<td>64%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Refrigerator</td>
<td>43%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Upright freezer</td>
<td>27%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Chest freezer</td>
<td>17%</td>
</tr>
<tr>
<td>Wet</td>
<td>2%</td>
<td>14%</td>
<td>Washing machine</td>
<td>79%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Tumble dryer</td>
<td>40%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Electric shower</td>
<td>35%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Dishwasher</td>
<td>25%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Washer dryer</td>
<td>15%</td>
</tr>
<tr>
<td>Cooking</td>
<td>3%</td>
<td>17%</td>
<td>Kettle</td>
<td>97%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Microwave</td>
<td>83%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Oven</td>
<td>80%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Electric oven</td>
<td>59%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Electric hob</td>
<td>46%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Deep fat fryers</td>
<td>34%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sandwich toaster</td>
<td>33%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Slow cooker</td>
<td>20%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cooker hood</td>
<td>18%</td>
</tr>
<tr>
<td>Lighting</td>
<td>3%</td>
<td>20%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consumer electronics</td>
<td>4%</td>
<td>21%</td>
<td>TV</td>
<td>98%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cassette player/radio</td>
<td>95%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hi-fis</td>
<td>94</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>VCR</td>
<td>87%</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>2%</td>
<td>10%</td>
<td>Personal care product</td>
<td>94% (hair care)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mobile phones</td>
<td>81%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Heater</td>
<td>80%</td>
</tr>
</tbody>
</table>
During the use phase, the total energy used by a product includes energy for functioning, intrinsic losses and behaviour related energy waste (Elias et al., 2008b). As the energy use for functioning and intrinsic losses could be reduced by improvements in technology and materials, a significant increase in a proportion of a product’s energy demand is determined by the user behaviour. In studies from the United States, the Netherlands and the UK cited by Wood and Newborough (2003), resident’s behaviour has been estimated to account for 26 - 36% of in-home energy use.

However, the behaviour related energy savings have not been quantified. Some studies indicate that the links between socio-demographic variables (e.g. income, level of education, and residential location) and household energy use and energy conservation behaviour (Gatersleben and Velk, 1998; DEFRA, 2002; Druckman and Jackson, 2008; Abrahamse and Stega, 2009). Gatersleben and Velk (1998) interviewed 496 homes in 1995 in three areas of the Netherlands. Their research found a relationship between being in possession of household appliances and the intensity of their use. The use of the microwave oven, dishwasher and computer depends to a large extent on the possession of these goods, whereas the use of a video recorder only depends to some extent on its possession. The home heating temperature and the number of times respondents wash laundry do not depend on the possession of a central heating system or washing machine respectively. The number of hours respondents watch TV depends to only a small extent on the possession. In the DEFRA (2002) Survey of Public Attitudes towards the Environment and to Quality of Life – 2001, 80% of the subjects indicate that they regularly cut down energy use to save money, 22% to save energy and 15% to help reduce environmental pollution. People in the age group of 65 and above are more likely to say that they conserve water, while 62% report that they do not regularly cut down water use. What is interesting is that 8% of the respondents express that they have no idea about water consumption, because they do not have a water meter. The potential solutions are discussed: endowing users with powerful psychological and economic motivation of pro-environmental behavioural change; and
offering the appropriate facilitators to keep them aware of the results, such as providing tailored information on energy use for different segments of households (Abrahamse et al., 2007; Druckman and Jackson, 2008). Appendix 2 displays some of the existing understanding of the socio-economic characteristics and its effect on the household consumption patterns and user needs (as expressed in quality of life aspects).

5.2.1 Energy consumption and potential of behavioural efficiency in each household appliance sector

Little research work has been undertaken around user behaviour and its impact during the use stage in the product life cycle. The following sections serve to present a summary of the current situation of energy consumption in each domestic sector as a basis for understanding the environmental challenges of different products when in use. It aims to choose a domestic appliance sector with a high behavioural potential for energy efficiency improvement for a further investigation. The potential energy savings identified as available within each household appliance sector through certain modifications of appliance usage behaviour are summarised below.

5.2.1.1 Space heating

Space and water heating which accounts for 83% (59% heating; 24% hot water) of domestic energy consumption and represents approximately 24% of total UK energy consumption (Energy Saving Trust, 2006b) has the biggest potential for energy saving. Energy use for space heating depends on technical factors including the type of dwelling, its levels of insulation and the efficiency of the heating mechanism (Druckman and Jackson, 2008). It is also related to user use habits. As shown in Appendix 3: Table 1, energy consumption in this sector could be lowered by reducing temperature settings, turning off the heating system when not required and providing more detailed information in the fuel bill about heating costs.

5.2.1.2 Domestic lighting

20% of total domestic electricity consumption is taken up by internal domestic lighting (Energy Saving Trust, 2006b). The main measure to achieve the energy saving in this sector is to encourage the purchase of low energy light bulbs. However, electricity consumption of domestic internal lighting has increased by 4% during the period 1996-2003 (Environmental Change Unit, 1997, Environmental Change Institute 2003 in: DTI, 2003). Besides the impact of falling household sizes and increasing household
numbers, the rebound effect related to the use of efficient compact fluorescent lights is one of the contributors to lighting use (van de Velden, 2003a), i.e. 70% users forget to turn lights off in unoccupied rooms (Rodriguez and Boks, 2005) (Appendix 3: Table 2).

5.2.1.3 Domestic cold appliances
The percentage of domestic electricity demand taken up by cold appliances is 18% (Energy Saving Trust, 2006b). It has been found that the product efficiency in this sector would be improved by limiting intrinsic losses due to the insulation, with technological and incremental engineering improvements (Environmental Change Institute, 2005; DEFRA, 2008a; 2008b). Behavioural potential energy savings could be actualized by reducing the opening of the door, avoiding putting hot food in and regular defrosting. Appendix 3: Table 3 gives further details of the user impacts with the cold appliance.

5.2.1.4 Domestic wet appliances
Domestic wet appliances are responsible for 14% of total domestic electricity consumption: of this, 57% is washing machines; 25% tumble dryers; 18% dishwashers (Energy Saving Trust, 2006b). The data does not include the electricity usage of electric showers but in last 30 years, ownership of electric showers has increased from 0% to 35% (Energy Saving Trust, 2006b) and daily electricity use is 7 kWh which is the highest electricity use of 47 investigated domestic electrical goods in the energy study of Elias et al. (2008a). The usage patterns of the wet appliance (Environmental Change Unit, 1997) (Appendix 3: Table 4) and rising standards of cleanliness (Shove, 2003) could be possible factors that have great effects on energy demand in this sector.

5.2.1.5 Domestic cooking
Cooking equipment accounts for 14% of total domestic electricity consumption: oven and hobs together take up 54% of the electricity usage in sector and kettles 27% (Energy Saving Trust, 2006b). Energy consumption in the cooking sector is highly dependent on cooking habits at all stages of food preparation (Environmental Change Unit, 1997), showed in Appendix 3: Table 5. The stand-by consumption in cooking appliances is considered as one of the sources of the unnecessary electricity use. Switching off the microwaves between usages could save 28% of energy consumption without affecting its primary function. It is difficult to purchase an electric oven, hob or microwave that does not have an inbuilt, always-on, digital clock. A light on the base of
electric kettles is used to indicate they are ready to use. The kettles sometimes have a “keep warm” function ensuring the water that always remains at a high temperature. Standby functions in digital microwaves maintaining a 24-hour clock display and/or a delay timer are not considered to be essential service.

5.2.1.6 Consumer electronics
The consumer electronics sector is becoming one of the largest users of domestic electricity, dwarfing all other sectors except for heating. In 2003, energy consumption of this sector comprised 21% of the total domestic electricity consumption. The high electricity demand in this sector overall is attributed mainly to duplicate possessions. In 2004, each UK households had 2.4 TVs, 1.9 video recorders, 0.5 digital adapters and 5.2 external power supply units on average (Energy Saving Trust, 2006b). There are several reasons for such a rise: the technological systemic features of this sector (section 2.2.1.3), individualisation trends in culture (section 2.2.1.4), specialised design gadgets in the current market (section 2.4.3) as well as use habits in daily life which are presented in Appendix 3: Table 6.

5.2.1.7 Other miscellaneous appliances
As stated in section 2.2.1, within the household, each product has its irreplaceable role and each member expects to possess his/her own device in this sector such as computer, telephone, printer and digital camera. Stand-by energy consumption and not unplugging the recharger (Appendix 3: Table 7) are two common causes of behavioural energy waste.

5.2.2 Selection of fridge and freezer as study objective
Having reviewed the behavioural potential of improvement in each household appliance sector, the research requires greater focus on one product or group of product in order to investigate how the design-led energy efficient approaches discussed previously can be tailored to one “test” product. It is worth noting that the “test” product could be any household appliance, but it is important to consider which product/group of products could have the most potential to achieve the objectives of this case study (section 1.2.2). It is not sufficient to take the energy usage of each household appliance group in the UK listed in Table 5.2 for reference, since the figures are not concerned with the user behaviour, i.e. why a product is operated in that way and how much energy is used to support for such operations. Products with complexity
in user’s interactions would be therefore suitable to explore the feasibility of Design for Sustainable Behaviour so that a detailed user study and new design concepts could be developed and discussed.

There are very few pieces of equipment in the home that use energy constantly. Fridges and freezers are two such products and account for around one-fifth of domestic energy consumption (Energy Saving Trust, 2006b). The Energy Saving Trust (2006b, p. 13) estimated that in the UK, “households spend £1.2 billion on electricity every year on cooling and freezing food and drinks” which is equivalent to the electricity consumed by all office buildings (Ethical Consumer 2001 cited in: CAT., 2007). The UK Government Energy White Paper (BERR, 2003) identified the need for further reductions in the energy used by cold appliances (Market Transformation Programme, 2007a). Prior studies of reducing the environmental impact in this cold sector focus on improving energy efficiency in manufacturing, distribution and disposal stages and reducing the energy for operation and intrinsic losses during the use stage. Nowadays, fridge and/or freezer, as one of necessities in the home, have arguably lost their meaning in use (Shove and Warde, 2002). However, they are widely used by a variety of user groups related to a range of habitual use behaviour and routine activities (daily cooking and food shopping). The complexity of user’s interactions with household cold appliances makes the refrigeration a far more interesting case study over other appliances.

5.3 Literature Review of Fridge and/or Freezer

As part of the research a literature review was conducted to build understanding of current research, commentaries and solutions for reducing environmental impact in three areas: directions of policy and legislation, solutions of manufacturers and technology, and knowledge exploration of institutes and public bodies. Figure 5.1 offers the schematic representation of the relationship between these areas. It helps to uncover the gaps by acknowledging the current limitations expressed by each one of the drivers and the connectivity between them. Legislations and policies affect industry, since they mark limits and set rules and goals for future performance. Most responses from design and manufacture are confined to the adoption of the environmental friendly technologies and materials. Limited measures have been put forward for the academic concerns regarding the environmental impacts resulting from the use of cold appliances.
5.3.1 Policy and legislation – Directive
There has been a great deal of energy efficiency legislation and policies focused on shifting the market towards more efficient appliances and influencing users’ purchase by providing information. In the current market, an efficient new fridge-freezer consumes only half of the electricity of an inefficient older model (Energy Saving Trust, 2006b). As a result of the implementation of the European energy label and minimum standards, the average consumption of a 140 litre refrigerator dropped by 29% between 1990 and 2001 (Boardman 2004, in: Environmental Change Institute, 2005). A fuller picture of the existing Legislations and Directives can be found in Appendix 4.

5.3.2 Manufacture, technology, user guideline and design – Solution
This section will review the products from Arçelik, Electrolux Group, Indesit, BSH Home Appliances, Norfrost, Miele, LG which between them have the majority share of the fridge and/or freezer market (Appendix 5 Table 1: A Brand Map of Selected Cold Appliance Brands and Their Parent Company) (Mintel, 2007c). The basic design of refrigerated appliances remains seemingly unchanged since their introduction in the early part of the 20th century. The five basic parts of the cooling system adopting by the majority of domestic appliances are the compressor, heat exchanging pipes inside and outside of the unit, a capillary tube and refrigerant (Market Transformation Programme, 2007b).
5.3.2.1 Technological improvement

To reduce environmental impact in this cold sector, most solutions have focused on technological innovations, such as using eco-friendly refrigerants (Sustainable Development Unit, 2005) and improving energy efficiency of insulated walls, compressor and fan (Market Transformation Programme, 2007a). Appendix 5 provides a detailed description of the technological improvements. However, about half the efficiency gains have been offset (Energy Saving Trust, 2006b) by the “rebound effect” (van de Velden, 2003a; Hertwich, 2005; Dimitropoulos and Sorrell, 2006). The rebound effect is linked to the supply side. Manufacturers are providing bigger volume cold appliances. According to the Environmental Change Institute (2005), the average size of cold appliances on the market increased by 15% between 1995 and 2001. This has resulted in manufacturers not selling appliances with lower overall energy consumption (Lockwood and Murray, 2005). On the demand side, it is reported that every household owns at least one cold appliance often with two or more (Environmental Change Institute, 2005). A survey by Mintel (2007c) shows that in 2007, the sales in this sector grew by 8% compared with 2005. Recently, users are enthusing about larger and more energy hungry appliances, such as American style fridge freezers containing integrated LCDs or ice producers. Over its lifetime, an American style fridge and freezer consumes 1800 KWh more than the typical average sized A-rated appliance. Furthermore, using small drink chillers and coolers in the bedroom, living room and car are becoming popular. The Energy Saving Trust report (2006b, p. 27) states that “a small drinks chiller can use half more electricity than an under-the-counter A-rated fridge”.

5.3.2.2 User instruction

Manufacturers and related government departments provide educational information and user guidance which include every detail form purchase to the disposal of the products. Appendix 6 gives a summary of these tips and principles. Environmental education initiatives and information campaigns, as discussed in the literature review, have had limited success in halting environmental damaging practices of fridge and/or freezer use.
5.3.2.3 Current designed innovations for energy saving

A number of product designs for reducing the environmental impact of the fridge and/or freezer during use stage can be realised through technological innovations which are summarised in Table 5-3.

Table 5-3: Technological innovations for enhancing energy savings during use

- Automatic defrosting: defrosting takes place independently and systematically;
- Frost free: refrigerator or freezer incorporates technology to keep the unit from icing up automatically;
- Door open alarm/self-closing door: a visual or visual and/or acoustic alarm sounds when door left ajar or open for too long;
- Through-the-door ice dispensers: ice tray is set into the door in order to give easy access to ice cubes without door opening, Hotpoint, “Ice care” feature (2007);
- Temperature display: (electronic) panel shows the exact temperature;
- Eco button: energy efficient mode sets the internal temperature of the fridge to the most optimum energy efficient level dependent on fridge content, e.g. “I Care function” (Hotpoint, 2007);
- Twin motor models with two thermostats: Electrolux’ (2005), holiday/winter modes, the temperature of the fridge and freezer compartments are regulated separately and the compartments can be turned off independently of each other;
- Quick freeze and super cool: lowering temperature rapidly after a large number of new items are added in the freezer or fridge to relieve workloads;
- Minimising temperature variation via multi-air flow system: LG (2006) IceBeam Door Cooling System combined with technology distributes the cool air not only from the vent at back side and side with a temperature variation 1.2 ºC compared with 2.9 ºC;
- Removable door seal: the removable design makes the gaskets round the doors easy to clean and replace, limiting energy waste during use;
- DAC (Divide and Cool) - Divisible Cooling Technology from Arçelik (Beko) (2009) has managed to operate with one compressor per fridge split into seven sections which could work separately, consuming 30% less power than a regular refrigerator compressor. This provides the technical possibility for further reduction in behavioural energy use of the module designed fridge.

Manufacturers are more inclined to help users obtain energy saving simply by technological means during the use stage. However, there are some disputes or even contradictions in the technological improvements within the literature. The automatic defrost freezer consumes 40 % more electricity than similar manual defrost models (Consumer Energy Centre, 2007). Eartheasy (2007) comments that the auto defrost and through-the-door ice makers not only save money on purchase, but also save up to 60% of the energy cost by reducing the need to open the door. Others argue that this feature can result in 14-20% more energy consumption (Consumer Energy Centre, 2007) and increase the purchase price about 75-250 U.S. dollars (Healthgoods, 2007).
5.3.2.4 Existing Fridge Design Concepts with Behavioural Intervention Features

Findings from a period of market research show that in terms of user's interaction and provision, the refrigerator market is stale. Even the top range of products, which offer better power efficiency, internal technology and storage capacity, are all the same boxes, providing the same use experience. The environmental impact of fridge use, however, is considered by a few designers. There are some features embodied in the commercial and conceptual fridge designs presented below which attempt to address environmental issues of use behaviour.

Door alarm, eco button and holiday setting are common energy saving features on the refrigerators that provide the users with options to help the environment when using the products. As seen in Figure 5.2, “I Care” (Hotpoint, 2009), using the eco button sets the internal temperature of the fridge to the most optimum energy efficient level, dependent on content. Holiday Setting (Hotpoint, 2009) configures the fridge, when empty with the door closed, to operate at 12ºC. To prevent cold leaking out, ESFridge, one concept of ESKitchen from Electrolux (2008a), has disk-shaped shelves attached to the door. As illustrated in Figure 5.3, shelves could be rotated slightly for the users to remove their desired items located near to the door.

The drawer fridge in Figure 5.4 from Norcool (2007), similar to offerings, CoolDrawer in Figure 5.5, from Izona (2009), is not only an idea to keep cold air which has higher density at the bottom of the fridge drawers, but also to display items at back while the drawers are pulled out.
Users usually open the fridge too often or for too long because of the uncertainty of its contents or layout. The company Sub-Zero has a few household fridges with glass doors offering easy-access refrigerated storage (Figure 5.6). Users can make their selection without letting out the cool air. However, the insulation of the glass is questioned, as is the cultural and psychological tolerance of allowing visitors into user's private “gastronomic” world. FridgeCam (Bonanni et al., 2005, Lee et al., 2006) projects spatial information about the contents of the refrigerator onto the door. FridgeCam is an augmented reality interface developed by the Massachusetts Institute of Technology (MIT) Media Laboratory (Figure 5.7). The cameras (Figure 5.8) capture the contents in three dimensions each time when the refrigerator door is opened and projects an image on the outside of the door. This allows the refrigerator to perform better at showing items inside, when it is necessary, than transparent doors.

There is a trend toward mobility and personalisation in recent conceptual fridge design which enable users to configure as the appliance to their individual preference, such as "NFRIDGE" (Santos et al., 2004). As it can be seen in Figure 5.9, NFRIDGE is modular...
fridge composed of small refrigeration cubes that allow users to purchase quantities that respond to their needs. “Go Fresh” (He, 2007) is another interesting example of a modular fridge which is divided into 12 individual honeycomb-shaped compartments with individual temperature controllers (Figure 5.10). These compartments automatically close the air inlet when the desired temperature is reached so that energy savings could be gained from the controllable temperature settings.

Figure 5:9: NFRIDGE (Santos et al., 2004)  
Figure 5:10: “Go fresh” (He, 2007)

Soft mobile refrigerator (Ou et al., 2005) is an imaginative concept from “Imagine the home in 2020” of Electrolux Design Lab 2005. Folding configuration offers convenient portability and deformable storage (Figure 5.11). Using a soft-membrane coat and a retractile bracing, its size can be increased and decreased to accommodate differing contents with a view to saving energy.

Figure 5:11: Soft mobile refrigerator (Ou et al., 2005)

The design concepts discussed above exemplify the common ways to decrease the impacts of the fridge use. Most of these ideas distinguished themselves by providing an innovative design with new technology, materials, textures and forms in order to reflect
users’ personalities or improve their confidence. Few cases were particularly designed for moderating behaviour to limit energy use. Additionally, the majority of the existing design examples lacked a comprehensive research context for their concepts and rigorous tests with users. Potentially, these concepts may increase the energy consumption generated through a rebound effect.

5.3.3 Institute and public bodies – Academic concerns
The impact of fridge and freezer consumption has attracted increasing academic attention. The social, cultural and demographic changes as well as the consumption motivations discussed in Chapter 2, also have significant effects on the fridge and/or freezer consumption. This section will briefly review the current academic concerns, including the change in refrigeration and freezing consumption and the difference in electricity consumption between real use and test.

5.3.3.1 Refrigeration and freezing consumption
When reviewing the history of the fridge and/or freezer, it is found that they have become “standard” items within a very short space of time (Shove and Southerton, 1999). As the representative of the development of the rational economy and domestic efficiency and convenience, the fridge and/or freezer use reflects the relationship between environmentally problematic user practices and shifting domestic demands regarding the management of time and scheduling of daily life (ibid).

The cold appliance, a kind of “time machine”, is used to beat the seasons and ensure domestic food safety. With the improvement in living standards, users are becoming more health-conscious and more informed (often using the internet to research potential purchase) (Market Transformation Programme, 2007b). The pursuit of a high food quality and specific taste rather than its safety results in the continued need for refrigeration (Garnett, 2007). More recently, because of the greater convenience in a fast-moving world, higher disposable income and lack of food preparation skills, people are inclined to refrigerate a large range and quantity of chilled ready meals and frozen food (Mintel, 2007c). These changes in food purchase, shopping and cooking habits have driven the overall demand for larger and more energy hungry cold appliances. Furthermore, the increase in the number of households and the decrease in average household size have led to the constant rise in ownership of cold appliances (Market Transformation Programme, 2007b). The appearance of specialised designed
refrigerated appliances, such as beer and wine chillers, may further increase the energy use of the household cold appliances (Energy Saving Trust, 2006b).

Pantzar et al. (1999) identify that the fridge and/or freezer are not only necessities for the household, but also carry cultural meanings. Fashion over functionality increasingly dictated the role of the fridge, becoming the main driver of the growth in purchase (Mintel, 2007c). Fridges and/or freezers are large household appliances that may reflect the way in which users lead their lives. Mintel’s survey (2007c) on the life cycle of the fridge and/ freezer suggests that people buy a new appliance when they enter a new life stage, such as starting to live independently or moving into a new house. Users attach importance to the appearance of their homes and look for good designs, attractive finish, toning colours and added features, and are prepared to pay more for such a unit (Mintel, 2007c). In terms of disposal, the main reason for the breakdown of cold appliances is compressor malfunction followed by a failure of the door seals. According to Cooper’s survey (2004), 37% of discarded fridges and freezers are still functioning and 19% in need of repair. The average age of obsolete products is “below the age considered ‘reasonable’” (Cooper, 2005, p.60). Parts for products are rendered obsolete by the introduction of newer models. These make it increasingly difficult for users to maintain products which are still fit for purpose. It seems economically viable to reuse an existing item. However, the cost of repairing items is often seen as prohibitive and is likely to represent around 70% of the total value of appliance (Mintel, 2007c). With this in mind people often opt for replacement rather than having the original item repaired. As discussed previously, in some cases replacing older machines with newer more efficient ones can be beneficial in reducing energy consumption (Fletcher et al., 2001).

5.3.3.2 Difference between real use and test

The current energy label test has been criticised by consumer bodies and experts for not reflecting actual energy consumption of home use. For example, during the test doors are not opened, the test load is unrealistic and also temperature recovery from insertion of warmer food and response to ingress of humidity is not examined (VHK, 2005; Market Transformation Programme, 2007b). Consumer surveys on actual energy consumption of cold appliances have given the following results in Table 5-4.
Table 5-4: Difference in electricity consumption of fridge and/or freezer between actual and the label provided by research from different countries

<table>
<thead>
<tr>
<th>User behaviour effects on energy use</th>
<th>Research community/reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Door opening</strong></td>
<td></td>
</tr>
<tr>
<td>The effect of door opening is 1-2%</td>
<td>Food Refrigeration and Process Engineering Research Centre (FRPERC) report (in: Market Transformation Programme, 2007c)</td>
</tr>
<tr>
<td>Door openings are responsible for 3% of the total electricity use</td>
<td>Böhmer et al. (1998) in EuP report (Stamminger et al., 2007)</td>
</tr>
<tr>
<td>20 door openings a day increase electricity use between 1-6%</td>
<td>Leptien (2000) in EuP report (Stamminger et al., 2007)</td>
</tr>
<tr>
<td>The effect of 20 door opening times with a 5-second opening time is 8% (2.2W)</td>
<td>Mennink and Berchowitz (1998) tested a 200 litre refrigerator</td>
</tr>
<tr>
<td>a12-second door opening causes energy impact of 9Wh - 12.4Wh</td>
<td>Saidur et al. (2002)</td>
</tr>
<tr>
<td>40 door openings per day adds between 50 - 120 kWh to its yearly energy use</td>
<td>A study by Peart (in: Stamminger et al., 2007)</td>
</tr>
<tr>
<td><strong>Inserting hot or cold items</strong></td>
<td></td>
</tr>
<tr>
<td>The influence of warm food is 4-10%</td>
<td>FRPERC (in: Market Transformation Programme, 2007c)</td>
</tr>
<tr>
<td>The influence of adding food at room temperature is 11% (3.1W)</td>
<td>Mennink and Berchowitz (1998)</td>
</tr>
<tr>
<td>The insertion of food into the fridge is made up 10% of its yearly energy use; Cooling food with a temperature of 50°C uses three times more energy than cooling food with a temperature of 20°C</td>
<td>Böhmer et al. (1998) in EuP report (Stamminger et al., 2007)</td>
</tr>
<tr>
<td>Thawing frozen food in the refrigerator reduces energy use up to 26%</td>
<td>Leptien (2000) in EuP report (Stamminger et al., 2007)</td>
</tr>
<tr>
<td><strong>Operating Temperature</strong></td>
<td></td>
</tr>
<tr>
<td>On average, freezers were operating at 3.1°C colder than the recommended temperature (-18°C), leading to 17.6% more energy use</td>
<td>ECUEL project SAVE (1999) in France metered appliances in 98 households for a month (in: Market Transformation Programme, 2007c)</td>
</tr>
<tr>
<td>1°C difference in temperature causes a 4% difference in energy consumption</td>
<td>Methodology Study Eco-design of Energy-using Products (MEEUP) for European Commission (in: Market Transformation Programme, 2007c)</td>
</tr>
<tr>
<td>1°C difference in temperature results in a 7.8% difference</td>
<td>Saidur et al. (2002)</td>
</tr>
<tr>
<td><strong>Surrounding Temperature</strong></td>
<td></td>
</tr>
<tr>
<td>Keeping a cold appliance in a non-heated storeroom rather than a kitchen gives an average energy saving of 36%</td>
<td>ECUEL project SAVE (1999, in: Market Transformation Programme, 2007c)</td>
</tr>
<tr>
<td>Refrigerators use 16% less energy in a room with temperature of 21 - 23°C instead of 25°C; 32% less with room temperature of 17 - 21°C</td>
<td>Studies in EuP report (Stamminger et al., 2007)</td>
</tr>
</tbody>
</table>
52% less with room temperature of 13 - 17°C; a higher temperature of 32°C instead of 25°C increased the energy use by 55%

<table>
<thead>
<tr>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ice-up of the evaporator deteriorate the efficiency by 10-20%</td>
</tr>
<tr>
<td>Average annual actual electricity consumption was 65% larger than the JIS test value (Japan Industrial Standards test in 1999)</td>
</tr>
<tr>
<td>MEEUP (in: Market Transformation Programme, 2007c)</td>
</tr>
<tr>
<td>Japanese surveys on Actual Energy Consumption (Tsurusaki et al., 2006) monitored over 100 household fridges for one year</td>
</tr>
</tbody>
</table>

These studies from different countries provide interesting data on the real-life of fridges and freezers, but they are generally concerned with the end result of quantitative data collection, not the use process. However, fridges and freezers, essential products in the household, are widely used by a variety of user groups in a range of habitual use behaviours and routine activities. There is limited work within design concerned with the environmental impact of operation and energy consumption of real-life usage of the product.

5.4 Next Step

The cold sector, after space heating, lighting and consumer electronics, accounts for the next most significant portion of household energy consumption. The complexity of user’s interaction with cold appliances opens the way for a more detailed user study to investigate the relationship between product design and use behaviour and its environmental impact. The fridge and freezer can be considered as an epitome of the user’s personal lifestyle. Food that is stored in the fridge and/or freezer is a reflection of the quality of the users’ lifestyle, i.e. their approach to healthy eating and drinking, shopping habits, daily routines and arrangement of leisure time.

Although prior research from different countries has provided interesting data on real fridge and/or freezer use, they are generally concerned with the end result by collecting the quantitative data, not the use process. Few existing design concepts have consciously addressed the impacts of use from reality and brought behavioural change. There is an opportunity to explore knowledge of strategic approaches to gaining more energy savings by influencing the real use behaviour and habits through design-led solutions. In the following chapters, the empirical research will be explored through the implementation of a design case study which demonstrates the process of applying user centred research techniques and the Design Behaviour Intervention Model to identify and decrease negative environmental impact resulting from product use.
6 PILOT STUDIES

The pilot studies aimed to test the effectiveness of the data collection methods employed in gaining users’ perceptions of environmental issues and exploring mundane practices and routines related to fridge and/or freezer use.

6.1 Introduction

This chapter reports the methodology and subsequent findings of two pilot studies which aim to assess the feasibility and effects of the data collection methods for the next step of the research.

The literature that was reviewed in Chapter 5 highlighted the gap in qualitative assessment of the impact of household appliances use. A single product type (household cold appliance) was selected as a case. In this chapter, two pilot studies are described. They were conducted in an attempt to study the use behaviour and support the designer in “Design for Sustainable Behaviour” of household cold appliances. Utilising the user centred approach, a series of observations, questionnaires and interviews were conducted to understand more about the daily use of the selected case. Three British families were involved in each pilot study. The studies cover a range of data collection methods and both sets of results are brought together in the conclusion section to present the overall findings of these activities. By comparing the results of the two studies and research methods applied, the more effective user research design is chosen for the main user study which is presented in Chapter 7.

6.2 Methodology for Pilot Studies

This section is concerned with why the selected research methods were applied and how the pilot studies were conducted. The strengths and weakness of the chosen methods are also discussed. Finally, a number of the video recording techniques used in this ethnographic and observational research are presented.

6.2.1 Methods of Study

User centred research techniques (Maguire, 2001; Evans et al., 2002) were used to capture opportunities for designs that solve environmental problems of use behaviour and activities around the fridge and freezer relevant to energy consumption.
6.2.1.1 Observation

Product-in-Use observation was carried out with aid of audio-visual equipment. It is stressed that “focusing solely on individual behaviour without attending to contexts runs a serious risk of misunderstanding the meaning of events” (Miles and Huberman, 1994, p. 102). Visual recordings enable researchers to capture actual behaviour in its real-life context (Evans et al., 2002) and to look at the interaction between people and their environment (Sanoff, 1992), offering researchers detailed and accurate source of daily practices and routines (Knoblauch et al., 2006). This method is also an interactive and naturalistic (Evans et al., 2002, p. 18) method and helps the observer to identify true opinions and actions, as people often say one thing but think or do another (Kelley and Littman, 2001). For instance, people may not report or be able to articulate habitual behaviour when asked (Lofthouse and Lilley, 2006). Video not only provides a rich source of data which is recorded and retained and in the moving picture, but also the availability for close study and multiple replays of the action and interactions of people going about their ordinary life (Daut, 2004). As identified in the literature, analysis of the practices and everyday routines can be used to uncover misuse of products, generate new product ideas, redesign existing products and evaluate new concepts or prototypes.

Two pilot studies were developed to assess the data collection strategy. As illustrated in Figure 6.1, the interactions between the user and the product encompassed three stages - before use (selection and purchase), mid-use (operation and maintenance) and after use (disposal or recycle). Mid-use were broken down into five parts – getting started, use, sequence of use, context of use and life of usage. Considering the household fridge and freezer and their central relationship to food preparation and consumption, the use activities around the fridge and freezer were arranged into three related groups including condition and environment of product in use, food shopping unpacking and food preparation. Correspondingly, three observations of Product-in-Use were conducted.
Figure 6.1: Interaction with the fridge and freezer and the “Before → Mid → After Use”
6.2.1.2 Questionnaire and Semi-structured Interview

Observation has been emphasised as the main method of primary data collection, however, Rodriguez (2006) argues that observation by itself is not sufficient to identify the complexity of behaviour. Self-completion questionnaires and semi-structured interviews would clearly offer an advantage in supplementary data collection. Used together, they helped to overcome the limitations of forming conclusions from a specific method. Therefore, multiple methods were chosen for the user study to give a better representation of fridge and freezer use as well as to provide an in-depth profile of users’ values and intentions behind the daily practice.

A self-completion questionnaire, containing a series questions with a limited set of response categories, was designed for the participants to evaluate themselves. The results would provide the assessment of participants’ environmental attitudes and action in different environmental subject areas, including energy efficiency and waste recycling. Responses could be directly compared and easily aggregated and a number of areas could be covered in a short space of time, when they were correctly constructed and coded (Robson, 2002b). Open ended questions provided participants with opportunities to talk about the “like” and “dislike” issues of their cold appliances in more detail.

The disadvantage of self-completion questionnaires is that the participants must fit their answers into response categories perceived by the researcher. In this study, the face-to-face interviews would offer insightful information about the users routine practice ingrained in fridge and freezer use patterns. Semi-structured interviews with a pre-determined agenda, would enable discussions around specific issues, avoiding irrelevant content and making it easy to compare the data (Robson, 2002b). Furthermore, face-to-face interviews would offer the possibility of modifying researcher’s enquiry according to the real situation, since some of the questions have not been predetermined, but asked in an open-ended manner to discuss not only “what have people done” but also “why have people done it” (Berger, 1998, P. 62).

All the activities conducted in the pilot studies were recorded by notes, photos and video recordings. The audio recordings, captured images and original field notes assisted the researchers in discussions with participants and in carrying out the subsequent data analysis to extract, compare and collate similarities and differences.
6.2.2 Pilot Studies Design

It is suggested that a comparison between interview statements and everyday observations for the same person often reveals the gap between their intentions and own actions (Schmid, 2006). Therefore, these research methods are combined in one study to solicit opinions, knowledge, beliefs and/or attitudes as well as to mirror the actual behaviour in its context. This section reports the design process of two pilot studies of fridge and freezer use. They were designed to test the appropriateness of research techniques and to develop the framework for the main user study to sense the real life and pressing environmental issues concerning household fridge and freeze use.

6.2.2.1 Pilot Study 1

Fridges and freezers are essential to a range of habitual use behaviour and routine activities. The close relationship between the activities and the private life of the users could prevent potential participants from taking part in the observation part of the study. This made manually observing and recording in use activities a challenging proposition. Therefore, in the first pilot study, as seen in Figure 6.2, the participants were asked to fill out a kitchen user profile questionnaire and were provided with Participant Information Sheet and Informed Consent Form which detailed the research, its significance, the use of the data and their right to withdraw from this study (Appendix 7). This questionnaire aimed to gather the basic information about the potential participants and enabled them to get familiar with the study and the researcher. The kitchen user profile questionnaire comprised of 15 questions. These were asked participants for the appliance information, shopping habits, cooking habits and user information.

![Figure 6.2: User centred research methods used in Pilot Study 1.](image-url)
At the first stage, the participants were told that the study aimed to understand the relationship between the user and their kitchen. Verplanken and Faes (1999) suggested using a “cover story” to avoid the unnatural desirable response tendencies. Participants were therefore unaware of the importance of their specific actions (Sanoff, 1992). Three observations (Appendix 8) were then carried out to record grocery shopping unpacking, fridge and freezer use and food preparation. Guided by the Observation Task (Appendix 9), seven questions about the food storage and preparation habits were asked during these observations. Finally, a post intervention questionnaire (Appendix 10) and a semi-structured interview (Appendix 11) were employed to address the issues regarding fridge and freezer use patterns, users’ perceptions of environmental responsibility and the impacts of use.

Three fridge and freezer users were involved in Pilot Study 1 and were aged between 21 and 40 and had owned their fridge or freezer for between 6 months and 6 years. Table 6-1 illustrates the composition of the participants involved.

Table 6-1: Composition of the participants for Pilot Study 1.

<table>
<thead>
<tr>
<th>Participant Code</th>
<th>Age</th>
<th>Living status</th>
<th>Make &amp; style of fridge and/or freezer</th>
<th>Duration of ownership</th>
</tr>
</thead>
<tbody>
<tr>
<td>PUS1-01</td>
<td>35-39</td>
<td>4-person family with two children in the age group below 11</td>
<td>combined - LEC</td>
<td>6 years</td>
</tr>
<tr>
<td>PUS1-02</td>
<td>25-29</td>
<td>2-person household without children</td>
<td>separate built-in - INDESIT</td>
<td>6 months</td>
</tr>
<tr>
<td>PUS1-03</td>
<td>21-24</td>
<td>2-person household without children</td>
<td>separate fridge – WHILPOOL; separate chest freezer - NORFORST</td>
<td>1 year</td>
</tr>
</tbody>
</table>

6.2.2.2 Pilot Study 2

Pilot Study 2 consisted of four research activities, a user profile questionnaire (including Participant Information Sheet and Informed Consent Form) (Appendix 12), food unpacking and Product-in-Use observation, 24-hour fridge use recording and a Post-intervention and a Semi-structured Interview. Figure 6.3 demonstrates the methods employed to understand user behaviours in Pilot Study 2.
To appropriately capture a range of behaviours and the causes of such behaviour related to the everyday use of fridge and freezer, Pilot Study 2 added a Product-in-Use environment observation and a 24-hour recording of fridge use to the observation section (Appendix 13 modified version Information Sheet and User Profile Questionnaire). A hand-held Digital Camcorder was used to film the food unpacking and product in use environment and the web-camcorder and recording equipment were placed strategically to get the best view of the fridge. As the camera was small, it was easily positioned in place. It was hoped to cause the least amount of inconvenience for the household and observe more natural and realistic use behaviour. The recording equipment was then collected after 24 hours.

The post-intervention questionnaire and interview guide were conducted through several iterations to refine the questions. A range of closed questions (adapted from DEFRA, 2007b) about the factors influencing decision making and behavioural change were added to the post-intervention questionnaire. It aimed to ascertain the existing links between the environmental knowledge, belief, awareness and life values and day-to-day use behaviour of the household appliance. The final version, found in Appendix 14, was split into the following four sections:

1. General information regarding Fridge and Freezer Use Context (Questions 1-13) - product information, use status, users’ perceptions and expectations of cold appliances and thoughts of its purchase, use and its impacts. Two open ended questions were designed to encourage a greater depth of discussion about the “like” and “dislike” issues about their fridge and/or freezer.

2. Ten issues about Life Values (Question 14) – seven scales from definitely disagree to definitely agree used to indicate the individual opinions on these statements.
3. The environmental awareness, attitudes and performance as a whole (Questions 15-26) – identifying individual’s knowledge and attitudes towards energy and resource efficiency and eco-friendly purchasing as well as performance of environmental behaviour.


Following the questionnaire, an in-depth interview was viewed as a good opportunity to obtain qualitative information behind the routine practice ingrained in cold appliance use. Carrying out these linked activities consecutively would not only allow data gained in the observation sections and questionnaire to be explained and clarified, but also provide the additional time for participants to consider and revise their responses. The open-ended questions were devised to encourage the participants to talk about their own practices in relation to the specific context about and around fridge and freezer use. Issues such as the reason for the previous fridge and freezer being discarded and new ones purchased, food storage design, cooking plan, kitchen memories and kitchen habits formation were explored. Combining the questions asked during the observation sections and interview in Pilot Study 1, the modified interviews were semi-structured within a simpler framework. As seen in Appendix 14, the topic guide consisted of four parts, each representing the research objectives: food storage, cooking habits, fridge-freezer information and environmental responsibility. In addition, the prompting questions were available to the researcher to aid the elicitation of appropriate responses. These questions had a certain amount of flexibility. This allowed the interview to shift between topics and particular avenues to be explored further. Also, the flexible nature of the interview enables the questions to be readjusted to the actual condition and individual’s experience. It was hoped to entice their true opinions and to promote substantial discussions on the reasons for their particular behaviour, the users’ environmental responsibility and the changes that should be made to the fridge and freezer design. The interviews lasted for between 35 and 45 minutes and were audio taped and then later transcribed.

Three families (illustrated in Table 6-2) took part in Pilot Study 2 which recorded their fridge and freezer use in a “normal” week day over 24 hours. The participants were in the age group of 30-49 and had owned their fridge or freezer for between 1 year and 9 years.
Table 6-2: Composition of the participants for Pilot Study 2.

<table>
<thead>
<tr>
<th>Participant Code</th>
<th>Age</th>
<th>Living status</th>
<th>Make &amp; style of fridge and/or freezer</th>
<th>Duration of ownership</th>
</tr>
</thead>
<tbody>
<tr>
<td>PUS2-01</td>
<td>45-49</td>
<td>4-person family with two children in the age group of 12-18</td>
<td>combined - Electrolux separate chest freezer</td>
<td>9 years</td>
</tr>
<tr>
<td>PUS2-02</td>
<td>45-49</td>
<td>3-person family with one child in the age group of 12-18</td>
<td>combined –BOSCH separate built-in - Hotpoint</td>
<td>5 years</td>
</tr>
<tr>
<td>PUS2-03</td>
<td>35-39</td>
<td>4-person family with two children in the age group below 11</td>
<td>combined – LEC</td>
<td>6 years</td>
</tr>
</tbody>
</table>

6.2.3 Video recording techniques

One element of study was to assess the potential benefits and difficulties of video recording as an instrument of observing and interpreting everyday practices to be applied within design. There were a variety of recording technologies and associated equipment available. Equipment would be at a reasonable cost and offer the most appropriate method to conduct the observation and analysis of the use behaviour, such as what, where, when and how the participants took out from the fridge. Prior to collecting visual data in the participants’ house, the equipment was set up on the researcher’s fridge for several trial runs. This ensured that relevant data was gathered and made the observation more user friendly. As depicted in Table 6-3, in 24-hour fridge use observation, the camera was used to record images only and not sound. The recording was triggered by installed software which could detect motion.

Table 6-3: Types of visual material generated and recording techniques used in this study

<table>
<thead>
<tr>
<th>Visual Data</th>
<th>Recording Techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fridge and freezer use environment-kitchen, utility room, garage, lounge, dining room...</td>
<td>Digital camera and digital camcorder</td>
</tr>
<tr>
<td>Food storage</td>
<td>Digital camcorder</td>
</tr>
<tr>
<td>Use condition of fridge and freezer</td>
<td>Digital camera</td>
</tr>
<tr>
<td>Food unpacking recording</td>
<td>Hand-held digital camcorder</td>
</tr>
<tr>
<td>24-hour fridge use</td>
<td>Web camera, recording equipment and software</td>
</tr>
</tbody>
</table>
6.3 Findings and Discussion

The following discussion reflects on the effectiveness of research methods and study design in the pilot studies and the potential for designers to improve energy efficiency of household fridge and freezer use.

6.3.1 Studying user behaviour through a detailed designed user study

Concealing the research objectives from the participants at the beginning of the study through a “cover story” (please refer to section 6.2.2.1) reduced the unnatural behavioural response tendencies in Product-in-Use, which recorded what people actually do with the product, not what they say they do, including the sustainable and unsustainable use behaviour. The video recording could expand details of everyday practices and mundane interactions between the users and products which might have not been perceived by the participants (Rodriguez, 2006). Also, the video footage could be reviewed to check on the details of context and sequence of use, participants’ gestures, movements and emotions when they operated the products. Combining Product-in-Use with post-intervention questionnaires and semi-structured interviews was particularly useful in exposing the environmental intention - actual behaviour gap in energy consumption. The post-intervention questionnaire and semi-structured interview provided the explanation of motives and reasoning for such behaviour, revealed information about the decision-making process and the emotional and social context of product use. The methods adopted in Pilot Study 2 were more effective in representing the real situation of the product use than in Pilot Study 1. Table 6-4 shows the benefits and drawbacks of the approaches adopted in the pilot studies and the reflection of the researcher.
<table>
<thead>
<tr>
<th>Benefits</th>
<th>Drawbacks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Through carrying out the interview just after recording food shopping</td>
<td>The observations of unpacking shopping and cooking should not be carried out on the same day,</td>
</tr>
<tr>
<td>unpacking, direct and immediate responses from the participants could be</td>
<td>since participants always kept what they want to cook outside and times and duration of the</td>
</tr>
<tr>
<td>obtained. The short time observation allowed one observer to take notes</td>
<td>fridge and/or freezer use are reduced.</td>
</tr>
<tr>
<td>while filming and to get detailed reflection of the behaviour from the</td>
<td>The cooking observation took 20-30 minutes but only part of the recording related to the</td>
</tr>
<tr>
<td>user in the short interview.</td>
<td>fridge use was useful. There was a long period of non-activity with the cold appliance.</td>
</tr>
<tr>
<td></td>
<td>It was difficult to ensure the authenticity of the user behaviour during the direct</td>
</tr>
<tr>
<td></td>
<td>observation since overt filming may be the barrier for natural and realistic user</td>
</tr>
<tr>
<td></td>
<td>behaviour.</td>
</tr>
<tr>
<td></td>
<td>Questions on the attitude, knowledge, intention and emotion affected on the user decision-</td>
</tr>
<tr>
<td></td>
<td>making process need to be added to the questionnaire to detect the factors for behavioural</td>
</tr>
<tr>
<td></td>
<td>change to reduce energy use.</td>
</tr>
</tbody>
</table>

**Pilot study 2**

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Drawbacks</th>
</tr>
</thead>
<tbody>
<tr>
<td>A variety of use behaviour and habits of the whole family members can be</td>
<td>Recording for 24 hours, analyzing, editing and logging behavioural data would be time</td>
</tr>
<tr>
<td>recorded in the 24-hour observation, including cooking meals, preparing</td>
<td>consuming (May, 2001; Evans et al., 2002); sourcing appropriate equipments and software for</td>
</tr>
<tr>
<td>food box as well as making drinks.</td>
<td>24-hour recording required specialist knowledge of the area.</td>
</tr>
<tr>
<td></td>
<td>It is not easy to recruit participants for the long term behaviour record. Since home is a</td>
</tr>
<tr>
<td></td>
<td>private place, not everyone is willing to be filmed in their home. Data protection legislation</td>
</tr>
<tr>
<td></td>
<td>and ethical issues need to be considered undertaking the study and publishing the</td>
</tr>
<tr>
<td></td>
<td>observational data.</td>
</tr>
</tbody>
</table>

6.3.2 Changing user behaviour through sustainable product design

Data collected from the pilot studies provided interesting evidence to support the theory that an understanding of real use behaviour was an essential starting point for improving product design for behavioural change to reduce environment impacts.
In the observation of unpacking grocery shopping, it was seen that most of the time spent putting food into the fridge and freezer was used for making room for new items and transferring items between shelves (Figure 6.4). In the 24-hour recording, it took more time to take desired items out, looking for the desired item inside the fridge i.e. at the back or bottom. However, this previous experience and knowledge saved time when returning to the fridge.

Understanding what was an operational principle of the user could help to reduce door opening time. The results of observations showed that users located items according to a range of principles including:

- Expiry date of food: all participants put newly purchased items at the back of the fridge and old or used food in an obvious place in the fridge such as in the front of the shelf at eye-height level or in the top door bin;

- Types of food: packing the same type of things together helped to locate food that they wanted, for example, all pizzas were put in the chest freezer vertically side by side so the pizza type can be read on the spine easily (PUS1-03), as shown in Figure 6.5;

- Food packaging: sealed and packed foods and drinks such as strawberries, ready meals, beers, are stuffed on the shelves and often overlap one another (PUS1-01, illustrated in Figure 6.6); meat often goes to the bottom glass shelf because the packaging may be broken and “it will not drip on everything” (PUS1-03);

- Weight of the items: “heavy” things, such as potatoes and carrots often were kept in the bottom of the drawer, the crisper, underneath the soft vegetables and fruit such as tomatoes and grapes, since “the heavy items squash everything” (PUS1-01);
- User of food and drinks: for example, foods often sorted for children, i.e. children’s foods are located at the eye height level (PUS1-01) and their mini cheese in the top door bin;

- Temperature distribution in the fridge: users used different temperatures inside their fridges to decide where to locate raw meat, cooked meat and cheese; this was usually at the back of the fridge. However, this lower temperature at the back of the fridge near the walls was said to often freeze vegetables;

- Door bins: bottom always kept wine and milk and the mid bin often kept small jars and bottles, and juice; items in top door bin varied and included cut onion, garlic and cheese;

- Habitual place for certain food and drinks.

These routine fridge and freezer use patterns can be considered so as to develop more acceptable product-led solutions to improving the loading efficiency. A more adaptable interior, for example, would enable users to create the optimum arrangement of their food and drinks in the fridge and freezer. Additionally, according to the type of the food and the shape of the food packaging, more behaviour constraints and affordances can be designed to lock the location of the food. What is more, designs that display the contents better would reduce the opening time for seeking items inside the fridge.

The findings indicated that the real condition of fridge and freezer use varied during the product life. It was not only related to the householders’ shopping and cooking
habits, but also the life stage of the users. The reasons for placing different amounts of consumables in fridges and freezers and the reasons given for purchasing new appliances were reported as follows:

- On the day of shopping, the fridge and/or freezer were always full;

- Parties, holidays and hot weather affected the amount and content of food and drink loads;

- One of the families had a less full fridge with “lighter” food than they used to have, because they chose a healthy eating style a couple of years ago (PUS2-02, Figure 6.7);

- One of the households’ fridges became over full after they had children (PUS2-03);

- The most important motivations for buying a new appliance were moving into a new house or decorating the kitchen. Often a modern kitchen design required a second counter fridge and freezer to fit in and the participants had a second fridge or freezer running for keeping party food occasionally (Figure 6.8).

Figure 6:7: A less full fridge with “Lighter” Food

Figure 6:8: A modern kitchen design required a second counter fridge and/or freezer to fit in

Providing users with options through product and system or service design could encourage them to think about their use behaviour and take responsibility for their actions. This may be achieved by designing a flexible modular system with separate temperature settings, and supplying a modular service with the customer to meet their needs during their different life stages. This could avoid unnecessary replacement and usage of a second cold appliance.
The findings also pointed to some potential opportunities for improving product design from an environmental perspective. It was found that milk and margarine were identified as the most in-and-out items in a normal day (Figure 6.9). Also, by comparing the data of the unpacking observation with the cooking observation, the results showed that all participants were more organized on placing food inside the fridge and/or freezer than cooking. During cooking, they often took out and put in items much more frequently. To reduce door opening times, designers could create internal structures for organising food preparation and special milk and butter/margarine storage solutions for making quick meals and drinks, as in the case of through-the-door ice dispenser. In addition, in the user study, food hidden at the back of the shelf was one of the reasons for food waste and unnecessary food purchase, as shown in Figure 6.10. It took the family members a lot of time with the door open to browse what had been bought. Using shallow drawers or software to keep a food shopping record can provide users with a clear view of the food inside the fridge and freezer and decrease food waste and the amount of time with the door open.

![Image of a refrigerator with food items](image1.jpg)  
**Figure 6.9:** Milk and margarine were the most in-and-out items  

![Image of a refrigerator with food items and a shelf](image2.jpg)  
**Figure 6.10:** Food hidden at the back of the shelf caused needless food purchase and wastage

### 6.3.3 Guiding and maintaining changes in user’s intentions and habits through sustainable product design

The interviews showed a lack of user awareness of the link between personal behaviour of the fridge and freezer use and the direct impact on energy use. The barriers that may prevent energy-conscious practices taking place are summarized below:

- Invisible energy: users were not aware of the amount of energy individual electric equipment used;
- Unawareness of the link: often, the way a fridge is used is regarded to have little effect on overall energy use in the home;

- Lack of information: users felt that fridges and freezers are an essential part of modern life and it was more important to set lower temperature to ensure the quality and taste of the food and drinks than to be concerned with the energy use. Although none of participants had ever measured the actual temperature inside the appliances, on average, fridges are operating at 2.3°C higher than recommended temperature;

- Lack of concern: Product-in-Use observation showed that all young family members left the door open while transferring items between the fridge and the worktop;

- Lock in lifestyle: participants assume that “the cold appliance is efficient enough by itself” (PUS1-01) and there is no need for a conscious behaviour to improve the overall energy performance (PUS2-01).

To address these, design-led interventions would need to build on the energy conversation to guide behavioural change elements of the model. Designing an effective way of communicating makes sure users know how to use the product efficiently through a range of design interventions such as providing information, choice, feedback or behaviour spur.

6.3.4 Changing user behaviour through sustainable system design
Modern kitchens were identified by participants to be one of the restrictions of consumption behaviour with regard to fridges and freezers. It not only required a second, often empty, counter fridge and freezer to fit in (Figure 6.11) but also half of cold appliances were built-in style fridges and freezers and one third were located next to the oven (Figure 6.12). What is more, limited storage space in the kitchen was another reason for unnecessary refrigeration. Therefore, designing a food storage system in the kitchen could provide design-led solutions to facilitate sustainable energy and food consumption behaviour.
6.4 Conclusions

Evidence has been drawn upon to support the research techniques used in pilot study 2. The use of ethnographic and observational research techniques captured the actual habitual behaviour in its context. By combining questionnaires, in-depth interviews and everyday observations in one study, the difference between people’s thoughts and their actual actions was revealed. The “cover story” used to inform participants about the reasons for the observations (please refer to section 6.2.2.1) minimised the unnatural factors affecting behavioural responses. Running consecutive research activities was a good remedy for the unrealistic tendency that allowed participants to elaborate from different aspects of their behaviour and to discuss the reasons for the particular behaviour and its environmental impact. This qualitative flexible design of the pilot studies allowed the researcher to validate the data collection process. Carrying out the face-to-face interviews in the context was helpful to adjust questions according to the individual cases.

The findings from the fridge and freezer use behaviour study highlighted that understanding user behaviour could be the preliminary step for seeking solutions to minimising environmental impact of household energy consumption through improving product design. The pilot studies uncovered the different ways of using the product and its unnecessary energy and food consumption. The results showed a lack of user awareness of the link between personal behaviour of the fridge and freezer use and the direct impact on energy use. The younger users tended to behave in a less sustainable way related to energy consumption (i.e. preparing food and filling vegetable box with fridge door open). The pilot studies exposed that the food stored in the fridge and freezer was connected with the activities around the products and reflected the
quality of life - users’ approach to healthy eating and drinking, shopping habits, daily
routines and arrangement of the leisure time. This justified the product choice with
reference to the complexity of the user's interaction (section 5.2.2) and supported the
next step of the research. The user study strategy of Pilot Study 2 would be applied in
the main study of fridge and freezer use in Chapter 7.
7 MAIN STUDY

To collect data about “actual” and “assumed” needs, unsustainable and sustainable use patterns and hidden factors behind the usage across a broader sample, the main user study was conducted with eighteen British families. This chapter described the collection and analysis of the data and the interpretation of it within the context of Design for Sustainable Behaviour. Some design suggestions for sustainable fridge and freezer use were outlined. The main study demonstrated how design solutions could be drawn from a detailed user study to reduce the impact of product use on the environment.

7.1 Introduction

This chapter presents the findings that emerged from the data analysis of the main user study, providing an insight into the type of information required by designers to reduce energy consumption in use. As discussed in Chapter 6, the research techniques employed for Pilot Study 2 were used to collect information about “actual” and “assumed” needs, the diversity in use, unsustainable and sustainable use patterns and hidden factors behind use across a broader sample in the main study. It outlined the methods and processes for extracting design oriented information from the behaviour study in the early phases of energy efficient product development. The final section discusses the implications for the future design of household cold appliances.

7.2 Aim and Objectives of Main Study

The aim of this phase of the research was to explore environmental impact of household cold appliance use, investigating how design could be applied to enable users to adopt more sustainable practice.

This aim was broken down into the following objectives:

1. To explore mundane practice and routine of fridge and freezer use in the household;

2. To identify the sustainable and unsustainable use patterns, the barriers and enablers to sustainable behaviour and environmental impact of fridge and freezer use;
3. To understand the current levels of and the existing links between knowledge, belief, awareness and life values and daily behaviour across of issues relevant to the environment, including fridge and freezer use;

4. To gain insight of the capacity of product design to solve the environmental problems of fridge and/or freezer use.

7.3 Methods of Data Collection and Analysis

The further investigation of fridge and freezer use applied the data collection strategy developed for Pilot Study 2. As outlined in section 3.8, the main user study combined purposive and snowball sampling techniques to involve a wider range of participants. The data was analysed by using coding, matrix and mapping and clustering techniques, to reduce and display the data and to draw and verify the conclusions.

7.3.1 Recruitment and Selection of Participants

To be eligible for the study, participants needed to do food shopping and cooking regularly, be the owners of the fridges and freezers and live within easy travelling distance of the researcher.

At the recruitment stage, the participants were contacted either by email or through direct contact. The potential participants received a recruiting letter (Appendix 15) which explained the intentions of this user study. Then the respondents signed the Participant Information Sheet and Informed Consent Form before they took part in this study. The Participant Information Sheet and Informed Consent Form (Appendix 12) outlined the use of the data and the participants’ rights to withdraw from this study. The main user study included a 24-hour recording in the kitchen. As anticipated, it was a particular challenge to recruit participants whose whole family agreed fully to be interviewed and recorded. Two potential participants who initially wanted to be involved in this study declined the request after discussion with their family members. The video element made this study daunting for people to co-operate in. The householders needed to be very culturally tolerant to accept the intrusion of strangers and recording equipment into their private domestic sphere.

According to Strauss and Corbin (1998), ten high quality interviews can provide the skeleton of a theoretical structure. Eighteen British families, recruited through social network snowballing (Strauss and Corbin, 1998), were involved in this qualitative
study. As shown in Table 7-1, the participants aged between 25 and 65 and had owned their fridge(s) or freezer(s) for between 4 months and 16 years. Appendix 16 provides the coding and description for these participants in detail. Results of the pilot studies showed that more diversity of use context and more environmental stressed fridge and freezer use behaviour could be obtained in multi-person households. It was therefore decided to reduce the number of single person household in the main study.

<table>
<thead>
<tr>
<th>Age</th>
<th>Had owned fridge/freezer for</th>
<th>Family Size</th>
<th>Person/Household</th>
<th>Single</th>
<th>Two</th>
<th>Three</th>
<th>Four</th>
<th>Five</th>
</tr>
</thead>
<tbody>
<tr>
<td>25-65</td>
<td>4months - 16years</td>
<td>Single</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>7</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

### 7.3.2 Data Collection Process

A number of different data collection methods were trialled in the pilot studies. Pilot Study 2 was shown as the most appropriate combination of research techniques to achieve the research aim. The main user study took place as follows:

- The participants were asked to fill out a kitchen user profile questionnaire (Appendix 12);
- Each household was provided with a Participant Information Sheet and required to fill out a consent form (Appendix 12).
- Each household was asked to take part in a grocery shopping unpacking observation, filmed by hand-held digital camcorder;
- Product-in-Use observation and kitchen tours were carried out with digital camera and digital camcorder and guided by Observation Task (Appendix 8);
- The web-camcorder, recording equipment and motion detected software were set up to conduct 24-hour recording of fridge and freezer use. The recording equipment were then collected after 24 hours;
- As soon as possible after the completion of the observation, each household was asked to complete the Post-intervention Questionnaire (Appendix 13);
- A 40 minute interview commenced adopting a topic guide (Appendix 14); the interviews were recorded by a voice recorder;

An overview of the data process for the main study is shown in Table 7-2.
Table 7-2: Research methods used for the Main Study

<table>
<thead>
<tr>
<th>Research Activity</th>
<th>Time</th>
<th>Equipments</th>
<th>Participants</th>
<th>Aim</th>
<th>Appendix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Questionnaire: User profile, Participant Information</td>
<td>10m</td>
<td>Hand-held digital camcorder</td>
<td>Wife and/or Husband</td>
<td>To brief the research, its significance, the use of the data and their right to withdraw from this study; To gather the basic information from the potential participants; To enable participants to get familiar with the study and the researcher.</td>
<td>Appendix</td>
</tr>
<tr>
<td>Observation: Food Unpacking Recording</td>
<td>15-30m</td>
<td>Digital camera and digital camcorder</td>
<td>Wife and/or Husband</td>
<td>To uncover the behaviour related to unpacking grocery shopping.</td>
<td>Appendix 8</td>
</tr>
<tr>
<td>Observation: Fridge and Freezer Use Condition, Use Environment</td>
<td>10m</td>
<td>Fixed camera, laptop and motion detected software</td>
<td>Family member(s)</td>
<td>To gain insight of fridge and freezer use and reasons for particular use behaviour</td>
<td>Appendix 8</td>
</tr>
<tr>
<td>Observation: 24-hour Behaviour Recording</td>
<td>24.5h</td>
<td></td>
<td></td>
<td>To adequately capture a range of behaviours related to the everyday use of fridge and freezer,</td>
<td>Appendix 13</td>
</tr>
<tr>
<td>Post-intervention Questionnaire</td>
<td>15m</td>
<td>Digital camera</td>
<td>Wife and/or Husband</td>
<td>To identify individual’s knowledge and attitudes towards energy and resource efficiency and eco-friendly purchasing and performance of environmental behaviour. To ascertain the links between intentions and daily use behaviour of the fridge and freezer.</td>
<td>Appendix 13</td>
</tr>
<tr>
<td>Semi-structured Interview, Explanations to 24-hour record</td>
<td>30-40m</td>
<td>Voice recorder</td>
<td>Wife and/or Husband</td>
<td>To discover the attitudes in relation to environment and energy use of fridge and freezer. To entice users’ true opinions and promote substantial discussions about the reasons for their particular behaviour, the users’ environmental responsibility and the changes that should be made to the fridge and freezer design.</td>
<td>Appendix 14</td>
</tr>
</tbody>
</table>
7.3.3 Data Analysis

The qualitative nature of the data collected throughout the study has informed the data analysis process. The three main analysis methods, coding, matrix and mapping and clustering, were adopted to deal with the data, carrying out the three analysis activities, data reduction, data display and conclusion drawing and verification.

Coding and ordering the raw data allowed the researcher to extract the meaning from phrases, sentences or whole paragraphs and to develop the understanding of the links between thematic areas. A code is a symbol which is composed of a sequence of letters or numbers (Robson, 2002b). Coding is a process to assign units of meaning to the descriptive or inferential information (Miles and Huberman, 1994) so as to systematically classify and categorise the data. To prepare for the analysis, all raw qualitative data were transcribed and transferred into a computer-based format. The data were analysed manually rather than by using electronic methods to code them. The manual approach allowed the researcher to feel the data and become familiar with the content (Robson, 2002b) through continuous reading and typing, to be able to code confidently. The transcripts of the responses and descriptions of the recorded behaviour were used to sift out any issues pertinent to the specific practice and concerns. The particular content and phenomenon which dealt with the same topic were labelled with macro-codes. Then the data was divided into subtopics at different levels of analysis tagged with micro-codes. For example, “Lv-Op-Ovr-Cou-TRS-FLO-F” is shown in Table 7-3 below. “Lv-Op” as the macro-codes related to the behaviour of “leaving door open”. The “over counter fridge/freezer” is a secondary level marked with “Ovr-Cou” and “transferring items between the nearest floor and fridge” is a tertiary level. Appendix 16 includes the codes of the visual data of photographs and video.

Table 7-3: Example of hierarchical coding system

<table>
<thead>
<tr>
<th>Lv-Op</th>
<th>Leaving door open</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lv-Op-Ovr-Cou</td>
<td>Using an over counter fridge/freezer</td>
</tr>
<tr>
<td>Lv-Op-Ovr-Cou-TRS-FLO-F</td>
<td>Transferring items from the nearest floor, bending down to pick them up and putting them into fridge</td>
</tr>
</tbody>
</table>

The coded information was compressed into maps, to enable reviewing and unscrambling of the research data. The facts that had similar characteristics were
clustered to build theory (Miles and Huberman, 1994). There were three types of data that required analysis in the main study:

- Data from questionnaires;
- Visual data;
- Transcript data.

7.3.3.1 Analysis of the data from questionnaires

Analysis of the qualitative data from the questionnaires was carried out using a “matrix” of forms. The results were presented in two matrices, one of general information of participants (Appendix 16) and one for Post-intervention questionnaires. The matrices were designed to show the questions and corresponding responses of each participant. Responses are given under question headings. General information on participants was presented as an introduction to provide a brief summary of the socio-demographic information and food shopping and cooking habits of each household. In the matrix of post-intervention questionnaires, the individuals’ environmental attitude, knowledge and daily domestic routines regarding recycling, eco-friendly purchasing and household energy management, were presented in a visual manner to establish a user profile for each participant. Comparing the user profile with the results of the visual data analysis helped to uncover the connections between the environmental intention, actual cold appliance use behaviour and the other environmental friendly behaviours.

7.3.3.2 Analysis of the visual data

The visual data came both from photographs of the cold appliance and its environment observation and video records of users’ interactions with the fridge and freezer. The video data that required analysis was from the 15-30 minutes video of food shopping unpacking and 24-hour fridge use recordings.

All the video activities in the main study were recorded by audio-visual equipment with detailed descriptions being made. With the aim of obtaining accurate and reliable information, the analysis of video data was split into four stages:

1. Description of the video activity:

The videos were viewed as soon as possible to aid any clarification required with the participants. Mapping daily practices in finer detail provided the infinite possibilities of
organising and categorising the video data. Loading food shopping into the fridge and freezer, for instance, was often achieved through an infinite number of actions that each took a very short time and that were mingled with other activities, such as tidying up the shelves or taking foods out for meals. The detailed descriptions of each action were documented in the time log which tracked the sequences and process of the happenings. The video-activity records were grouped into five columns: start time, person and items involved, how long the action lasted and the detailed description of this particular action. Organising the video data by time period, in sequence, it aimed to identify:

- When, how and why the interaction with the fridge and freezer occurred;
- Which were the most energy-consuming behaviours;
- Which were the most frequent behaviours;
- How the same task was done by different people differently.

2. Coding visual data:

Together with an initial interpretation of the video footage, a video-activity coding framework was devised to shadow each occurrence of domestic refrigerator use conducted by each of the household members. The coding stripes facilitated the extraction and reduction of the visual data. The full coding system of the visual data can be seen in Appendix 16. Figure 7.1 features an exemplar page of the video activity log with coding stripes. The understanding of the visual materials was developed through creating these codes, which underpinned the subsequent analysis.

<table>
<thead>
<tr>
<th>Time</th>
<th>Person</th>
<th>Activity</th>
<th>Purpose</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>14:30</td>
<td>TAC</td>
<td>Open fridge</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14:33</td>
<td>TAC</td>
<td>Shelve used</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14:39</td>
<td>TAC</td>
<td>Close fridge</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 7:1: An exemplar page of the video activity log with coding stripes
3. Displaying the video data:

By using the time log to code the visual data, “morning”, “evening meal” and “unpacking grocery shopping” were identified as the three main time periods that intensive usage of household fridges occurred. In order to avoid missing out any vital behaviour in the 24-hour recording, the usage of the fridge happened in the general day was brought together, summarised in the “general day” matrix. All the data was, therefore, grouped into the matrices with the theme of “unpacking grocery shopping”, “morning”, “evening meal” and “general day”. The frequency and impact of particular behaviour, hot spots and co-occurrence of practices could be quantified and examined using the matrices showed in Figure 7.2. By presenting the video analysis for each household in this visual manner, an assessment of any regularity and anomaly was made to elicit main themes and features to form the theory.

![Figure 7:2: An exemplar page of the “morning” matrix](image)

4. Grouping data into clusters:

The final stage focused in greater depth on the video activity by using summary activity categories. For example, all data labelled with “Che-dat-yog” (Checking the expiry date of yogurts with the fridge door open) were sorted together. Working at a more detailed level of video activity analysis would reveal the nature of daily practices of the cold appliance use and help the researcher to translate the unsustainable use behaviour into design opportunities.

Coding and clustering techniques were employed for analysing the information captured by the digital camera. After collecting the photographs of the products and
environment in use together in the log book, comparison was made to extract and collate particularity and commonality in the real situation of product-in-use

7.3.3.3 Analysis of the transcript data
The interviews were conducted with eighteen households in the main study. The audio recordings were transcribed. This process resulted in a vast amount of information from the transcripts and field notes. Adopting coding and clustering techniques, the data was organised and reorganised in terms of categories which was labelled with macro-codes. Then within these clusters, the data was analysed further and assigned with micro-codes. The complete coding system for the interview can be found in Appendix 16. Finally, a thematic analysis provided an understanding of the links between environmental awareness and behaviour individually and collectively as well as the opportunities and barriers to designing for behavioural change in the household fridge and freezer use.

7.4 Results
Analysing commonalities and irregularities in the empirical data from both pilot studies and the main user study has identified six themes:

- Use scenarios of the household fridge and freezer;
- Fridge and freezer in use and design;
- Kitchen plans;
- Life of usage and lifestyle of user;
- Food packaging;
- Links between the fridge and freezer use behaviour and environmental awareness, intention and other daily actions.

7.4.1 Use Scenarios of the Household Fridge and Freezer
The main user study investigated the behaviour of people using the household fridge and freezer. The information was collected to understand the rational for each action and would assist the designer to develop new energy efficient products. Table 5-4 in Chapter 5 and Table 3 in Appendix 3 show the results from some of the studies that focused on the calculation of energy loses due to the door openings. There are few
research projects in this area that carried out a qualitative assessment of the impact of the studied behaviours and investigated the reasons for the use patterns.

The video footages illustrated the flow, order and disorder of “everyday life” in 18 households regarding the use of cold appliances. It exposed that the user impacts with the household fridge are closely tied to the temporal routines of food preparation and consumption. Bouts of intensive activities that took place around unpacking grocery shopping and meal time characterised the typical scenarios for the use of the household appliance. The analysis focused on three areas of intensive work with the household cold appliance: “morning”, “evening meal” and “unpacking grocery shopping” to identify the sequence of routinising use. The findings from the “general day” matrix made during the data analysis process were integrated into other themes, which could illustrate the problems more appropriately.

7.4.1.1 Morning

In the households where members were out at work or school during the weekday, a flurry of activities was conducted with the fridge in the early morning. A selection of unsustainable use patterns of 15 fridge samples during the breakfast preparation in a normal weekday is presented in Figure 7.3. It reveals two most damaging behaviours of the fridge use in the morning: “high frequency of door opening” and “the door left open”. Combined with the demographic information from user profile questionnaires, a more detailed analysis of the factors influencing the way of fridge use produced then follows in Figure 7.4.
Figure 7:3: Unsustainable use patterns of the household fridge during the breakfast preparation selected from 24-hour behaviour observation in 15 households

Figure 7:4: Factors influencing the way of fridge use patterns in the morning

It suggested that “rushers” were heedless of the fridge door openings, as all the tasks were achieved with the largest amount of convenience and the least amount of effort.

On one hand, this “rush” was embodied in the high frequency of fridge door opening for food preparation. The more family members, the larger the variety of food that was
needed from the fridge, the more the fridge door was opened. The detailed description of the observed behaviour below illustrated the various agents that affected the times of door opening:

- **Number of family members**: the more family members, the more door openings. In a 5-person household, the fridge opened 20 times to prepare breakfast and lunch boxes for the children and 18 times within 24 minutes (MUS-F18); while in the observational studies in MUS-F02, MUS-F06, MUS-F09 and MUS-F13, these 2-person families only used the fridge 5-6 times mostly for a drink during breakfast.

- **Age of children**: adults got up early to prepare and have breakfast with their younger children; while in the family with teenage children, older children had independent breakfast and the fridge was used more. In the video record, a 4-person family with two teenage resident children, MUS-F04, opened the fridge 7 times more than, MUS-F01, the family with two children under seven years old.

- **Time of breakfast preparation**: in some of the households, the husband was the first one to appear in the video and often organised and ate his own breakfast in the early weekday morning. So the same food for breakfast, such as milk, was always taken out repeatedly (MUS-F05, MUS-F10, MUS-F11, MUS-F13, MUS-F15).

- **Different types of drinks**: the variety of drinks for breakfast increased the frequency of door openings. As seen in Figure 7.5, the fridge door opened four times within 5 minutes by the wife (MUS-F13) for milk and juice being taken out and put back in the fridge in preparing her breakfast. Also, if two family members drank different juices, in the behavioural records, they usually opened the door for each kind of drink for taking it out and putting it back in (MUS-F05).

- **Food variety**: compared with all childless and in full-time employment, families with children at home consumed more vegetables, fruit and yogurts, had more proper breakfasts and used fridge more.

- **The preparation of the fruit bags and lunch boxes for work and school.**
On the other hand, in the video, it can be found that “rushers” often intended to get “quick tasks” done with the door open, such as checking expiry date of the items, pouring drinks for breakfast (Figure 7.6), searching for vegetables in the bottom drawers, making lunch boxes and fruit bags and transferring items between the worktop and fridge one by one. For example, the wife spent 68s transferring foods for breakfast between the worktop and fridge and the son left the door open for 70s to make sandwiches (MUS-F04) (Figure 7.7).

Food packaging design as a factor that affected both the length of time and frequency of fridge door opening and will be further discussed in section 5.4.5.

Householders who were immersed in morning chaos failed to be organised during breakfast preparation. Firstly, they were not planning in advance. The wife opened the fridge 5 times in total for her and her husband’s breakfast, but 4 times within 1 minute (MUS-F16). Secondly, they opened the fridge for making breakfast without thinking about all family members. Milk was taken out 4 times by 4 different family members
7.4.1.2 Evening meal

In the user profile questionnaires, all of the participants regarded “dinner” as the "main meal of the day". Compared with the morning rush, people usually took more time to organise their evening meals which normally consisted of a great combination of cooked or uncooked ingredients from the fridge. It resulted in a high level of interaction with the fridge and subsequent energy intensive behaviours which are summarised in Figure 7.8, as more openings of the door, door left open, cooking together, overcrowding the fridge and loading in hot food/leftovers.

Figure 7.8: Energy intensive use behaviour of the fridge for organising evening meals

In the evening, most of the preparers had ample time for their dinner and sometimes the couples were able to share the preparation tasks. Results of the observation showed that there was time wasted, when the door was open to search for the desired item and decide, discuss and choose what they wish to remove. Taking a bottle of sauce cost the wife 10 seconds to make her decision (MUS-F01) (Figure 7.9). In the same way, when the husband and wife did dinner preparation together, they opened the fridge door,
bending to search for the wanted food at back, and spent 66 seconds on the food selection and discussion (MUS-F05) (Figure 7.10).

![Figure 7:9: Taking a bottle of sauce cost the wife 10 seconds to make her decision (MUS-F01)](image1)

![Figure 7:10: 66 seconds for the food selection and transferring to the worktop behind the wife (MUS-F05)](image2)

Observations showed that some other factors also slowed the actions with the fridge stimulating long periods and more times of the door opening. For example, the boiling water interrupted the operation of the fridge and the cooker was switched off with the door open (MUS-F06). In MUS-F13, it took the wife 46 seconds to search and take one lettuce out while talking over her mobile phone. Also, 47 seconds were used to tidy up the right bottom drawer while taking vegetables out from the fridge (MUS-F14). After dinner, the mum opened the fridge and made space on the shelves for returning the items. As she chatted with her son, she did not add anything in for this opening. “I found that the uneaten chicken (leftover) has not been ready for the fridge... it is not wrapped” she explained in the interview (MUS-F04).

Video footage also illustrated how a lack of organisation in the preparation of the evening meal caused more opening of the fridge door. Common in the records was the practice of, looking inside and sorting out the contents, but taking out nothing from the fridge (e.g. MUS-F03, MUS-F07, MUS-F10, MUS-F18). During dinner preparation, the same items were taken out and put back repeatedly. A lettuce was taken out and put back twice in MUS-F02. The fridge was opened 3 times for cheese spread, butter spread and cream, the same type of food out in MUS-F13 and 4 times for cheese out in MUS-F14. When the couples cooked the evening meal together, the same type of items, such as the mayonnaise and the ketchup (MUS-F07), were always out from the fridge separately in a short time by different preparers. Leaving the door open while considering what needed to be cooked for the evening, desired and undesired items
were transferred between the worktop and fridge one by one. An excellent illustration of this was found in the 24-hour recording of fridge use in MUS-F16, spending 72 seconds on food selection and transferring (Figure 7.11). Returning unused and uneaten items back to the fridge individually after dinner preparation and having dinner caused more door opening. The wife opened the fridge 3 times for sorting uneaten food back from the dining table (MUS-F07).

![Figure 7:11: A segment of the description of 24-hour fridge use record in MUS-F16](image)

As the most important meal of the day, dinner was usually served in a bigger portion and with more types of food from the fridge. Longer opening times were required to look for wanted items, especially vegetables which were usually kept in bottom drawers and/or at the back of shelves. MUS-F06 left the under counter fridge open 36 seconds, with one knee down on the floor, to search on shelves and in drawers, to decide and transfer a bag of mushrooms, a cucumber and an avocado to the worktop above one by one. After dinner, adding unused items and cooked leftovers into the fridge was also observed to be responsible for energy wastage and potential health risks. It was evidenced by overfilling the fridge (Figure 7.12), storing uneaten or unused food in uncovered containers (Figure 7.13) and stowing hot leftovers before cooling for least 1.5 hours. In MUS-F04, the raw chicken was removed from the fridge and the uneaten bits wrapped by the foil were loaded back at 53 minutes later.
7.4.1.3 Unpacking grocery shopping

The previous section illustrated that during unpacking grocery shopping, most of the time spent organising and reorganising the food into the fridge and freezer was used for making room for new items and transferring items between shelves. Besides the loading principles (discussed in section 6.3.2 and 7.4.2), packing and unpacking habits also affected the time and the frequency of the fridge and freezer door opening. As illustrated in Figure 7.14, packing the shopping in the bag ready to unpack, taking all the food out from bags and sorting them near to the fridge and freezer before putting them away would eliminate much of the time and times needed for stowing items one by one from shopping bags and unpacking places.
Figure 7.14: Factors affected the time and frequency of the fridge and/or freezer door opening.

Interviews with the householders indicated that most people tended to pack shopping in a certain order, such as according to the food storage place, the weight and the type of the food. However, in MUS-F04’s kitchen, the wife opened the freezer and pulled the drawer out but failed to find the frozen items in the shopping bags against the wall opposite the fridge (Figure 7.15). She had to return to push the drawer back and closed the freezer. The freezer was opened again after the item was found. It required fewer openings when the user packed and piled up shopping ready for putting them away. For example, MUS-F02 opened the fridge twice to load food, since she “piled them on the top (of the built-in under counter fridge and freezer) first (Figure 7.16), we do it on purpose to make sure the fridge and freezer open as little time as possible”. In a reverse manner, MUS-F08 and MUS-F16’s fridge opened 6 and 8 times respectively for loading the shopping.
It was interesting to see how kitchen design influenced the use patterns of the fridge which is discussed in detail in section 7.4.3. In the interview, the wife said that “… I have everything how I wanted; when I get home I just have everything ready for unpacking” (MUS-F10). However, in the observation, she still opened the fridges 8 times to load the food; since her second fridge was in the utility room and items were unpacked in the kitchen. The same case in MUS-F07’s kitchen, there was no space allowing the wife to pile refrigerated food near to her fridge. Although she took all the items out from the shopping bags and piled them on the worktop before putting them away, a large time was associated with opening the door to transfer items between the worktop and the fridge (MUS-F07).
Figure 7.17: Piled the shopping on the top of the under counter fridge in the kitchen since her second fridge was in the utility room, she has to transfer things with batches. It results in more times of the door opening (MUS-F10).

Unpacking observation showed that the service design could help to reduce the impact of fridge use by classifying the foods for buyers in supermarket. Waitrose delivered the shopping sorted into items for fridge, freezer and store cupboard by using different colours of bags; red for fridge, green for frozen, purple for cupboard. According to the colour, MUS-F15 piled bags near to the place where items belonged directly from the delivery truck. This reduced the fridge door openings to once. For those supermarkets that delivered orders with the same bags, users did not know what was inside and where the items belonged until they opened the bags. They often transferred items from the unpacking place to fridge and freezer one by one, and it was found that usually one bag for fridge contributed to one door opening (MUS-Fo4, MUS-Fo6).

As presented in Figure 7.18 below, discussion about damaging behaviours of cold appliance use during the unpacking food shopping revealed other environmental stress issues, such as overfilling the fridge, food waste and reasons for such problems, such as loading principles, fridge and kitchen design and food packaging which are discussed further in other sections.
7.4.2 Fridge and Freezer in Use and Design
The findings from the Product-in-Use observations and interviews indicated that there existed a variety of use patterns for the fridge and freezer. These are performed with or without intentions which contributed to the creation of many environmental stresses. The results discussed below presented the gap between product design and their real requirement.

7.4.2.1 Use content
The interviewees pointed out that the main functions of the household fridge were to; prevent bacteria multiplying; keep food fresh; maintain and chill food and drink. Figure 7.19 gives a snapshot of the responses to the questions: How do you decide what needs to put into the fridge and what needs not to? The divergences in the opinions lay with egg storage and individual preference for cold food and drink. Some of the participants stressed the need for chilling certain food and drinks, such as carrots (e.g. MUS-F01), grapefruits (e.g. MUS-F02, MUS-F09, MUS-F11), apples (e.g. MUS-F16, Figure 7.20), coke and wine. In some households, there was a second fridge particularly for keeping wine cool as illustrated in Figure 7.21.
Figure 7:19: A snapshot of the responses to what needs to put into the fridge and what does not

Besides the loading principles, “Expiry date of food”, “Types of food”, “Weight of the items”, “User of food and drinks”, “Temperature distribution in the fridge”, outlined in section 6.3.2, combination of the results from the interviews and observation showed that users also located items because of;

- Frequency of the use - for ease of access; as MUS-F07 explained, “the things in the middle like in the supermarket, ones that you want most often than normal in the middle. That is why these shelves (in the middle) are bigger and so many things are on them”. For MUS-F10, the things she needed most often she put on the front or in the door. “Yogurts (into the door bin), because my husband and my son eat a
lot of yogurts. It is just easy for them... it is just quick” (Figure 7.22). As illustrated in Figure 7.23, margarine, in MUS-F11's, needed come out 2 or 3 times a day, “that is handy there (on the 1st shelf).”

- Routinising practice, habitual place; in talking about her food location, MUS-F14 mentioned that “I do not know, it just a sort of happened. I have never consciously thought and I just find a place for everything and then you just keep putting in same place”. Similarly, MUS-F17 has a shelf for “…bits and pieces” and MUS-F15 put vegetables and yogurts on the top (in the under counter fridge), “because they seem to be better in that way” (MUS-F15). MUS-F07 also responded that: “we always put yogurt, meat and butter together there (on the third shelf)...even when we take everything out and clean the fridge, we put them back at the same place.”

- Where there is space - MUS-F13 described her routine as “just everything in the middle... I sort of stuck with where it can fit.” MUS-F16 emphasized that “the question” is “which shelf has space on it”. This accounted for how the time wasted for the user to search for the desired item, for example, why the wife spent 45 seconds searching for ginger at the back of shelves and in the bottom drawer (MUS-F16).

- Fridge design – all depends on the size, depth and shape of the shelves, drawers and compartments on the door, such as vegetables could pile up in the bottom drawer, meat could stow on the bottom glass shelf for food hygiene purpose and milk and drink bottles in the door sections.
Additionally, load conditions which also affected the energy efficiency, could be seen in the following three aspects; having refrigerator overcrowded or too empty and placing food in a mess represented in Figure 7.24 - Figure 7.26.

![Figure 7:24: Overfull fridge (MUS-F08)](image)
![Figure 7:25: “Empty” fridge (MUS-F14)](image)
![Figure 7:26: Food placed in a mess (MUS-F02)](image)

There were several issues influencing overfilling including; having parties or visitors, the frequency of shopping affected by the work patterns and distance between the shops/supermarket and home, the life stage of the users affected by having children and having a healthier diet (Figure 7.18). Going on holiday was the time for users to use up or throw away the food to ensure the fridge as empty as possible. In the interview, MUS-F07’s response was typical: “it would be empty when we go on holiday; we try to empty out and throw away things. By the time we come back, there will be no goods. But we have it on, because a few things are still there”. Leaving the empty fridge running then became one of the harmful use behaviours which should draw the designers’ concern.

On reflection, these examples strongly supported the argument for three determinants of behaviour change (intention, habit, control) in the behaviour model (Figure 2.9) and in Design Behaviour Invention Model (Figure 4.3). When participants interacted with the fridges, they oscillated between:

1. Keeping in control with intentions and understandings from a conscious assessment of existing practice, for example, “frequency of the use” and knowledge learnt from past experience (e.g. MUS-F07) and others, such as family home (e.g. MUS-F02, MUS-F03, MUS-F04), friends (e.g. MUS-F04) and media including magazines, cookery magazines, TV and radio (e.g. MUS-F04).
2. Routinising behaviour without awareness - a habit that is “highly automated” (Jager 2003 in: Jackson, 2005) as immediate responses to specific cues, operating outside awareness with a minimum of deliberation or little cognitive effort. In the observation, it could be seen that users maintained a certain degree of routine to operate the fridge while they could not explain why they do so in the interview.

3. Lacking principles without plans - letting things go in a disorganised manner. No standard routine related to locating items into the refrigerator was one of the contributory factors for the increase of the open time. This was certainly confirmed by the locating principles of “where there is space” and interestingly “fridge design” might offer the possible solutions to this problem caused by user behaviour.

Element 1 corresponding to “intention” in the behaviour model (in Figure 2.9) implied that the users’ real actions were consistent with their intentions and desires for “being green people”. Element 3 corresponding to “control” in the behaviour model (in Figure 2.9) meant that the user behaviours were “out of control” or “locked-into the daily practice” and could be influenced by external constraints. Observing routines indicated participant use patterns of the household cold appliance use shifted from element 1 to element 3. However, the habitual character of the interaction with the household appliance was seen to be a major barrier for more sustainable practice. It was a challenge for users to integrate the environmental concerns into every daily routines related to the fridge use. For instance, MUS-F02 was observed to adopt a mindful approach to fridge use in the unpacking video but her daily interaction with the fridge, such as placing food inside the fridge (Figure 7.26), food preparation, was a lot more “relaxed” than putting away her grocery shopping as discussed in section 7.4.1.3.

Results from the main study underlined the necessity to regulate the product use behaviour. Rather than being guided by universal standards, how the product should be used was a rather nebulous concept, largely dependent on the view and habit of the users. Take the fridge use for example, the question was: how the fridge can be operated in an environmentally responsible manner?

7.4.2.2 Fridge and freezer design and use behaviour

“If I have got room, I just put everything in the fridge, because it is easier. Because I do not know where to put...” (MUS-F09). The fridge and freezer afforded such
convenient food storage solutions that some of participants expressed their preference for a much bigger fridge and thought about the American style fridge and freezer when they purchased or would purchase in the future. However, it was reported that the space left for the refrigerator was the main restriction of the purchase of the American side by side style or bigger size refrigerator (MUS-F02, MUS-F06, MUS-F07, MUS-F15, MUS-F16, MUS-F18).

The household freezer was usually used to stock:

- Food for emergency — “...I keep one small bottle of milk in the freezer, so if we are going to run out of milk at night, I can get it out and leave it in the kitchen. And by the morning, it will thaw. And we will have milk for breakfast” (MUS-F04);

- Items for later use — “Something is on special offer...I need to freeze it because we cannot eat it all in time” (MUS-F04); “in terms of chicken, beef and pork that sort of things I maybe keep a little bit out (in the fridge) for a couple of days. We have got a bit of choice, then I freezer everything so they will last longer” (MUS-F13). For those (e.g. MUS-F06, MUS-F13) who did not plan in advance and would transfer the ingredients later from the fridge to freezer there was a bigger user impact, increasing the door opening;

- Ready meals or homemade meals for convenience — “We would like to cook big portions and save another portion for lunch or tomorrow ...for 6 or 8 people, I freeze the portions in the freezer and use microwave to defrost them as ready meal” (MUS-F06);

- Vegetables grown in the garden.

Many users felt that the freezer was always pretty full, even “before holiday I plan to eat food up but the freezer just stays the same” (MUS-F12). Participants also reported that shopping patterns and having children at home were the main reasons for them to store more stuff. In addition, they usually located the food in the freezer depending on how strong the shelves and drawers were. “In the middle, the two compartments are weaker, I put light things, such as pastas, bread, and pizzas here...that (drawer at bottom) is strong and solid. I have got ice-cream, meat and chicken which are heavy here (MUS-F11).
Observing use routines of the fridge and/or freezer exposed how these were linked to body movement, to the design of the appliance and users’ capability of adaptation to the design. The following sections illustrated the typical refrigerator behaviour scenarios for identifying the relationship between the mundane practice and the product design:

- **Issues related to style of the fridge and/or freezer:**
The users of under counter fridges had to always bend down, squat down or kneel down to reach the back and bottom of the fridge to search for the desired item and sort out content. Figure 7.27 illustrated this in more detail.

- **Issues related to interior design of the fridge and/or freezer:**
There is time wasted, when the door is open, for the user to search for the desired item and to shuffle food stuffs around to make them fit when restocking between the shelves, in doors and drawers. The observation also exhibited how the participants designed and rearranged their fridge to meet their individualised needs so that the tasks could get achieved with a degree of effortlessness. Figure 7.28 gives some examples of this.
Figure 7: Routines of movement when using the under counter fridge
The top shelf is too high to reach. "It can be hard to find these things on the top shelf which is quite high so you cannot really see into it" (MUS-F16).

"The things on the top may be the things that you do not pull out very open. It is just storage. We do not use those bottles of milk. We use that one (in the door)" (MUS-F07).

Kneel down to search back of the narrow shelves.

Rearrange narrow shelves as storage according to the size of food packaging. Additional container is added to remove items at back easily.

It is hard to sort the content out at the bottom. "Drawers never seem to open wide enough to get larger packet in. I end up emptying a drawer to be able to fill it again" (MUS-F14).

"I have a lot of things to put in, then I take the drawer out ... I put the fresh, new items at the bottom, I can reorganized the drawer" (MUS-F10).

Observing routines showed that users often take drawers or containers out of fridge to load food in on the near floor or the worktop far away from the fridge with the door open.

Users usually need check every drawer in freezer before shopping or to look for the desired item.

Figure 7:28: Daily interaction with the shelves and drawers
- Issues related to the accessories of the fridge and/or freezer:

Product-in-Use observation not only captured flaws in product performance and highlighted design limitations of the accessories and functioning parts in the fridge and/or freezer but also uncovered the latent customer needs and ways in which users adapt products to better suit their needs. Combined with the findings of observation and the interview, the gaps between the users’ “actual” versus “assumed” needs were identified as follows, some examples were given in Figure 7.29 below.

Poorly designed door – “the door compartments are difficult to arrange for cartons and bottles” (MUS-F09). The door bin (MUS-02) is not high enough for the big bottle of milk or wine. “We took out egg tray out here (to make the space high enough for keep the big bottle)” (MUS-F03).

User’s arrangement of the shelf - According to her need, MUS-11 took out the tray to maintain the big bottles of milk on the top shelf.

Poorly designed door bin and can holder – “This is space for cans but it just wastes space. We have hardly even put cans. We tend to put in there (bin with rack).” (MUS-F07).

Poorly designed temperature control panel - Inside in the door users have to open the door to check or adjust the setting.
Poorly designed temperature adjuster - Hard to understand - “It is complicated meaning of temperature setting, because the scale we are given to set up the temperature is an arbitrary scale. So it is not easy to use. The temperature you have to set up somewhere in the middle, see if it is alright, see you think personally, you feel cold” (MUS-F08).

Poorly designed temperature setting - Hard to read - The temperature setting is too low nearly at the bottom edge of the freezer; users have to bend over and see it. MUS-F04 even does not know that her fridge has separate temperature adjuster as shown in this figure above.

Poorly designed ice-cube tray - “when you actually take it out if you fill it up too high, that is not big enough to get this out, so you have to melt the ice cubes a little bit in order to take them out on one end. I like a normal tray we still put normal tray in there...it is nice by the freezer makers but it does not actually work becase you cannot get them out”(MUS-F14).

Use condition of egg trays - most of the participants do not use the egg tray. “I think it has just gone to the cabinet” (MUS-13). One of the explanations of not using the egg tray is that “I do not put eggs in the fridge because I suppose to cook them from the room temperature, so I keep them at the room temperature and they do not go off” (MUS-04).

User’s way of storing eggs - MUS-F01 explained that “we put eggs into the fridge with box since there is date on the box”.

User’s way of storing eggs - keep eggs with boxes on the egg tray (MUS-18).
User’s adaptation to design - Butter is stored on the egg tray, while the egg box is on the top shelf (MUS-02).

Poorly designed egg tray - if user got eggs in, it wastes a lot of space on the top and second shelves (MUS-F15).

Useless feature with big environmental impact – “It wastes space. I would like to change the freezing compartment into the extra shelf. And it needs defrost every 2 or 3 weeks. It is very bad. We do not trust them” (MUS-F03); “This (freezing compartment) has got (my husband’s) coffee. He likes his coffee in there...” (MUS-F11).

Use condition of ice-cube maker storage - “I do not like the very large ice cube maker storage in the freezer which takes up too much room. Because the ice does not drop very well. So I just use for storing other things” (MUS-F10).

Use condition of bottle racks (MUS-F08).

Underlying needs – additional containers are often used to keep cheese, fruit and vegetables.
Poorly designed instruction – it is useful to instruct how to store frozen food but the participants responded that they have never seen the instruction “since it is not coloured” (MUS-F03).

Underlying needs of “food calendar” – a note of the expiry date of food in the fridge

Figure 7:29: Use condition of the accessories of the fridge and/or freezer.

When asked about their dislikes of the fridge and freezer, “no sensible storage for bottles except to lay them down (e.g. ketchup, wine, etc)” was raised by the participants. “This is ok when unopened but not once (e.g. when is opened)” (MUS-F07). MUS-F09 stated that she liked the two vegetable drawers in her previous fridge, “this (fridge) has one large drawer for vegetables. It is a bit too packed together”. Participants also recounted their dislike of the drawers in the freezer: they sometimes got stuck and broken easily.

- Issues related to feature design of the fridge and/or freezer:
  Difficulty in defrosting freezer was noted as “a nightmare” (MUS-F07) in terms of being unaware of when the freezer needed defrosting. MUS-F14 helplessly said that “the bottom (in the fridge) is salad. That is normally when I know my freezer needs defrosting, because my tomatoes get frozen, because it comes built-up”.

Alarm on the fridge and/or freezer was designed to alert the user when the door left open. However, in the unpacking observation, it was found that the noise not only speeded up their unpacking behaviour but also irritated the users. “When I am loading the food, I find it is annoying. Because you have to shut the door, then you unpack your shopping” (MUS-F12), “sometimes, it is necessary to leave the door open for more than a minute” (MUS-F10). Some of the participants suggested to improve the accuracy of the door sensor, since the alarm did not sound, “if it is only a little bit gap, you do not know” (MUS-F07).
Participants who had a digital temperature display usually set the freezers at -21°C, since lower temperature setting made user feel more secure. “It is suggested that it is set at -18°C and we just set it colder. I tend to make things colder than people told me, because I think it is colder to keep things fresh” (MUS-F07). MUS-F05 also cited this feeling of security as the reason for why they have never used the Eco-button. “...we try to run it on 2°C and -21°C rather than 5°C and -18°C (which are the suggested temperature of eco-mode)” (MUS-F05). As discussed in section 6.3.3, users felt that rather than being energy conscious, it was more important to set temperature lower to maintain the best quality, freshness and taste of the food and drinks. However, none of the research participants had ever measured the actual temperature inside the appliances; some have never changed the temperature since it was set originally (MUS-F08, MUS-F09; MUS-F10; MUS-F12, MUS-F13) and some did not change it until the food went off (MUS-F11) or got frozen (MUS-F03, MUS-F15); on average, fridges were operating at 2°C higher than recommended temperature. Unclear meaning of the temperature setting was cited by the participants as an area of concern, “it is difficult to know the right temperature” (MUS-F03, MUS-F06) and “I always forget...which way is warmer, which is colder, I have never know which way I should turn it” (MUS-F15). Furthermore, the lack of instructions caused different opinions on the temperature distribution in the fridge. Some thought that the coldest section in the fridge was the top shelf while some felt that it was at the bottom drawer.

There existed two opposing views and usage of the feature of Quick Freeze. A few of the users thought that it was good to have the quick freeze feature. Since things could freeze more quickly when they put a lot of items in one go, such as pressed it before I go shopping (MUS-F17) or when they emptied and defrosted the freezer and restocked a lot of food in (MUS-F18). Most of the others only used it when they first bought it or “have never touched it” (MUS-F07), since they put a very small amount of items in (MUS-F05), or do not remember to use it (MUS-F07), or have no problems with freezing (MUS-F03).

For the new features, the digital panel for example, the users felt that “it took a little while to get used to what the temperatures were, now I keep everything on the minimum. When we first had it, it was too cold. Now, I understand what it is” (MUS-F10). With regard to LCD screen built into the fridge door, most of the participants argued that “it seems too much for the fridge because it is just a simple appliance” (MUS-F04).
7.4.3 Kitchen Design and Refrigerator Use

Another emerging theme linking interview and observation was kitchen design and its effects on the refrigerator use. As seen as in Figure 7.30, the issues addressed in this section have been divided into two categories; section 7.4.3.1 outlines the effects of the structural changes in the modern house, particularly in the kitchen on the food storage solutions; section 7.4.3.2 assesses the use environment related barriers to sustainable use of the fridge and freezer.

![Figure 7.30: Kitchen design and its effects on the refrigerator use](image)

**7.4.3.1 Kitchen/house design and food storage**

Increased indoor temperature and limited space in the modern kitchen were considered by the participants to be directly responsible for putting more items in the fridge and occasionally locating the fridge and/or freezer in another room. At busy times such as parties and Christmas, food was kept in places, such as the garage, a porch, an unheated dining room and even a toilet. “The room temperature is too high to keep things in the kitchen (MUS-01)” “…because it gets all the sun in windows and it has a flat roof so it lets a lot of heat through” (MUS-15) and “…I would like to put the bread in the fridge because it is too hot. It gets mouldy” (MUS-11); because “we have
got lights underneath as well, storage in the cupboard...can get warm” (MUS-07) (Figure 7.31).

The conversation about the food storage solutions elicited some interesting discussions about changes in the routines since the fridge and freezer were widely used in the home. For instance, MUS-F14, the only participant in the study who owned a pantry (Figure 7.32), stated that “...or store it (foods) under the stairs because it has a very cold slab completely unheated...That slab there originally would be used to put meat and things on so it stays very very cold. That would be pantry years ago...It (the house) is about 80 years. Actually, we blocked that (the air brick) off because it gets too cold...In the winter, the cold comes out from the door so it affects the rest of the house”. MUS-07 discussed the sad obsolescence of the larders and pantries. “It is a shame that we do not have them anymore. I guess that the utility room with the washing room replaced the space that used to be a pantry, but you can get a fridge like a pantry section which is not really really cold but it does not get too hot” (MUS-07).

As new appliances have arrived, the formerly used food storages such as pantries and larders have become rare in newly built apartments and houses. The food storage solutions mirrored the great technological changes that have taken place in the last hundred years.

7.4.3.2 Modern kitchen plan and fridge and freezer use

The pilot studies illustrated that the design of modern kitchens contributed to the ownership of the built-in style and the second under counter fridges and freezers. It also caused the placement of the fridge and/or freezer near to the heat sources, such as
besides the oven, the cooker or facing the sun. MUS-F06 emphasised the restriction of the kitchen design on the operating condition of the fridge and freezer. “We have got it (under counter fridge) next to the cooker, which is stupid, but we did not design the kitchen. There needs to be good advice for people when they are designing their kitchen: if they do by themselves, they need advice; if the kitchen suppliers design it, they need to be forced to consider that...”

Observing routines also illustrated that the kitchen plan was responsible for increased opening of the door for transferring items between the fridge and/or freezer and the unpacking place or the dinner table in batches. Figure 7.33 - 7.35 represent how the location of the fridge and/or freezer influenced the user actual performance and latent needs, as well as kitchen design limitations.

Figure 7:33: The need of the facilitator or worktop near to the fridge and freezer
The need for the facilitator for loading things near the fridge and freezer was explicitly captured by observing video footage. In this case the door was open for long periods of time because of the distance between where the food was unpacked and the location of the fridge and freezer.

![Figure 7:34: Piled items up when transferring (e.g.MUS-F01, MUS-F07)](image)

It could be observed that participants piled boxes up for transferring between the fridge and unpacking place or dining table. However, MUS-F07 still opened fridge three times for tidying leftover away.

![Figure 7:35: Transferring from the unpacking place to the fridge and freezer in the utility room](image)

When the fridge and freezer were located in the utility room and the grocery shopping was unpacked in the kitchen, the participants opened the door more times when transferring food in batches.
7.4.4 Life of Usage and Lifestyle of User

Changes in users’ lifestyles and life stage had an influence on the usage and obsolescence of the fridge and/or freezer, was evident in the main study.

7.4.4.1 Impacts of changes in user’s lifestyle and life stage

“It is useful to have a bigger freezer, specially, when I have children at home and also something in the garden. I used to freeze vegetables”, MUS-09 explained the reasons for her to have two empty drawers in the upright freezer. It was apparent that the use condition of fridges and freezer was changing during all the stages in the family’s life, such as amending the lifestyle and embarking upon a new life stage. For instance, moving into a new house or decorating the kitchen increased the purchase of new appliance and second fridge and freezer. The relevant factors affecting the fridge usage patterns are summarised in Figure 7.36.

Figure 7.36: The condition of real use of fridges varied during the different stages in the family’s life
As mentioned in section 7.4.2.1, the quantity of food in fridge and freezer was determined by various factors, such as the frequency of shopping, going on holiday, having healthier diets, the number of children in the family, parties or visitors,. In addition, the quantity of food in fridge and freezer was influenced by whether the family was growing vegetables in the garden, receiving food from friends and neighbours or online food deliveries. As MUS-F13 recounted, “we probably eat more from the fridge...we grow our own tomatoes, we probably have a lot more salad (in summer), whereas in winter, because we do not use the fridge quite so much, we are using vegetables and often the vegetables are not in the fridge, we got something out from freezer...so anything we grow, go to the big freezer at the far end”... “Before we go to holiday” or “if we have leftovers, sometimes we gave them to our neighbours. We live in a friendly street”. The food delivery not only contributed to more door openings, but also the overcrowded fridge and freezer, because “when I do an internet shop, I would like to get my money worth, so I always get too much” (MUS-F17).

One of the striking things about observing use routines of the fridge and/or freezer was when there were children in the family and how the differing ages of the children interacted with the appliance. Having children (section 6.3.2), grown-up children at home and leaving home were the three key stages for the change in food loads in fridge and freezer. The foods in the fridge needed particular sorting for the younger children, such as locating their food together for adults to prepare dinner for them and placing drinks in the lowest door bin for them to access easily. As the children grew, they challenged the routines of fridge and freezer use. For example, MUS-F18 stated that “when they are little, the size (of fridge) is fine, but now they are eating adult portions, we do get more food” (MUS-F18). The high energy impacts and high level of children’s interaction with the fridge and freezer were also witnessed in the observation. Figure 7.37 provided illustrative examples for how the young generation behaved in a less environmental responsibly manner: “more door openings” and “the door left open”. Figure 7.38 listed the items that were often taken out by younger users to make packed lunches and quick meals, such as toast, milk for cereal and sandwiches.
In talking about the reason why younger users tended to be less concerned about the environmental impact of their own use, one of the participants pointed out that this was because “children are lazy”, “when they are paying for the bills for electricity by themselves and when they know more about the electricity and food storage and their behaviour will change” (MUS-F04). Interestingly, it was found that rather than educating the young generation, the parents set the fridge and freezer at the lower temperature to ensure the food quality and freshness. “We have never used the eco-button because my son always goes to the fridge to get something out. We ran it on
2 °C and -21°C rather than 4°C and -18°C (which is the eco temperature setting of the fridge)” (MUS-F05). This revealed that reducing the high energy impacts of children’s interaction is a vital consideration for the cold appliance designer.

7.4.4.2 Product life stage

This section reports the findings from the main study which relate to the issue of the useful life of the fridge and freezer; purchase, use and maintenance as well as disposal.

In the purchase phase, size, energy efficiency of the model, and refrigerant with less environmental impact were considered the most important. Price, brand, appearance and style were less important; additional features had least effect on their choice. In terms of use and maintenance, a few of the participants deliberately made it last longer by replacing the broken part of the fridge and freezer. The importance of the quality and the guarantee of product in the use stage were emphasised as follows:

“The reason I decided to buy this fridge was because of the five-year-guarantee” (MUS-F06).

“They should be well made. Some of the appliance is five years old. You have to replace them. But things like the handle is broken, I have to stick it with glue. It was not too bad, I could mend it. But things like that should not happen, if the handle is not there, you cannot use the fridge. The quality should be very important” (MUS-F18).

The responses to where old refrigerators go were divided into the following four classes:

- Gave away: the working units were given to a friend of participants (MUS-F10), the cricket club (MUS-F02) or others through the freecycle website (MUS-F10);

- Sold: the old fridge was sold to the people who bought the last house (MUS-F04, MUS-F16);

- Recycled: abandoned unit was collected by the manufacturer (MUS-F12) and the local council (MUS-F07, MUS-F14, MUS-F16);
- Wait for the council to collect: “it is outside; I do not know what to do with it. I hope the council will collect it. We are good at not doing things, aren't we?” (MUS-F09).

It is reported that a ten-year-old fridge or freezer used up to a third more energy than a newer A-rated model (Energy Saving Trust, 2008). Yet many users felt that it was more environmentally sensible to get maximum use of this appliance. “If you buy a new fridge before it stopped working, it is a lot of energy to manufacture and also material and resource” (MUS-F06). Some of the participants stated that the economic benefits of replacing items seemed to be seen as prohibitive. As reviewed in literature, in some cases, replacing older machines with newer, more efficient ones could be beneficial in reducing energy consumption (Fletcher et al., 2001), but it is economically viable to reuse an existing item. “We do not need that fridge in the garage; I did look at the pay-back period for replacing it with just the freezer. We have got a plug-in electricity monitor which I bought and we tested the electricity that used and it was not economically fair for us to replace it with just a freezer. It would not save a significant amount of money. The pay-back period would not have been longer than the life of the appliance which is about 10 years. If it has a shorter payback period, I would like to place it, we may do just a freezer” (MUS-F06).

7.4.5 Food packaging and fridge and freezer use behaviour

Two main energy intensive behaviours relating to the food packaging design emerged from the observational analysis; “more door opening times” and “the door left open” as presented in Figure 7.39.
“Whole or one” stood for the facts that no matter whether they remove the whole pack or one item out from the package, such as yogurt packs, beverages can packs (Figure 7.41), egg boxes and packed carrots, there would be one more time or longer time for door opening. Figure 7.40 provides observational behaviour to explain it in detail.

It suggested how research participants “turn around every jar” to take out desired item with efforts. For example, as shown in Figure 7.42, MUS-F16 opened fridge door 53 seconds for taking out a peanut butter jar from top shelf which is their habitual place for the condiment jars, turning around every jar to read the label. The top shelf was too high for the wife to read labels easily.
“Tear me off” not only meant that the users often left the door open and tore off the packages of cherry tomatoes, fennel and potatoes (Figure 7.43) but also that the useful life of packages would be finished at this stage.

As illustrated in the previous section, packaging was helpful to prevent food from getting bacteria, to organise food storage, to make a good use of the space in the fridge and to transmit the information with labels. The time wasted for checking the expiry date for yogurts and sliced cooked meat products before use or for later use with the door open was also evident, as presented in Figure 7.44.

MUS-F13 uncovered the cherry box but took some out to eat...took some more...one dropped down onto the floor. Picked it up with door open; put cherry box back... Eventually, the wife spent 26 seconds taking a cheese spread out for a quick lunch while
eating some cherries. This was the “some...some more, drop down” phenomenon in the 24-hour behaviour recording.

7.4.6 Links between Fridge and Freezer Use Patterns and Environmental Awareness, Intentions and Other Daily Practices

Analysing the questionnaires and the interview disclosed recurring and interconnected themes during the decision making process and behind everyday actions. It helped to uncover possible motivations and barriers to behavioural change in the fridge and freezer usage patterns. The main findings are presented below.

7.4.6.1 Environmental intentions and daily practices

Most of the participants felt that they knew a lot or a fair amount about environmental issues, such as climate change, global warming and CO2 (carbon dioxide) emissions. For most people, it was a duty to reduce electricity use of household appliances. They did give much thought to saving energy in their home and would like to do a bit or a lot more to help the environment. If they were buying a kitchen appliance, they would choose one with a high energy efficiency rating, even if it cost more. Both helping the environment and saving money could promote environmentally friendly lifestyles. Some people would favour a system that rewarded the “good” behaviour and penalised the “bad”. A few people were resistant to sacrifice their home comforts to save energy and satisfied with what they were currently doing to help the environment.

Seventeen habitual behaviours relating to energy and water use, reuse and recycling, worded as practical measures, were presented to participants who were asked how often they engaged in these behaviours. It was found that few people could avoid wasting behaviour on every aspect. For example, the respondent who always left the mobile charger switched on at the socket when not in use, filled the kettle with more water than needed and turned the heating up rather putting on clothes when he/she felt cold, quite often took their own shopping bags when shopping and checked the origin of fruit and vegetables (MUS-F03).

7.4.6.2 Environmental intentions and fridge and freezer use

“End of life of the product” and “using electricity all the time” were cited as the two
main negative environmental impact of using fridge-freezers. When asked about the environmentally responsible behaviours of using a fridge-freezer, the most common answers are outlined in Table 7-4 below.

Table 7-4: Participants’ responses to the environmentally responsible behaviour of using a fridge-freezer

| Look at the rating to choose one that get higher efficiency (MUS-F04, MUS-F05, MUS-F06, MUS-F07, MUS-F08, MUS-F09, MUS-F12, MUS-F15); |  |
| Do not have a bigger one than need (MUS-F18); |  |
| Do not leave the door open (MUS-F01, MUS-F04, MUS-F05, MUS-F06, MUS-F08, MUS-F09, MUS-F10, MUS-F13); |  |
| Try to plan when open the fridge to get all out at same time (MUS-F03); |  |
| Have the fridge and freezer quite full (MUS-F06, MUS-F09); |  |
| Do not stuff so full of food that the air cannot circulate properly (MUS-F08); |  |
| Do not run it at half empty (MUS-F14); |  |
| Make sure the fridge and freezer to have got the right amount of the things in (MUS-F10, MUS-F16); |  |
| Set at right temperature without being too cold (MUS-F07, MUS-F12, MUS-F14); |  |
| Cool down hot food before put it in (MUS-F07, MUS-F14); |  |
| Dispose of it right in terms of taking to recycling centres (MUS-F09, MUS-F16, MUS-F18). |  |

Many people mentioned that it was important to keep the fridge not too full or too empty. However, there was no facilitator or visual standard to show what the right amount of items in the fridge, consequently it was only vaguely understood.

Participants were shown a list of nine items and asked about their self-assessments of fridge and freezer use behaviour. A large group reported that before they did the main food shopping, they always opened the fridge and/or freezer to see what were in then decided what they needed to buy. They admitted that during use they sometimes left the door open while transferring items; they forgot what they wanted to remove after opening it; and when they felt hungry, opened the fridge and/or freezer to decide what to eat. It was also common that people found the fridge/freezer door left open and old food at back gone out of date and that they forgot to replace the wrappings on items before put them into the fridge. Moreover, better performance could be seen in the two usage patterns of cooling hot dishes and covering liquids before putting them into the fridge.

When asked about their attitudes toward positive behavioural change in fridge and freezer use patterns, all participants expressed that they would like to do the right things to reduce the energy use, to help the environment and to save money. Most of them disagreed that “it was not worth doing the right things, since they have minor
impacts on environment or they couldn’t save lots of money”. In talking about the need for individuals to change their use behaviour of the fridge and freezer, most people preferred to choose a fridge and freezer with high energy efficiency rating, even if it cost more, rather than changing their use habits. There were a whole range of reasons for preventing them doing more, such as:

- Assuming that the 24/7 working fridge and freezer was the most efficient household appliance: in section 5.4.6.1, most people said that they did give much thought to saving energy in their home, but to the amount of electricity of fridge and freezer use, seldom of them paid much attention. “The power of the fridge is not much, since the fridge is working 24/7 so it is much more efficient appliance than the tumble dryer, dishwasher…we spend more energy…more money on the other things, drying clothes” (MUS-F01); “…the modern fridge and freezer would be very environmental friendly...The things which produce heat use more electricity, the kettle, for example” (MUS-F09);

- Unawareness of the link, believing individual actions would not make a big difference: “the way of using the fridge has small effects on electricity use” (MUS-F01) and “I do not think the fridge is the particularly issue for the environment...” (MUS-F16), “so I do not think we need to consider it” (MUS-F05); since “it is not very much you can do to make different, maybe changing temperature setting probably...and not putting hot things in...probably not, because I am not really aware of what I could do to make very big difference” (MUS-F07);

- Doing good enough: some participants thought that they needed not change anything (MUS-F04); since “that is nothing can I do with the fridge; I just use it” (MUS-F12);

- Finding it hard to change established habits and taking too much effort to change: “Try to plan when I open the fridge, I get everything that I need, when I cook a meal I need butter, cheese, meat and some vegetables ideally, I get all out at same time and shut the door. But in reality, it does not happen. Sometime I just go to the fridge open it looking and forget what I want, shut it and open again” (MUS-F03); “when cooking, I think I can take all things beforehand... after that I can put all back...just open twice, but I have never done...” (MUS-F02); “I think probably the biggest difference I can do to make sure not to leave the door open. But when there is so much else going on in your life, you cannot really think about
it. It is difficult to change habit to do that” (MUS-F09); most of users expressed that they would like to sacrifice their comforts of fridge and freezer use to save energy, while some still insisted on that “if there were anything ... (that) was not too inconvenient then I could do” (MUS-F07);

- Locked-in lifestyle: “Well, I would change in terms of my lifestyle, I could do quite a lot but it is not practical. I would store less food, if I have more time to go shopping, if I have a local shop. I shop every day. I do try to buy my food locally. I do not mind to give up the time. Fortunately, I am able to afford to buy the highly energy efficient product, if I so choose, but I cannot change the way of shopping anything easily” (MUS-F08); “We may set lower temperature than others. But we are not wasting... (It) prevents foods from going bad” (MUS-F07);

- Lacking information: Most of them required more information on the fridge and/or freezer use to be more environmentally friendly. “I do not know if there is a lot I can do on the top of what I have already been doing” (MUS-F14); “I would like to have more understandings so I could it more efficiently” (MUS-F11). “I have never seen any publicity and anything about how you can use the fridge more efficiently. You often see about other things: turning off or not leaving standby; not to using tumble dryer too much if you can dry outside... But you do not get much advice on fridge and freezer use. So I would say that because the users could not do very much about it, maybe that is wrong” (MUS-F07);

- Lacking motivation: although financial incentives, such as saving money were not citted as a major reason for behavioural change, a small group still favoured a system that rewarded or penalised them to encourage the “good” or block the “bad” behaviour.

Two questions were asked in the interview about who, users or manufacturers, should be responsible to reduce the environmental impact of using fridge-freezers: most agreed that it was users’ responsibility to purchase a fridge and/or freezer with a good energy rating; but it was up to the manufacturers to design more efficient and cleaner products. These could include offering more efficient models, providing information for efficient use and recycling the refrigerants and physical frame of products. Some gave emphasis to the power of the user to promote manufacturing the energy efficient products. “Buying most energy efficient draws manufacture’s design. Because they are the least efficient they do not get product purchase” (MUS-F07).
7.5 Discussion

This chapter reports on the behaviour study findings by extracting regularities of the behavioural responses and the spectrum of views and opinions from the questionnaires and interviews. They provide a suitable grounding on which to build the following discussion of factors affecting behavioural change of fridge and freezer use as well as design recommendations from four perspectives for diminishing the environmental impact of household cold appliance use.

7.5.1 Factors Affecting Behavioural Change of Fridge and Freezer Use

The results of the main user study clearly illustrated that the different usage patterns of household fridges and freezers resulted in unnecessary energy consumption. It explicitly suggested that the use behaviour of the household cold appliance swung the three determinants of behavioural change in the behaviour model (Figure 2.9) and Design Behaviour Intervention Model (Figure 4.3). The product use behaviour was complex and informed or restricted by a range of internal and external factors. There was a gap between environmental intention and real action as well as issues arising from the routine practice performed automatically with little deliberation ingrained in the use patterns of the fridge and freezer. It was a challenge for users to integrate the conscious behaviour into every part of their daily routines although users intended to do so. The behaviour study of the fridge and freezer, as the case, illustrated that the barriers to sustainable practice are:

- Invisible nature of energy;
- Unawareness of the link between the individual behaviour and its effect on the energy usage;
- Lack of information;
- Lack of concern;
- Disempowerment of big change;
- Lack of motivation;
- Lock in lifestyle.

The results also showed how the household appliances and kitchen infrastructures direct and influence users to behave in a specific way, such as:
- Product design modified user behaviour: “We know that those will fit into the door, so I do not buy three 4 pints of skimmed milk. I do not buy what would not fit in the door. So I may modify what I buy” (MUS-F07);

- Product design restricted use patterns: “The fridge in the garage only works when the weather is quite warm; when the weather is cold it does not work. We bought that fridge and freezer without knowing that. Wanting to use it all the time, but then it does not work half the time in the garage” (MUS-F04);

- Product design led to misuse or inappropriate use: as illustrated above, observational data showed, due to a lack of clear design cues, how the users “convert things to serve their own ends” (Koskijoki, 1997); and

- User adaptation to the product design: the behaviour study offered the opportunities for the designers to learn the underlying user needs and what people do to overcome the failures of product design.

Due to the complexity of motivations for behaviour change, different levels of interventions need to be designed accordingly to ensure behavioural and habitual change in household cold appliance use.

7.5.2 Design-led Solutions
The following sections present a few examples of how design-led interventions can facilitate user behaviour change to improve the energy efficiency of the fridge and freezer. Based on the discussion, the suggestions are divided into four levels; product design, system design, service design and food packaging design.

7.5.2.1 Product design
Firstly, the results show there is a lack of user awareness of the link between their personal behaviour and the direct impact on the environment and energy use. Design-led interventions need to build on energy conversation to guide a behavioural change. Designing an effective way of communicating makes sure users know how to use the product efficiently through a range of design interventions through providing information, choice, feedback or behaviour spur, such as to inform the most energy efficient temperature of the fridge, “I have no idea what it is at the right temperature
or wrong temperature” (MUS-08). Also as MUS-03 suggested, a counter is set on the door to count the door opening times, “when you know you open the door a lot, maybe you try to reduce that (MUS-03).

A few design features can limit behavioural energy wastage when using the fridge and/or freezer, such as separate temperature drawers, the changeable size of the cooling or freezing sections. The fridge and freezer cools and freezes a large area regardless of whether it is going to be used or not (MUS-F02, MUS-F04). Also “more doors” is considered to be one of the solutions to keep cold air from escaping when the door is open. “If you do open part of it you only have it re-cooled a smaller (part). The freezer has already done it, because everything is on a separate tray. However, if you cannot see what is in there, you explore it anyway” (MUS-05).

Making good use of space inside the fridge is also raised. “The design means you must be careful to leave about 4 inches unfilled at the front of each shelf” (MUS-F09). Reducing the intervals between the shelves and pulling out the shelves like a drawer could be useful to get things at the back easily and to make more useful room in fridge. Additionally, rather than dictated by the fridge manufacturers, the fridge could “be modular”. A more adaptable interior and a kit of compartments, for example, to provide sufficient adjustability of shelves would enable individuals to decide the food location and to create the optimum arrangement of their food and drinks in the fridge.

To reduce door opening times, designers could create internal structures for organising food for children’s use or for the temporal routines of food preparation and consumption including morning breakfast and evening meals and special milk and butter/margarine storage solutions for making quick meals and drinks, as in the case of through-the-door ice dispenser. What is more, designing to display the contents better would reduce the opening time for seeking items inside the fridge or even seeing the foods without opening the door. For instance, using shallow drawers or software to keep a food shopping record can provide users with a clear view of the food inside the fridge and freezer decreasing food waste and the amount of time with the door open.

7.5.2.2 System design

The modern kitchen design restricted the operating condition of the fridge and freezer. “We have got it (under counter fridge) next to the cooker, which is stupid, but we did not design the kitchen” (MUS-F06). There needs to be good advice for people when
they are were designing their kitchen, and if the kitchen suppliers design it, the suppliers need to be forced to consider that. Taking the food storage, preparation, fridge and freezer design and kitchen design as a whole into consideration, designing a food system in the kitchen can encourage sustainable energy and food consumption behaviour, such as to reduce the energy losses of transferring items and the food waste. Furthermore, kitchen infrastructures can be designed for the user to operate electronic appliances with ease and get tasks achieved with deftness and effortlessness. For accessing the items inside easily, the fridge might be placed at a suitable height and location for the participants, to reduce the time wasted for body movements.

7.5.2.3 Service design

As discussed, a number of issues are important for changing the loads in the fridge and freezer, such as having parties or visitors, the frequency of shopping, going on holiday, having a healthier diet, having children, growing vegetables in garden, living in friendly community as well as whether they ordered a food delivery online. To address these changes in loads in the fridge and freezer during all the stages in the family’s life, providing users with options through service design could encourage them to think about their use behaviour and take responsibility for their actions. This may be achieved by designing a flexible modular system with separate temperature settings, and supplying a modular service with the customer to meet their needs during their different life stages. For example, when they harvest the vegetables or had visitors, an additional fridge or freezer module can be switched on; when their grown-up children left home, the fridge unit could be dissembled and the needless parts could be collected by the manufacturers. Or local community services may be set up to reduce the energy and food waste during the food life cycle from growing, storage, consuming, giving away leftover or needless purchase to the disposal. Moreover, considering the life cycle of the fridge and freezer, more services should be provided by manufacturers including supplying more choices of the accessories kit, such as the compartments, shelves and drawers, detailed DIY repairing tips. These measurements would avoid unnecessary replacement and usage of a second cold appliance. Other actions would be taken to encourage the user to replace older machines with newer, more efficient ones in order to prevent the unnecessary energy used by more than ten-year-old cold appliances. Additionally, this flexibility could allow applications to maximise the use of the total system resources as needed instead of being confined by the product physical boundaries.
7.5.2.4 Packaging design

According to the type and shape of the food or food packaging, more behaviour constraints and affordances can be designed to locate the food quickly. The label on the packaging needs to be read easily in order to transmit the information better and to reduce the time for users to check the expiry date or look for the desired item with the fridge door open.

7.6 Conclusions

To successfully integrate energy conscious concerns into daily routine, and to make this process repeatable, appropriate products must be developed. The findings of the main study have provided an insight into the type of information required by designers to consider these issues and appropriate formats for conveying this information. The studies uncovered the way in which the product is used and its unnecessary energy use, interrelated factors affecting the usage, the disablers for unsustainable practices and “triggers” for sustainable behaviours. The critical role product design plays in daily routines is also evident. By understanding the limitations with current designs and the effects they have on user behaviour, a real potential is identified to enable design to create “better” user behaviour to reduce the environmental impact.

7.7 Next steps

The suggestions presented are some examples of design ideas that are drawn from the behaviour study. Adopting a range of design intervention strategies, the next step would be to develop some “behaviour changing” design concepts of the fridge which are observed in the 24-hour recording and relate to more behavioural environmental issues. These concepts would be tested with users to evaluate their effectiveness. In addition, it is the intention to demonstrate how design can lead to overall reduced energy use by modifying user behaviour.
8 DESIGN AND TESTING

Two design studies aiming to reduce the environmental impact of household fridge use are outlined in this chapter. Design Study 1 investigates how designers tackle designing for behavioural change by applying conventional user centred research techniques. Design Study 2 is a more detailed design project. It describes how the findings from the specific behaviour study and the Design Behaviour Intervention Model can offer design solutions with the aim of reducing the impacts of product use. By holding a focus group, the outcomes from Design Study 2 are evaluated in order to investigate the users’ acceptances of these concepts as well as the behavioural interventions applied. These studies present the evidence to suggest feasible solutions for making a difference to user behaviour.

8.1 Introduction

This chapter reports on two design studies aiming to apply and evaluate design-led intervention approaches for behavioural change to reduce the environmental impact of household fridge use. Design Study 1 was carried out by Industrial Design Masters students in the Department of Design and Technology at Loughborough University. The idea was to determine the conventional way designers overcome the challenges of a changing behaviour project. In Design Study 2, a range of design concepts were developed by the researcher as the designer to reflect the key themes generated in the Pilot and Main Study. A focus group was conducted to test four selected concepts in order to obtain the feedback on the application of Design for Sustainable Behaviour approaches and their acceptance, from a range of participants. Finally, by comparing and discussing the outcomes of these activities, conclusions were drawn on the appropriateness of these design-led interventions and the potential for designers to change use behaviour. Conclusions were also drawn on the effectiveness of in-depth user centred research and the appropriateness of the approaches to creating a sustainable change in user behaviour.

8.2 Design for Sustainable Use of Domestic Fridge: Study 1

Design Study 1 was motivated by the desire to understand the ways designers can promote sustainable behaviour through their perceptions of behaviour influencing techniques. Using a group of Industrial Design Masters students in the Department of Design and Technology at Loughborough University, the aim was to adopt a range of user centred research methods and design behaviour changing products to reduce environmental impact of household fridge use. This aim was broken down into the following objectives:
1. To explore how the user centred methods were applied by the designers to enlighten the design process;
2. To test their ability to respond to Design for Sustainable Behaviour without introduction of Design Behaviour Intervention Model;
3. To record their research techniques adopted, design processes and design outcomes for subsequent analysis.

8.2.1 Methodology for Design Study 1

In Design Study 1, five student designers worked individually for three weeks full time to deliver solutions to influence user behaviour towards conserving energy or reducing food waste. To enhance the understanding of the issue, the students were provided with background contextual information and an introduction to designing for sustainable behaviour. This did not contain information about the antecedents of behavioural change and design-led intervention approaches in the Design Behaviour Intervention Model. Several existing features with behavioural change elements on the fridge market and some examples of sustainable and unsustainable fridge use patterns were also given as inspiration. This information was delivered and the design brief was assigned in a preparatory lecture (by Debra Lilley and Tang Tang). Design practice of Design Study 1 consists of 2 main stages including the concept generation and design development (Baxter, 1995; Ulrich and Eppinger, 2004). The sketches and drawings, and foam models, as design tools, supported the concept generation stage (Bhamra and Lofthouse, 2007). A range of design concepts were generated and fed into the next stage. At the design development stage, the concepts were developed and improved through 2D sketches, 3D card models, CAD models, layout drawings and mock-ups. Design Study 1 required the designers to select one solution to the design problem at the end of the design development stage. The process of the behaviour changing design exercise is outlined in Figure 8.1 and will be explained in detail in following sections.

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**Figure 8:1: Research activities conducted for Design Study 1**

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8.2.1.1 Setting the Brief

The design brief (Appendix 17) was assigned for the Industrial Design Masters module, Sustainability and Design, containing the problem statement, goals, solution analysis, and assessment criteria. This project was comprised of three tasks; Research and Development (R&D), Redesign and Presentation of the final concept. Each task was assessed on the basis of predetermined marking criteria. The R&D section was weighted as 20% of the overall module mark and required each student to undertake their own user centred research to inform their design processes. In the Redesign stage, weighted as 50% the students were asked to apply research results and their understanding of the behaviour influencing techniques to product design. As described in Table 8-1, individual marking criteria for the R&D and Redesign stages were specified to represent the research objectives (section 8.2), establishing a framework for analysis.

<table>
<thead>
<tr>
<th>Task</th>
<th>Assessment criteria</th>
<th>Objectives of Design Study 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>R&amp;D</td>
<td>Produced quality user centred research on fridge use and related observed user behaviour to wider environmental impact</td>
<td>1, 3</td>
</tr>
<tr>
<td></td>
<td>Analysed users’ perception about environmental impact</td>
<td>1</td>
</tr>
<tr>
<td>Redesign</td>
<td>Applied results of research to product designs generated</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Demonstrated good understanding of design-led intervention and applied this understanding in product design ideas</td>
<td>2, 3</td>
</tr>
<tr>
<td></td>
<td>Demonstrated iterative designing process</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Produced quality design output</td>
<td>3</td>
</tr>
</tbody>
</table>

8.2.1.2 Data Collection Techniques

Following completion of the project each student was required to submit a logbook and to give a 15-minute verbal presentation, a copy of which was kept for marking and further analysis. The logbook recorded the transition from their research development and analysis to idea generation and selection, which was used to trace their design processes. The students used MS Excel to statistically process the data from surveys. The observational data was recorded and analysed through the use of images and storyboards. The presentation exhibited how their concepts addressed the environmental problem(s) identified in their behaviour study.
8.2.1.3 *Analysis of Design Activity Outputs*  
After the presentation, ideas emerging from Design Study 1 were evaluated by the preset assessment criteria, as seen in Figure 8.2. The logbooks and the copies of the presentation handed in by the students provided the evidence for examining the relevant data of the project objectives. The outcomes assessment sheet contained information about the research and design processes of each subject. Facilitated by the assessment sheet, the raw data with similar patterns or characteristics was clustered into a series of themes which could set the foundation of theories (Robson, 2002b).

![Figure 8:2: Criteria for analysing the outcomes from Design Study 1](image)

8.2.2 *Results of Design Study 1*  
This section discusses the student designers’ design processes and outcomes with the embodied design approaches of Design Study 1.

8.2.2.1 *Research Methods Applied for Design*  
The means of conducting research and development were mostly as follows: user research, product analysis, technology search and secondary literature on the environmental impact of fridge use. To meet the requirements of the design brief, students adopted combined user centred research methods to capture the impacts of the fridge use. This consisted of a survey and/or interviews with users and observational studies. According to the records in their logbooks, those students who undertook surveys distributed the questions as paper versions as well as via the internet. There were 8 to 14 respondents of their surveys. Most of the students carried out the observation with 1 to 3 fridges in shared houses. An exception to this was Student 1 who interviewed and observed 9 British householders, providing a richer source of data. The observational studies were mainly concentrated on the analysis of photographs of
the product and its use environment. Figures 8.3 and 8.4 illustrate the different use conditions of the fridge photographed in different households. Some of them used storyboards, images with explanation notes, to illustrate problems occurring during the operation process of the product. Few students undertook videos or long term observational techniques.

The students’ logbooks and presentations showed that the results of their user studies were analysed in several aspects:

1. the use condition including the loads and the location of the fridge;
2. the participants’ food shopping, storing and cooking habits;
3. the characteristics of the user (e.g. living condition, working patterns, etc.) and participants’ perceptions about the impacts of the fridge use.

However, most of conclusions were drawn from the students’ own experiences or of those around them, in the shared flats. The limited quantity and diversity of participants had an effect on the quality of observational studies. Most of design directions were established by the analysis of the responses to the survey conducted and the secondary literature, rather than first-hand observational studies.
8.2.2.2 Design Outcomes

Analysis of the student’s logbooks revealed the process and the way in which they engaged with the brief of designing for behavioural change without the introduction of specific intervention approaches. The students applied a mixed approach, combining two or more approaches to solve problems identified in the research and development stage, including Eco-choice, Eco-feedback, Eco-steer and Eco-technical intervention. Most design concepts embodied the behavioural change elements which could be classified as Eco-steer (section 4.3). The following commentary offers a brief overview of approaches for behavioural change applied by the students, illustrated with the design examples from Design Study 1.

The example in Figure 8.5 shows how the Eco-choice technique was employed to provide the users with options to enable sustainable use to take place. Student 1 observed a lack of flexibility in use to allow for power-saving when the fridge is empty and the inability to provide more space in the fridge, e.g. at Christmas, etc. Therefore, his concept provided users with the option of changing the operation temperature in the different sections of the fridge. Each section could be operated as a freezer, a chiller, or even could be switched off, negating the effect of wasted space.

Student 1’s observational studies showed that single householders had too much fridge space, but were not given much of an option for smaller refrigeration. To meet the users’ different needs, his final design solution was a flexible modular fridge featuring a different combination of chest drawers (Figure 8.6). There would be less wasted space inside the fridge by offering choices for users when purchasing.

![Figure 8.5: Multi-option fridge with off mode](image)

![Figure 8.6: Modular drawer fridge](image)

Some students attempted to influence the user decision-making process through the provision of aural or visual information or signs. To reduce energy use, the type of
feedback typically included: the time and the amount of energy wasted when the door was opened on each occasion and the number of opening during the day. Student 5 designed a screen with the coding system that is fitted to the door, to limit the chance of wasting food. Foods could be scanned by the code reader before being refrigerated and the screen would show the information about foods, e.g. the name of food, expiry dates and storage rules. This usually was achieved by means of supportive technologies, such as temperature sensor, light-emitting diode (LED) and radio-frequency identification (RFID).

Design for visualising and organising the contents inside was chosen as the design direction by some students after reflection on the findings of the user centred research. They changed the product form to constrain or afford actions, such as to shorten the time and/or reduce the frequency of opening. In the concept illustrated in Figure 8.7, the fridge creates a new way to interact with items. The salvers could be rotated by the users to access the food at the back easily.

Student 1 got the inspiration from his secondary literature that identified that a chest freezer converted from a chest fridge used much less energy than a traditional upright fridge (Chalko, 2005). This is due to the losses from an open door and the cold air sinking. Drawers varied in depth were designed as mini chest freezers, to categorise the foodstuffs, rather than pullout sections of a normal fridge shelf. The technological solution was also applied for visualising the content. Student 4 found that polymer-dispersed liquid crystals (PDLCs) would allow users to control the amount of light passing through with the press of a button, by changing the orientation of the liquid crystal molecules with an electric field. As seen in Figure 8.8, “smart glass” concept was designed to integrate this technology to a drawer fridge. The front cover could be changed from opaque to transparent to give a clear view of the items inside when needed without pulling out the drawer.
8.2.3 Conclusions of Design Study 1

Design Study 1 exemplified how designers usually engaged with the challenge of design, for the purpose of changing user behaviour in order to reduce the impacts of use. The design brief was set in a traditional way to initiate the design project. To respond to the design brief, the groups conducted typical investigations to detect and frame the problems and the direction for their concept development. This included the user study combined with secondary literature, market research and technology search. The following conclusions are drawn from the design outcomes generated:

1. The links between the user research undertaken and the conceptual ideas generated were not explicitly demonstrated either in the logbooks or the verbal presentation. The lack of concrete data on in situ behaviour and the in-depth elaboration on reasons behind the daily use routes are the main causes of basing their ideas on conjecture or deduction of the results from the survey and the interview conducted. Therefore tools that stimulate new ideas or encourage relationships among ideas could be helpful for the designers to clarify the problem identified and to communicate their design intentions;

2. The students’ perceptions and evaluation of the effects of their own concepts in changing user behaviour were not clearly articulated. This is due to the shortage of knowledge and judgment on the antecedents of behavioural change and the effectiveness of the corresponding behavioural intervention techniques applied. Tools and references are required to aid the designers to construct the problems, to identify the working space at the conceptual stage;
3. The classification of behaviour influencing techniques applied instinctively by the designers within the product design, such as providing choices or feedback and affording actions through the product form, was evident. This illustrates the use of some approaches identified in the Design Behaviour Intervention Model.

**8.3 Design for Sustainable Use of Domestic Fridge: Study 2**

This section describes how the recommendations from the Pilot Studies and Main Study of household fridge use were implemented to develop a range of conceptual designs to stimulate changes in behaviour to improve the energy efficiency of the product. As the initiator of the Design Behaviour Intervention Model and the executor of the user behaviour study, the researcher then carried out a practice-based design project with the following objectives:

1. To investigate the effects of the more detailed observational methods on the design outcomes;
2. To explore the effects of the more detailed behavioural intervention approaches on designing behavioural change;
3. To document the design process, techniques adopted and design outcomes of the subsequent testing and analysis;
4. To evaluate the effectiveness and the acceptance of the selected design concepts on behavioural change with users.

**8.3.1 Methodology for Design Study 2**

At this stage, Design Study 2 was carried out as practice-based research (Schön, 1983; Seago and Dunne, 1999; Scrivener, 2000), and reflection-in-action (Schön, 1983) worked as an overall framework for the creative process. The researcher, as the designer, completed a design project demonstrating the process of designing for sustainable behaviour from developing the design brief, idea generation to concept selection and evaluation. As Löwgren and Stolterman (1999) argue “the result of any process will never be better than the people who participate in the process” since the quality of the outcomes of the design project, the concepts and/or the theory of “know-how” (Scrivener, 2000, p.3) embodied in the action are determined by the skills and abilities of the designer.
8.3.1.1 Concept Development Process and design methods for Design Study 2

To make new breakthroughs in fridge use patterns, a well-defined development process was established to conduct the concept development work. It consisted of six phases, as shown in Figure 8.9. These design activities were developed on the basis of systematic methods (Baxter, 1995; Ulrich and Eppinger, 2004) which have set the principles of creativity, to ensure the completeness, propriety and originality of the transformation of inputs into design outputs.

![Figure 8:9: Concept development process of Design Study 2](image-url)

The process began with the information collection phase. This provided the link to the two activities, the analysis of the products and/or concepts and the interaction between the product and the user. The current products and concepts have been systematically analysed in sections 5.2.1.3, 5.2.3 and 5.3 through three steps. These are the literature review, the market and technology investigation and the analysis of existing product and conceptual ideas. The conclusions of the current use pattern analysis were drawn on from the pilot and main behaviour studies outlined in Chapter 6 and Chapter 7. The findings of the information collection phase were extracted to define the problems. The output of the problems identification phase is the specific design briefs, which is the input required to initiate the idea generation for sustainable behaviour and concept selection for the later test phases. After the briefs were formulated, the design practice
involved the typical design stages (Baxter, 1995; Ulrich and Eppinger, 2004; Bhamra and Lofthouse, 2007) which were introduced in section 8.2.1.

Three design methods, brainstorming, sketching and drawing and CAD modelling were selected for concept and modelling development. Brainstorming (Furnham and Yazdanpanahi, 1995) was used for the initial idea generation with ongoing reflection (Schön, 1983). Sketching and drawing was performed to visualise and concretise the ideas during the reflection-in-action process (Schön, 1983). Further exploration of the form of the concepts and user’s interaction was manipulated and revolved by making the CAD models (Ulrich and Eppinger, 2004). After categorising of the concepts, product in use scenarios (Aldersey-Williams et al., 1999) were presented as storyboards to deliver and communicate the interaction process in the context for the user testing focus group. In the following sections, each phase is described in detail.

8.3.2 Developing the Briefs

To help refine the findings from previous behaviour studies, there are six basic questions to be asked alongside the context analysis. For each of the findings identified in the pilot and main user studies presented in Chapter 6 and Chapter 7, questions starting with the 5 W and 1 H question words (Table 8-2) have been asked to elicit the factual answers.

<table>
<thead>
<tr>
<th>5 W and 1 H</th>
<th>Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>W   Who</td>
<td>Who was/were involved?</td>
</tr>
<tr>
<td>W   What</td>
<td>What happened?</td>
</tr>
<tr>
<td>W   When</td>
<td>When did it take place</td>
</tr>
<tr>
<td>W   Where</td>
<td>Where did it happen?</td>
</tr>
<tr>
<td>W   Why</td>
<td>Why did it happen?</td>
</tr>
<tr>
<td>H   How</td>
<td>How did it happen?</td>
</tr>
</tbody>
</table>

Table 8-2: 5 W and 1 H questions

The facts were specified to formulate the briefs, concepts and design details. The rich data collected and in-depth analysis of product interaction enabled the designer to answer the 5 W and 1 H questions in detail which considered a formula for getting the full story on the product interaction. The intended market of this design project was the multi-person household user group, estimated as 70% of the households in the UK (Mintel, 2007b). Ten design briefs emerged as a result of the problem identification phase. These are illustrated in Table 8-3.
Table 8-3: Specific design brief development process

<table>
<thead>
<tr>
<th>5 W &amp; 1 H</th>
<th>Facts (How did it happen? = Source)</th>
<th>Design Briefs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Who</strong> was/were involved?</td>
<td>Wife &amp;/or Husband Children (aged 12+) (aged 5-11)</td>
<td>01. Making quick meals &amp; drinks</td>
</tr>
<tr>
<td><strong>What</strong> happened?</td>
<td>More of openings (7, 3.3; 7.4.1.2; 7.4.1.3; 7.4.3.2; 7.4.4.1) Door left open (6, 3.3; 7.4.1.1; 7.4.3.2) Loading in hot food (7.4.1.2) Co-operation (7.4.1.2) Overfill (7.4.1.2; 7.4.1.3) Change in loads (7.4.1.1) Purchasing more food than need (7.4.3.2) Refrigerating more items (7.4.3) Most in-out items: milk &amp; bread spread (6, 3.2) Bottle rack design (7.4.2.1) Temperature setting (6, 3.3; 7.4.1.1) Location of fridge (6, 3.4; 7.4.3) Fridge style (6.3.4; 7.4.1) Fridge purchase &amp; disposal (7.4.1.2) Second fridge purchase (7.4.3.3) &amp; use (7.4.3)</td>
<td>02. Organising food preparation</td>
</tr>
<tr>
<td><strong>When</strong> did it take place?</td>
<td>Intensive work</td>
<td>03. Displaying content</td>
</tr>
<tr>
<td></td>
<td>Morning (7.4.1.2)</td>
<td>04. Improving the loading efficiency</td>
</tr>
<tr>
<td></td>
<td>Evening meal (7.4.1.2); Unpacking grocery shopping (7.4.1.3);</td>
<td>05. Reducing children’s use</td>
</tr>
<tr>
<td></td>
<td>Change in loads:</td>
<td>06. Getting a healthy food portion</td>
</tr>
<tr>
<td></td>
<td>Having parties or visitors (7.4.1.2);</td>
<td>07. Keeping compartments 3/4 full</td>
</tr>
<tr>
<td></td>
<td>Frequency of shopping (7.4.1.1); Having children (6, 3.3; 7.4.1)</td>
<td>08. Avoiding loading in hot food</td>
</tr>
<tr>
<td></td>
<td>Having a healthier diet (7.4.1.1); Living in friendly community (7.4.4.1);</td>
<td>09. Designing a system to reduce the impacts of food consumption</td>
</tr>
<tr>
<td></td>
<td>Ordering food delivery online (7.4.1.1);</td>
<td>10. Meeting needs during different life stages &amp; product life stage</td>
</tr>
<tr>
<td></td>
<td>Growing vegetables (emptier fridge, fuller freezer) (7.4.1.3);</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Going on holiday (empty) (7.4.2.1);</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A second fridge running for keeping wine (6, 3.3; 7.5.2.1)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Purchase disposal</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Moving into a new house (6, 3.3);</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Decorating the kitchen (6, 3.3);</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Style &amp; brand fridge</td>
<td>Modern kitchen design - A second counter fridge (6.3.2; 6.3.4; 7.4.2.2); - Built-in style fridges (&amp; freezers) (6.3.4);</td>
</tr>
<tr>
<td><strong>Where</strong> did it happen?</td>
<td>Next to the oven (6, 3.3; 7.4.3.2);</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Under worktop (6, 3.3; 6.3.4; 7.4.1.2; 7.4.2.2);</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kitchen, Worktop, Dining table (7.4.3.2);</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Disorderly - taking nothing out, - taking some thing out more than once, - transferring items 2 by 2 from worktop to worktop (7.4.1.1);</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Deciding, Discussing, Searching (7.4.1.2); Making room (7.4.1.3);</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Loading principles (6, 3.3, 7.4.1.1);</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vegetable storage (7.4.1.1; 7.4.1.2);</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Interruption (7.4.1.2);</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Children (age) (7.4.1.1, 7.4.1.3);</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Number of family members (7.4.1.1);</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Time of breakfast preparation (7.4.1.3);</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Different types of drinks needed (7.4.1.1);</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Food variety (7.4.1.3);</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lunch box &amp; fruit bag preparation (7.4.1.1);</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Quick meal after dinner (milk &amp; bread spread) (6, 3.3; 7.4.1.2);</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fridge Design (alarm) (7.4.1.3; 7.4.2.1);</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lower temperature setting (7.4.3.2);</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Packing/Unpacking habits (7.4.1.3);</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Distance between fridge &amp; Unpacking/cutting area (7.4.1.1, 7.4.1.3, 7.4.3.2);</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lack of facilitators (7.4.3.2);</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Limited space/height temperature in kitchen/pantry &amp; larder obstruction (7.4.3.2);</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Date check (7.4.1.1);</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Food packing (7.4.1.1, 7.4.1.2, 7.4.1.3) (- turn around every jar; - whole or one; - tear it off; - Some… some… drop down) (7.4.5);</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gap between Intention and action-barriers to sustainable use (6, 3.3; 7.5.1);</td>
<td></td>
</tr>
</tbody>
</table>

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8.3.3 Concept Generation

In order to respond to each design brief, a range of relevant design issues, listed on the left in Table 8-2, were considered in the brainstorming session. The Design Behaviour Intervention Model was applied in the concept generation process, offering the designer a path to think about the problems. The “alarm”, on the fridge identified in the behaviour observation and interview (section 7.4.2.2) as an Eco-feedback feature, was not always accepted by users and failed to achieve the anticipated result. It was decided that those intervention approaches for building energy conservation, including Eco-information, Eco-choice and Eco-feedback, in the Design Behaviour Intervention Model would not be used solely to generate concepts. To ensure more variation among the resulting ideas, sketches started with pencils and markers, allowing a rapid flow of ideas to form and take shape on paper. Table 8-4 portrays a selection of ideas from the brainstorming session that were created for sustainable fridge use with behaviour intervention approaches applied.

Table 8-4: Ideas generated to respond to each design brief

<table>
<thead>
<tr>
<th>Idea 01-1. Milk dispenser</th>
</tr>
</thead>
<tbody>
<tr>
<td>With the milk dispenser, user can obtain chilled milk without opening the refrigerator door for making tea or having quick breakfast. This could save more electricity by reducing the number of times the door is opened for chilled water. However, the hygiene issues should be considered in the detailed concept design.</td>
</tr>
</tbody>
</table>
Idea 01-2. Separate door for quick meal & drinks

The fridge could have a section with its own door for milk and juice as well as bread spread, most in-out items.

Idea 01-3. Mini cooler for quick meal & drinks

A mini cooler could store all the items needed for a quick breakfast, such as milk, juice, margarine and cheese. The door openings for different drinks out or the same thing out could be reduced. The cooler door could be opened in three different ways:

A- a front opening door hinged at the bottom has the benefit that it reduces the amount of cold air escaping when the door is opened;

B-the cooler with a top opening cover is the best solution to retaining cold air inside, but could not be used easily on a worktop that has units above;

C-a front opening door that is hinged at the top would allow the cold air to escape easily, but cannot inadvertently be left open because of the gravity. The cooler door does not need to be opened fully to remove the most used items.
02. Design for organising food preparation

Idea 02-1. Breakfast box

Breakfast box was a compact unit to keep all the items for food preparation during the morning, including the milk bottle, food for younger children and things for lunch boxes and fruit bags for work and/or school. Users have to get the big container out of the fridge when preparing food and the door will be closed automatically.

Idea 02-2. “take me out”

This is an example for eliminating “rebound effects”, leaving the door open while sorting items into the fridge drawer, discussed in section 7.4.2.2. The drawer, a quarter of disk, is attached to the fridge door, with an arrow smiling face on its lid solicited users to detach it.

Idea 02-3. Dinner box

Solution A, the drawer design with the lift-up door, is used to constrain the occurrence of “leaving door open” while unpacking the shopping and preparing the meals; There are two ideas, B1 and B2, about the trays for removing the condiments from the fridge while cooking or eating. The most used jars and bottles could be placed in the front tray and the spare ones in the back one.
03. Design for displaying content

Idea 03-1. Narrow drawers, small containers & thick door bins

There are three ways to constrain or afford actions, providing a good view of the content. In Idea A, the fridge composed of two drawers is located on the worktop which is the right height for accessing the items inside easily and the height of the narrow drawer is for one small jar; the small container is specific for the used items in Idea B; the thick door in Idea C avoids the food hiding at the back of the shelf.

Idea 03-2. Design for bottles and optimizing internal space utilisation

Two solutions are designed for keeping the opened bottles upright. A is an adjustable bottle rack to hold the bottles from above using the lip of the bottle; adjustable shelves in B that can be moved independently to enable the variety of the size of the bottle.

Idea 03-3. Redesign the food packaging

To avert damaging behaviour related to the food packaging design mentioned in section 7.4.5, the sliced cooked meat could be hung up on the door in concept A and the label could be placed on the lid of the sauce jars. The label contains the information about the name of the items and the expiry date in bigger size of font.
04. Design for improving the loading efficiency

Idea 04-1. Eco-spur for classifying the food
Idea 04-2. Design for less cold air escape

To address the problems arising from the impact of unpacking shopping (7.4.1.3), the solutions should start in the supermarket. For instant, Idea 04-1, three colours of reusable bags are provided in the counter for users to pack items for fridge, freezer and store cupboard into different colours of bags – blue for fridge, green for cupboard and purple for frozen. This is also applicable for packing items for delivery. Additionally, the colour adopted for food package design may be regulated to accord with the shopping bags. For example, the food required to be refrigerated would be packed into a range of tones of blue packaging. This colour matching “game”, working as a perceived affordance (Norman, 1998), facilitates the changing of the packing habit by bringing “blue” chilled food to the blue bags. It would also encourage carrier bag reuse, and food classification could spur the one-off action into environmental responsible practice.

Concept A and B in 04-2 use a combination of the technical and design solutions to reduce the efficiency losses from cold air failing out of an open door. The design changes the conventional interaction between the user and the product. Users have to take the drawer out from the fridge (A) for sorting items in or out. The counter chest fridge (B) not only can be used as a normal working counter but also helps meet the latent need of the user for loading things near to the fridge realised by observational studies in section 7.4.3.2. Development of this concept leads to the internal design for organising the context, such as with the door bins and containers and the suitable depth of the chest fridge to avoid the “food loss”.
05. Design for children use

The children’s impact of the fridge use discussed in sections 7.4.1.1 and 7.4.4.1 could be limited by sorting the food for younger children together in a container which can be removed for cooking children’s food, or giving more divided openings to keep the items which are often taken out by grown up children separately.

06. Design for food portioning

As people become more health conscious and care about how much they eat and drink, portioning food packaging design offers a helping hand by dividing salad vegetables in to adult and children portions. In the supermarket, the bag or the cup could be provided as a measure. The portioned food speeds up the decision-making process with door opening.

07. Design for right full (3/4 full)

Section 7.4.6.2 raised the issue of defining the right quantity in the fridge, this concept attempts to establish the standard, at least 3/4 full (Peterson, 2009) by dividing the space with two distinguished colours, white and orange, for example. For optimum energy savings, the option to switch shelves off was given, if the orange part with ‘’comes forth. Eco-information and Eco-choice approaches are employed to raise awareness and get the product prepared for another situation.
08. Design for avoiding loading in hot food

A thermal sensor installed to detect the temperature of the leftovers. Different levels of behavioural interventions could be given ranging from the visual or audio feedback that arouses attention to the ultimate idea that fridge boxes cannot be opened till the food cools down.

09. Design for system design of food consumption

A food chilling system and a meal planner constitute a system for organising food consumption and leading a healthy and green lifestyle with the suggestions applied. The idea is that users sit down in the front of the computer to set their meal plan based on the information from food portion calculator and 5-A-day measurement. After the recipes have been chosen, the food shopping list could be printed or sent to the supermarket directly. The data of ingredients and preparation methods transfer to the chilling system via wireless internet, displayed on the screen of the chilling unit, as illustrated in Picture 2. The unit is designed for keeping food for each day. Once the user removes the container from the unit and closes the door, information about the ingredients and preparation methods will show on the screen of the day. The built-in sensor could detect the content, including the weight and the temperature and give advice to rescue the leftover from previous meals in-between shops.
As suggested in section 7.5.2.2, the chilling system could be placed on the work counter or fixed on the wall above at a suitable height and easy to operate.

10. Design for meeting needs during different life stages & product life stage

Idea 10 was developed to explore the potential for the service design, realising the most energy efficient use mode of the cold appliance. The manufacturers not only offer the modular designed chilling system but also the service, such as providing the most efficient mode of the product, delivering the new and collecting old or unused module. After signing the contract, the users bring the base module and pay for the service rather than the product. The components could be tapped to the central power source on the base mode, provided and taken away at any time for various user needs.
8.3.4 Concept Selection and Combination

A collection of ideas were specified to tackle each brief and these ideas were selected and combined to create new design concepts for user testing.

The concepts were refined by producing advanced sketches of the product and the manner in which interaction occurred. The point of this practice is to distil those ideas generated, by brainstorming, and to converge the related ideas into a singular concept. Four combinations of design concepts were chosen and explored further in CAD modelling, in which the parametric modellers cleared up the ambiguity inherent in hand sketches. A fully rendered CAD model allowed for a greater appreciation of what the final form may take by non-designers, forming the basis of the presentation for the user testing, the next stage of this design activity. The following concepts are not meant to be exhaustive but influence behaviour in varying degrees and from different design categories, including the single product solution, the system solution and the service solution.

1. Concept 1 - Drink and Spread MINI-COOLer

Linking Idea 01-3C, Idea 03-1A and Idea 05, the Concept 1 in Figure 8.10 is a Drink and Spread MINI-COOLer for drink and a quick meal. Milk bottles, juice cartons and margarine or butter boxes can be stored to provide a drink and a quick meal for breakfast, after school and in the late evening. This is also a possible solution to reducing grown up children’s impact, providing them with the facility to make toast after school or in the later evening (section 7.4.1.1 and 7.4.4.1).
Figure 8.11 demonstrates the use process of the cooler. The upper part is designed for keeping milk and/or juice. To retrieve one of those items the door only requires opening a small amount. Being hinged at the top, the door will also close automatically and reduce the time that the door is open for such tasks as pouring milk into the tea. The frequency of this particular task is one of the most damaging behaviour observed in the ethnographical user study.
As illustrated in Figure 8.12, the different sizes of the cooler are available for the different sizes of the household.

2. Concept 2 - BreakFAST BOX
The combined Concept 2 BreakFAST BOX in Figure 8.13 synthesizes Idea 02-1: breakfast box, Idea 02-3B2: condiment tray, Idea 03-1A: narrow drawers for display
content, Idea 03-2B: bottle drawer, Idea 03-3: redesign the food packaging and Idea 05 design for children use. Figure 8.14 below provides the views of pulling all sections out from the product.
As illustrated in Figure 8.15, BreakFAST BOX is not only used to keep salad vegetables, soft fruit, yogurt, cooked sliced meat for preparing lunch box and a proper breakfast with/without younger children, but also for tall wine bottles, jars of fillings and condiments for daily cooking. Figure 8.16 confers the responses to Idea 03-3A and Idea 03-3B, redesign the fridge, food package and labelling for displaying the contents.

Figure 8.15: Concept 2 - BreakFAST BOX for proper breakfast, lunch box preparation and daily cooking.
Having observed the problems with storage for opened bottles (section 7.4.2.2), a sensible design solution, Idea 03-2B, was generated. To accommodate for the varying sizes of the bottles, presented in Figure 8.17, sections of the shelves are removable to allow for the taller bottles to be stored and easily removed.

Idea 02-3 B2, condiment trays for food preparation was realised in Figure 8.18.
The most commonly used dairy products, jam, sauces and/or the condiments can be stored in the small tray in the front which could be removed for preparing and having breakfast as well as tidying up the table, as illustrated in Figure 8.19. This would lead to a reduction in door openings associated with intensive activities around meals, as described in sections 7.4.1 and 7.4.3.2.

3. Concept 3 – Weekly Meal Planner

Concept 3, a food organising system for planning evening meals, was inspired by the issues raised in section 7.4.1.2 on dinner preparation. A central theme running through
the concept was the idea of bringing bigger impacts on the users’ lifestyle. Beyond the single product design solutions, behaviour constraints were given within a systems context which focused on food consumption in the future. By building intelligent communication between products, the working status of each element within the system could react according to the actual use condition. This requires the coordination and cooperation of the chilling product manufacturers and designers, food producers and suppliers, nutritionists as well as software developers. The following use scenario (Table 8-5) maps the process of interaction between a family and an extremely organised food consumption system with suggestions from Idea 02-3A, Idea 04-1, Idea 06, Idea 08 and Idea 09 applied. In this scenario, the family is a four-person household, husband, wife, daughter and son, leading a busy but healthy lifestyle and with the intention of planning their evening meals for the following week.

Table 8-5: Concept 3 – Weekly Meal PlannER, the most extreme use scenario of the food organising system

01. On one Friday evening, it is the time for the family to sit down in front of the computer and make the meal plan for the coming week.

02. On the first time of setting up the meal planner program, the information needs to be put in to build the family members’ profile for husband, wife, daughter and son, including the age, height, weight, and so on.

The options of the time the meals planned for is also provided. In this scenario, the family chooses to set the meal for a week.
03. Then the family begins to set
the meal for each day. There are
some choices for the recipes and
people needed to cook for. The
food portion calculator, the 5-a-
day measurement and calorie
counter could give advice on the
day meal plan.

04. For example, it could suggest
that the husband needs one
more portion of fruit or
vegetables or if the wife is on a
diet, she may need to change the
cheesecake for afternoon tea
into a small piece or two biscuits,
or her original choice but plus
forty minutes jogging.

05. After the weekly meal plan
has been done, the shopping
list could be compiled with portions
based on the food left in the
fridge system from the previous
week and suggestions on the
cooking date.

Then, the decision needs to be
made between: ordering the
grocery deliver online or going to
supermarket personally.

06. In the supermarket,
packaging for food portioning
enables the wife/husband to buy
the proper amount of food
according to their meal plan.

At the cashier, the wife/husband
packs the items into the
shopping bags in different
colours and gets them ready for
unpacking when arrived home.
All green bags pile near to the
cupboards, all purple things to
the freezer...
07. All the blue bags are placed on the worktop.

08. The wife/husband takes out the box from each unit and puts them on the worktop.

At the same time, this triggers the wireless internet automatically to connect with the meal planner.

09. Once all the unit doors close, the food needed to be loaded into each box will display on the screen.

10. The list contains the dishes of the day with the portions.
11. When preparing the evening meal, the wife/husband takes out the box from the unit. The recipe appears on the screen after the food is taken out.

12. The recipe includes the information about the location of the ingredients, the preparation and cooking methods.

13. After dinner, the leftovers cannot be put into the unit for the next day, unless it cools down in a sealed container. The rest of the meal plan could be rearranged to use up the leftover.

Sensors installed could measure the use conditions to adjust the chilling space according to the content and detect the food temperature.

Different sizes offered to the different household sizes.

4. Concept 4 – Modular FRiDGE

The modular designed chilling system in Figure 8.20 is a CAD model of Idea 10, designed for meeting needs during different life stages and product life stage. This concept relates to the specific product design and the service design for the life of the product after the point of purchase. Figure 8.21 illustrates how this service would respond to the various needs, addressing the problems related back to section 7.4.4 in
the main study, which referred to the changes in users’ lifestyle, the life stage and product life stage. In Concept 4, manufacturing the fridge means providing a service and constructing a long-term relationship with the users. Selling the base model stands for nailing down the agreement. It aims to provide flexibility, for example, the users could have more components during Christmas, switch one off during the holidays and own a lot more components when having children. They also could turn some off when harvesting fruit and vegetables in the garden and keep fewer components when children left home.

Figure 8:20: Concept 4 – Modular FRiDGE.

Figure 8:21: Concept 4 – Modular FRiDGE, the service design.

5. The effectiveness and acceptance estimation of the selected concepts
Table 8-6 summarises the effectiveness and acceptance estimation of these selected concepts made by the researcher as the designer.

Table 8-6: The effectiveness and acceptance estimation of these selected concepts

<table>
<thead>
<tr>
<th>Concept</th>
<th>Feature</th>
<th>Approach Adopted</th>
<th>Design Category</th>
<th>Expected Effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concept 1 - Drink &amp; Spread MINI-COOLer</td>
<td>- organising drink &amp; quick meals;</td>
<td>Eco-steer</td>
<td>Single product design solution</td>
<td>Short term, immediate radical change</td>
</tr>
<tr>
<td></td>
<td>- automatically shuts door;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- storing food for children.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concept 2 - BreakFAST BOX</td>
<td>- preparing for proper breakfast, lunch box &amp; fruit bag;</td>
<td>Eco-steer</td>
<td>Single product design solution</td>
<td>Short term, immediate radical change</td>
</tr>
<tr>
<td></td>
<td>- salad vegetables &amp; soft fruit box;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- dairy product/condiment tray;</td>
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<td></td>
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<tr>
<td></td>
<td>- wine drawer.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concept 3 – Weekly Meal PlannER</td>
<td>- meal planner;</td>
<td>Eco-information</td>
<td>System design solution</td>
<td>Long term change in the lifestyle;</td>
</tr>
<tr>
<td></td>
<td>- chilling unit of each day;</td>
<td>Eco-feedback</td>
<td></td>
<td>Extreme behaviour intervention concepts.</td>
</tr>
<tr>
<td></td>
<td>- food portioning design;</td>
<td>Eco-spur</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- packing design;</td>
<td>Eco-steer</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- avoiding loading hot food;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- intelligent communication.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concept 4 – Modular FRiDGE</td>
<td>- modular fridge design;</td>
<td>Eco-spur</td>
<td>Service design solution</td>
<td>Long term change in the lifestyle;</td>
</tr>
<tr>
<td></td>
<td>- service design.</td>
<td>Eco-steer</td>
<td></td>
<td>Flexible concepts.</td>
</tr>
</tbody>
</table>

These four concepts are neither the definitive Design for Sustainable Behaviour, nor the finished products for real life use, but the first attempts made through the design behaviour invention model that can be tested with the users.

8.3.5 User Testing

The following sections describe and discuss the user testing. It aims to elicit user perceptions and responses to the behaviour changing concepts and design approaches applied.
8.3.5.1 Focus Group

In order to evaluate the effectiveness and the acceptance of the four selected design concepts, it was essential to encourage debate and to identify different views of a range of target users. A focus group was chosen to evaluate the concepts with the potential users since it would provide ample opportunities to give the participants a comprehensive brief. A focus group would also enable the designer to gather more extensive information in a single session than would result from one-to-one interviews (Morgan, 1998). The context of the focus group tends to provide a more informal setting to create greater spontaneity in the contributions of participants (Bruseberg and McDonagh-Philp, 2001a). In a group discussion, participants are given more control of the issues raised in the dialogue (Krueger, 1994) and they can influence each other by responding to ideas and comments of others. The research topic could be explored in depth, which might not occur without the discussion (Bruseberg and McDonagh-Philp, 2001a). To encourage communication with users, a user focus group was developed to present the concepts by using PowerPoint to solicit the comments from a more comprehensive and deeper perspective.

May (2001) suggests that the size of group should be kept between 8 and 12 people to provide all participants with the opportunity to contribute. In this user testing session, eight users from eight different families representing four different family sizes were involved for approximately one hour discussion, shown in Figure 8.22. A description of each participant and their corresponding code is provided in Table 8-7.

Figure 8.22: A snapshot from the user focus group
Table 8-7: Description of participants in the user testing

<table>
<thead>
<tr>
<th>Description</th>
<th>Code</th>
<th>Description</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-person households</td>
<td>CEP1-2</td>
<td>3-person household (child in 0-2 age group)</td>
<td>CEP5-3</td>
</tr>
<tr>
<td>CEP2-2</td>
<td></td>
<td>4-person household (children in 5-11 age group)</td>
<td>CEP6-4</td>
</tr>
<tr>
<td>CEP3-2</td>
<td></td>
<td>4-person household (children in 12-18 age group)</td>
<td>CEP7-4</td>
</tr>
<tr>
<td>CEP4-2</td>
<td></td>
<td>5-person household (children in 5-11 age group)</td>
<td>CEP8-5</td>
</tr>
</tbody>
</table>

An agenda and the presentation of the household fridge case study were established to define the desired outcomes of the event. The participants were given a brief introduction to the main study of household fridge use and the scenarios of use illustrating how the four design concepts and a combination concept of those (Figure 8.23) would affect user behaviours in a variety of specific contexts.

![Four design concepts selected for user testing](image)

Figure 8:23: Four design concepts selected for user testing

To ensure the right messages were identified and communicated, the open-ended questions listed in Table 8-8, were prepared to ask at the end of the introduction of each concept to prompt and guide the discussions. The whole event was recorded by digital video for further analysis. A full set of presentation boards from this focus group is available in Appendix 18.
Table 8-8: Questions for discussion in the user focus group

**Questions for Each Design Concept:**

1. What is your first impression of this concept?
2. Do you think that it is useful for your lifestyle?
3. What are the positive and negative things about this concept?
4. What concerns would you have with this redesigned product in your kitchen?
   - The space takes up in the kitchen
   - The cost of electricity
   - The changes to the use of fridge
   - The changes to the lifestyle
   - Other
5. Would you buy this concept? In what situation?

**Questions for Combination of the Four Concepts:**

1. Which concept do you think is the most effective solutions to reduce the energy use of the fridge?
2. Which concept would you like to have most? Why?
3. What combination of concepts would you consider?

### 8.3.5.2 Analysis Techniques for User Testing

The data was transcribed and the key quotes were mapped and clustered in a similar way to the main study. The participants’ responses to each concept were grouped in relevant categories on the map. By linking those viewpoints and concerns with the same theme, a panorama for understanding their perceptions of the design outcomes and acceptance of Design for Sustainable Behaviour was unearthed. The exemplar pages of the maps are given for illustration in Figure 8.24 and 8.25.

![Figure 8:24: Mapping the user testing data on concepts](image1)

![Figure 8:25: Building a whole picture for design for sustainable behaviour](image2)
8.3.5.3 Results of User Testing

The following section outlines the feedback on the fridge design concepts obtained from the user testing focus group.

1. Feedback on Concept 1 - Drink and Spread MINI-COOLer

There are two opposite attitudes towards Concept 1 - Drink and Spread MINI-COOLer. The impacts of making drink and quick meals were recognised but its potential effects on reducing the energy use questioned.

Participants argued about whether the energy needed to supply the extra cooler is “less than the energy wasted from getting the milk and spread out from the fridge” (CEP4-2). The rebound effects of having two chilling products were considered as a potential problem since “you buy the additional...just to see this as a second fridge it is the opportunity of storing more things in my main fridge” (CEP7-4). There were some concerns from the respondent (CEP8-5) living in 5-person family regarding the space in the kitchen and the difference in use among different types of household: “the kitchen is too small to have two separate fridges: one for milk and one for anything else; and most of the big families buy 6 pints of milk not 4”. In talking about the positive aspects of this concept, designing for use by children, a different way of door opening and the convenient location for use were elaborated. CEP7-4 mentioned that: “you could set up this at different areas, more convenient location; depends on where you eat, how you make a cup of tea. You can put it on the table to see...” and CEP3-2 agreed on this point “...quite a few people do have a little fridge in the kitchen for quick stuff”. The final question: “would you buy this concept? And in what situation?” drew out the key point of their considerations: “we are willing to hear that if there is a massive saving in the energy use then you buy; then it is about if you have got the space to use something... if I know it will have really big impacts, dramatically reducing that of my big fridge, then, yes!” (CEP3-2)

2. Feedback on Concept 2 - BreakFAST BOX

The behaviour constraints embodied in the Concept 2 - BreakFAST BOX were generally accepted and favoured by most of the participants. “I like everything that has its little place. Before you looked for where it is and at this moment, you have got particular space. I love them” (CEP3-2). Comments made by participants suggested that Concept 2 was not only a nice helper for organising their foodstuffs but also of enabled the user to gain energy savings from such a convenient use.
Having drawers rather than shelves could stop cold air falling out “because it is got the front top and you just draw out what you need sauce or jam, as the freezer has” (CEP5-3). The “pull out” feature, the vegetable and fruit box, the condiment and dairy product tray and the wine drawer, was regarded as a convenient and functional design. CEP4-2 discussed that “I really like the idea of pulling out the condiment tray and closing the door when cooking and you can put it back afterwards” and CEP3-2 thought that it was a good idea to take the dairy product tray out to “where you are having breakfast”. The ability to contribute to the ease of use and the eco-efficiency via the adjustable wine drawer design was identified: the way of “pulling out wine” and “separating things” (CEP8-5), “stopping spillage by keeping the bottle up” (CEP1-2), providing “options to change the size of the internal structures” (CEP3-2), “saving energy by not pulling out that wide” (CEP8-5). Also, design food packaging and labelling for displaying the contents provided some interesting discussion. Whilst CEP7-4 had concerns about pulling out the drawer to see what was in, “hoping to see the sell-by-date just from the top may be ambitious and you can’t always see what the things are, particularly when you put them into another container.” In CEP5-3’s opinion, the design was helpful because for most jars, once “you open it, you need to have it within 5 or 10 days”. CEP1-2 was in agreement that it could solve “the problem that a lot of families have, opening a second jar when the first one isn’t finished. A new unused jar can be hidden underneath until required”. One participant, however, felt this design concept would be more constraining about what could be put into the fridge because they put “a lot of irregular size things” and a half eaten meals “in the whole bowl” in their fridge (CEP6-4).

3. Feedback on Concept 3 – Weekly Meal PlannER
In analysis of the feedback on the three design elements in Concept 3, the coloured bags, meal planner and the chilling system, the distinction has been made between levels and types of the behavioural intervention design. Getting ready for unpacking by using coloured bags in the supermarket, as the one-off action with less deliberations to perform, was widely accepted. The only worrying was that “it takes long time to pack away” (CEP6-4). Planning a meal in advance, “keeping all the things in the central place” (CEP1-2) and protecting the food for “Friday night” (CEP7-4) from the naughty “glutton” were considered as useful. The meal planner was well positioned to satisfy the pressing needs in a diet (CEP8-5) or a single kitchen (CEP6-4) and of the people who already or intend to plan their meals (CEP4-2). However, as explained by CEP1-2, “my mum will love that because she plans all meals in advance and buys everything that
she needs. For me, two days before I go shopping, I have got a random selection of items in fridge and cupboard”.

It is apparent that people like being organised, but this concept, to some extent, challenged their established daily routines. The typical response to this concept was “it’s a lovely concept. I like the concept. But I don’t want it” (CEP3-2). Some felt that it lacked enough flexibility: “we plan ahead for some of our meals, if we are organised” (CEP1-2) and “the problem is that your friend turns up and you haven’t catered for him/her” (CEP7-4), “that cannot be predicted that far” (CEP1-2). Also, it was considered contrary to the prescriptive way of planning meals: “we open the fridge to see what is in, what we could make with the content” (CEP7-4) correctly revealed the change that the design concept schemed to make in user behaviour. A compromised design idea was suggested: rather than having the extreme behaviour constraints, “you could have shelves to put your planned meals on, so look at other shelves if you want something else” (CEP5-3). Another concern that came up in the discussion was that internet food planning and shopping could be a time-consuming process.

The “unit of the day” idea stimulated animated discussion about the hygiene issues, the potential effects of the behaviour constraints on emotional relationship with the food consumption as well as a series of design solutions to reducing food waste, such as a fridge with scanning technology, “if you can scan the content in the fridge” and “give the possible recipe for what is actually in there” (CEP1-2, CEP8-5). The participants’ feedback confirmed that the relationship between everyday use patterns of the fridge, the fridge design and food consumption could stimulate public discussion. The relationship between the fridge use, design and energy consumption was less noticeable to the ordinary users and prompted less discussion in the focus group.

Of particular interest to this research is discussion on Concept 3 – Weekly Meal PlannER. It explored the baseline of the user’s acceptance of behaviour interventions.

4. Feedback on Concept 4 – Modular FRiDGE
Modular FRiDGE, the service design, successfully satisfied the demands of everyone present by providing flexibility and energy efficiency in use without great effort to change and challenge their deep-set routines. It met the underlying user need to have a full fridge between shopping trips or during holidays. “My husband actually adores that, because when we go on holiday, he fills the fridge with cereal, pasta and dog food...all the things therefore saving energy” (CEP3-2). “My grandma stuffs the fridge
Participants in this user focus group not only distinguished Concept 4’s innovation points and effects on different ways of fridge use but also voiced their latent needs as the continuations of this concept. Some felt that it is quite useful to have the separate element, for example, “when you have one family member, who is vegetarian”, “you could separate those things” (CEP7-4, CEP1-2). Furthermore, more changeable functions between the different things were preferred, such as “changing one fridge component into freezer” (CEP8-5) at the time of “harvesting vegetables in the garden” (CEP8-5). To make more economic and sustainable use of this modular designed fridge, a good point of this was that a component could be taken away, for example, “when you are going away for a weekend or go camping and plug it into alternative power source” (CEP7-4) or “it will be used as well, after your children leave”, they could take one from the base (CEP1-2), which would be seen as a connection with their family.

5. Feedback on the combination of the concepts
When talking about the most effective solutions to reduce the energy use of the fridge, the pull out feature of the drawer, the boxes and the tray embodied in those concepts, was voted as a desirable design solution to mitigating the behavioural impact of the fridge use. The Modular FRiDGE, the service design solution, was the concept that they would like to have most. And the modular fridge connected to all of these design concepts, including Drink and Spread MINI-COOLer, BreakFAST BOX and one component for the days of the week or the particular meals, was considered as the preferred combination concept.

8.3.6 Conclusions of Design Study 2
In Design Study 2, a series of innovative design concepts was created to contribute a radical immediate or long-term change in the use pattern of the household fridge. The design briefs were set up, based on the findings from the long term behaviour studies in Chapters 6 and 7. It was the first application of the Design Behaviour Invention Model on the development of the concepts for reducing environmental impact of product use, from concept generation to user evaluation. This includes identifying the types and
characteristics of use behaviours relating to energy-consuming products, applying behaviour interventions into the concept generation process and testing the users' acceptances of the design concepts.

A significant aspect of this design activity is that the concepts emerged have shown the intrinsic characteristic of the fridge and its surrounding infrastructures that impede environmental friendly behaviour. The design outcomes redefined the interaction between the user and the product by embedding behavioural indicators or triggers into design with three different categories: single product solution, system design and service design. The design of behaviour constraints, such as organising fridges according to the temporal routine of eating, designing for presenting content, as well as, the “pull out” features, would allow users to save energy through affording easy use. The design ideas for system and service solutions can be implemented in the longer term to bridge the gap between intention and action and achieve more holistic changes in lifestyles. The flexibility in the service design meeting the users’ different needs during different life stages allows applications to maximise the use of total system resources as needed, instead of being confined by physical boundaries.

The study highlighted the users' perceptions and their acceptance of selected design concepts for behavioural change. For assessing the tolerance level of the behaviour intervention design, the design concepts served to illustrate the varying levels of intervention, representing different design categories. Reflecting on the results of the user testing focus group, the key points for Design for Sustainable Behaviour to eliminate the environmental impact of the product use are summarised below:

1. Show the measurable and prominent energy saving of each specific operation, e.g. in figures, in money, in trees (van de Velden, 2003a) or the other equivalents responding to the personal values. Helping users to link the redesign features to noticeable differences in energy use will increase the acceptance of the behaviour changing concepts, especially at the purchase stage;

2. Design a service to mitigate the “rebound effects” of the energy-consuming product use, e.g. seeing the Drink and Spread MINI-COOLer “as second fridge” (CEP7-4) increased energy consumed refrigerating the same amount of goods. The acceptable solution could be providing services with the modular designed product and incentives, e.g. upgrading the component to the more energy efficient mode. The user friendly connection or supervisory mechanism was established to increase
the benefits to the manufacturers and the environment through offering users a convenient life;

3. Offer choice in behaviour changing products to adapt to the requirements of different household types and compositions: as discussed in the section 8.3.5.3, the participant from 5-person household has concerns about the capacity of the fridge, it is important to distinguish the differences in product use patterns in the single household, the small or large family and to bring behaviour changing concepts into the people’s daily lives.

4. Target the impact of the children’s use: the features to reduce the children’s impact are considered as the useful design by the participants;

5. Build intelligent communication between products (Rodriguez and Boks, 2005) the meal planner element in Concept 3 (Weekly Meal PlannER) exemplars what information and how the communication technology could enable appliances to recognise the context and help users make better decisions during the operation of the product;

6. Meet the user’s “green” needs: behaviour changing concepts are more desirable and more effective on the use patterns of the users who are struggling with unsustainable use patterns or have the will to change;

7. Provide an adjustable and flexible design with innovation, reducing behavioural energy and resources waste: the wine drawer design of the Concept 2 (BreakFAST BOX) and modular designed fridge of the Concept 4 are examples to show how the flexible design neutralises feelings of antipathy to the change made to the users deeply ingrained habits;

8. Design behaviour constraints or controllers as simplified and convenient use features: people’s acceptance could be increased by making the behaviour changing products simple and convenient to use. Such as the “pulling out ” features of internal parts resulted from this design study were praised by all of the participants of the user testing focus group;

9. Establish an emotional relationship between the electrical appliance and the users: the discussion of the service design, Modular FRiDGE, recommends that one of the
components could be taken away when the grown-up child left home in order to keep the connections with the family as well as result in a longer lifespan;

10. Allow the user to control the decision-making process when applying the Design Behaviour Intervention Model: it is evident that for certain types of the products, people will not be prepared for to give up that much control, such as the behaviour controller design of Concept 3 (Weekly Meal Planner). To restrain the undesirable habitual behaviour of energy use, adopting eclectic behavioural intervention approaches would be less confrontational. The concepts which integrated design approaches from the mid-part of the Design Behaviour Intervention Model are fully endorsed by the participants.

8.4 Discussion

Having completed two design studies to reduce the environmental impact of household fridge use, comparisons of the design concepts generated are made to discuss how the designers could make a difference in behaviour through sustainable product design.

8.4.1 Reflections on Design Outcomes of Two Design Studies

The benefits of undertaking long term behaviour studies and applying the Design Behaviour Intervention Model into design processes were identified through comparing the design processes and outcomes from these two design studies.

Design study 1 presented a traditional design concept development process: how designers responded to a design brief of designing a sustainable use of the household fridge. As a part of the brief, students undertook the conventional user centred research methods, including the user survey and observational studies to facilitate design processes and product analysis, technology search and secondary literature on the environmental impact of fridge use. The student designers recorded and analysed the data through the use of storyboard, the images and the MS Excel. However, the limitation of the samples in the students’ studies restricted their understandings and elucidation of the essence of the phenomenon. Most design conclusions were drawn from the analysis of the responses to their survey and the secondary literature rather than first-hand behaviour studies. As a result, the damaging behaviours in the shared flats and use differences between the single household and multi-household were identified. The correlation between the results from their user research and the design
outcomes was not explicit, resulting in the student’s uncertainty of the users’ acceptance of the concepts.

The researcher as the designer conducted design practice research in Design Study 2 to demonstrate a new way of doing Design for Sustainable Behaviour. The design activity started with a literature review and detailed user centred research of household fridge use. Ten design briefs were extracted from the in-depth analysis of the consumer studies (Chapter 6 and Chapter 7). An ethnographical observation allowed the designer to enter the users’ private domestic sphere, examining the problems and relationships hidden in the use routine and the product design from the vision of a designer rather than a social psychologist. The data from observing and recording behaviour in situ of a range of typical British families and the questionnaire and interview as a supplementary means, formed a rich resource of fridge use patterns and their environmental impact. This provided sufficient space for the designer to see things in a different light. By applying the Design Behaviour Intervention Model in design processes, a series of novel design-led solutions were developed to respond to the problems identified. The judgment of the type of the fridge use behaviour made by accessing them through three antecedents of behavioural change helped to solidify the thoughts and the ideas of design. It was possible to have a definite object in view at the beginning of the “design for behaviour change” work, directing the project to the appropriate design approaches. To respond to the habitual nature of the fridge use behaviour, the researcher as the designer employed the corresponding design approaches which have greater influence on the behaviour, rather than solely adopted the approaches of building energy conversation.

Without providing the specific knowledge about the Design Behaviour Intervention Model, in Design Study 1, student designers drew on their design solutions based on the analysis of their own behaviour studies. The changing behaviour approaches in the Design Behaviour Intervention Model, as a guide at the beginning of the design generating process, helped the designer to understand how the different levels of the interventions could affect corresponding user behaviour. Design Study 2 showed that the effectiveness and acceptance estimation of these selected concepts made by the designer (Table 8-6) was consistent with the user testing results. Using the model, the designer could carry on a relatively accurate prediction of the user’s acceptance level of the behaviour changing concepts and deal with Design for Sustainable Behaviour tasks more effectively.
8.5 Conclusions

The contributions of the specific behaviour study and the Design Behaviour Intervention Model were evident by comparing the outcomes from the two design activities.

Design Study 1 showed how the designers usually reacted to a design project of design for behavioural change to reduce the impacts of use. It involved typical investigations conducted to detect problems and to generate design concepts, including the user focused study and secondary literature, market research and technology search.

A series of innovative design concepts was created in Design Study 2 to make a radical immediate or long-term change in the use pattern of the household fridge. It demonstrated how the wealth of rich data obtained from the behaviour study has been translated into design concepts. The concrete data on the behaviour in situ and in-depth elaboration on reasons behind the daily use routes resulted in the novel design concepts. The Design Behaviour Intervention Model set up the vision and strategy at the beginning of the design project. It not only empowered the designer with the ability to classify the behaviour type and construct the working space more actively, but also enabled her to identify the design directions and generate the design solutions more effectively. Furthermore, it enabled the designer to have an appropriate estimation of user acceptance and effectiveness of the design concepts. The study represented the first attempt to test the acceptance of behaviour changing concepts with users.

To summarise, through the testing it has been seen that users’ acceptance could be increased by:

- Showing measurable and prominent energy saving of each specific operation;
- Making the link of the redesign features to noticeable difference;
- Mitigating the “rebound effects” of the energy-consuming product use;
- Offering choice in behaviour invention products;
- Meeting the user’s “green” needs;
- Targeting the children’s impacts;
- Providing the adjustable and flexible design;
- Designing behaviour constraints or controllers as simplified and convenient use features;
- Establishing an emotional relationship between the electronics and the users
Empowering the user to control the decision-making process through adopting the design approaches from the mid-part of the Design Behaviour Intervention Model which focuses on maintaining the change by building an energy conversation with force.

Further insights of Design for Sustainable Behaviour change will be elaborated on in Chapter 9.
9 DISCUSSION

In this chapter, the findings of the model development, user study and designing and testing are discussed and expanded upon. Useful insights on substantial literatures and thoughts that have emerged from this research study within the Design for Sustainable Behaviour domains are given.

9.1 Introduction

This chapter presents thoughts, observation and additional findings that have emerged from this research study. By referring back to the existing concepts and theory, the discussion is presented in four parts: section 9.2 brings the author’s perspectives on the importance of understanding users for carrying out a sustainable behaviour design project; section 9.3 presents the effectiveness of applying the social-psychological theory in Design for Sustainable Behaviour. Section 9.4 identifies four principles of improving effectiveness and acceptability of the sustainable behaviour interventions, and section 9.5 concludes this chapter by offering a guide for Design for Sustainable Behaviour.

9.2 Comparison with Similar Studies

Design for Sustainable Behaviour is a branch of Sustainable Design concerned with the application of design strategies to influence user behaviour to reduce the negative impact of product use (section 2.7.1). It has advanced from the traditional area in Sustainable Design referred to as Ecodesign, where manufacturers focus on the supply side, considering the environmental impact of products and their production to a situation where designers are also able to explore the complex interactions between the individuals and artefacts and their impacts on the society and environment. Ultimately, explaining these interactions is required for a complete understanding of environmental issues of a product, a system or a service and is one of the major goals in Sustainable Design, limiting the over-harvesting of resources and the carbon footprint for daily activities. To meet this challenge a new interdisciplinary field known as Design for Sustainable Behaviour, has emerged. A few ways in which designers can try to encourage sustainable actions have been suggested previously (e.g. Akrich, 1992; Jelsma and Knot, 2002; van de Velden, 2003b). The first attempt to develop the strategies at a framework level was proposed by Lilley (2007, 2009). In Lilley’s investigation, three interventions were applied by designers to test the possibility of
Design for Sustainable Behaviour as a response to social problems of products during use (section 4.2). This research, however, describes the further exploration and development of the methodology for Design for Sustainable Behaviour and has had a significant part to play within a practice-based design case, focused on how design solutions could elicit pro-environmental behaviour in the use phase. The following sections discuss how the Design Behaviour Intervention Model’s attributes make it stand out from other studies through its joint use as a straightforward theoretical model.

9.2.1 A Framework Model for Design for Sustainable Behaviour

The Design Behaviour Intervention Model has been developed to integrate existing behaviour change models from social-psychological theory (Chapter 2) and seven approaches for changing user behaviour through design drawn from literature (Chapter 4). It bridges the behavioural change elements with the behaviour intervention approaches from disparate disciplines, and distils the complex relationship between the variables in one theoretical model. The practical examples are used to explain the approaches and to support the designers, providing inspiration and stimulus (section 4.2).

In light of the wide recognition of the barriers to participation in Sustainable Design or Ecodesign: requirement of a larger skill set (Design Council, 2005), “a lack of internal expertise” and “initiative fatigue/overload (i.e. too many offers of support with questionable delivery)” (O’Rafferty and O’Connor, 2006), there is a need to simplify the methodology/tools so as to reduce the effort and the time to understand and apply it in design practice. As a first step in this direction, this model maps the target behaviour to applicable approaches. The practical examples (section 4.2) of each approach serve as inspiration and stimuli to meet the requirements of industrial designers who are searching for images of related products and transferable material and technologies at the early stage of product design process (Sherwin, 2000; Lofthouse, 2001). Secondly, it classifies the design interventions by the degree of power for decision making between the user and three design categories (product, system and service). Integrating the axis of decision making power with the behaviour theory, the design interventions are categorised from the most user empowered solutions to total technological solutions. Consequently, the holistic nature of the model could trigger sustainable and effective design innovations, as it facilitates systems thinking by breaking the design process down into three stages (user study; intervention level selection; behaviour intervention approach application) and relating them to three different intervention
levels (guiding/maintaining/forcing the change) by three design categories (single product; system; service).

Compared to other tools, such as Design with Intent (DwI) (Lockton et al., 2009), the Design Behaviour Intervention Model offers an excellent starting point at the process level by bringing reason, purpose, approach and results together and flattening the hierarchical structure of the behaviour and design approaches. Integrating the behaviour theory into the behaviour interventions provides useful support to understand the underlying causes of the behaviour. To create effective solutions, designers would require a greater normative and motivational understanding of the user, ethical considerations, and ranking criteria, rather than only methods that may affect user behaviour. Also, the Design Behaviour Intervention Model is devoted largely to providing a more straightforward path for design to reduce the impacts of household appliance use rather than more comprehensive and universally applicable tools. For example, DwI is trying to “result in certain use behaviour across a range of disciplines from architecture to software” (Lockton et al., 2009).

9.2.2 Putting Users First in Design for Sustainable Behaviour

More recently, bringing human factors into the Sustainable Design domain has received growing attentions amongst academia (Lilley, 2007; Flemming et al., 2008; Wever et al., 2008). This model highlights the significance of understanding users’ perceptions and experience for reducing impacts of product use by directly introducing behavioural change elements into the sustainable design process. Three sets of influencing factors link the domain of sustainable product design and user centred design methods. It implies the techniques and steps that the designers need to follow to deliver a more sustainable product or system.

The detailed use/interaction study should be the first step in justifying the nature of the target behaviour or which main factor(s) of intention, habits and controls drives behavioural change. To reduce the impacts of product use, sustainable behaviour changing design should firstly satisfy the user need and enhance the usability of the products and services (Rodriguez and Boks, 2005; Wever et al., 2008). By applying user centred design methods, the designers aim to offer the solutions that users could learn and use with minimum effort and complete the tasks with optimal efficiency. Secondly, to achieve a more sustainable result, design interventions may need to address the wider goals that users might not have to eliminate the unintended usage (Beale, 2007) and the rebound effect (van de Velden, 2003a; Hertwich, 2005;
Dimitropoulos and Sorrell, 2006). Figure 9.1 depicts the difference between the detailed use/interaction study for capturing the potentials for shaping the behaviour at the discovery phases and the conventional user-centred design approaches.

![Diagram of User Centred Design Methods](image)

Figure 9.1: Differences in study aim between the detailed use/interaction study and the conventional user-centred design approaches.

The precondition of deciding the behaviour intervention approaches is to identify the type of target behaviour: which factor(s) could lead to the sustainable change in action. The judgement must be made on the basis of a thorough understanding of the user use/interaction behaviour. Ethnographic research method, rooted in traditional social science field studies, provide a range of techniques and tools designed to enable researchers to access consumers’ perceptions and behaviours when using a product or service (Robson, 2002). Product-in-use, a similar technique in user centred design, is concerned with collecting information about user practice in its context (Evans et al., 2002). This method not only looks at the interaction between the users and products and services but also the context of the use, such as the environment. By applying these research methods, the detailed use/interaction study enables designers not only to uncover what people need and they should do with products, but also what they do not need and they should not do with products. It involves qualitative evaluation of the user practice not only about what they say, what they have done and what they need, but also seeing what they actually do and analysing why they do so, as discussed in Chapter 6 and 7. The practice-based design activity of the household fridge provides a valuable case study showing how the Design Behaviour Intervention Model and the detailed use/interaction study could inform and influence the design process.
9.2.2.1 Observational studies for discovering unexpected use and inarticulate needs

The visual data (video and photograph) presents real behaviours in context, allowing the researcher and designer to enter the users’ intimate space and private practice. In the design case of household cold appliances, the observational studies reveal the gap between product design and users’ real requirement, e.g. the need for food’s expiration date reminder on the fridge door (section 7.4.2.2), and how they adapted to poor product design, e.g. using can holders, egg trays and the ice-cube maker storage for storing other things (section 7.4.2.2). A variety of problematic use patterns are also clearly portrayed, such as purchasing a second fridge/freezer for keeping drinks or Christmas food, overfilling the fridge (section 7.4.2.1) and storing uneaten or unused food in uncovered containers (section 7.4.1.2).

Articulating various details of people’s daily routines can be challenging. For example, when asked about their dislikes or any “bad” usage pattern of their cold appliance, the participants found it hard to identify any particular aspects or difficulties in the use of fridge/freezer that they had consciously thought about and deliberately remembered. Ethnographic observation provides an excellent way to look at the mundane activity with new eyes, particularly a from sustainable use perspective. It enables the designer to track and review the long-term routines and the patterns of activity in a wider context, to quantify times and duration of different activities and to reflect on them. There include the detail, the sequence and the consequence of the use and participants’ gestures, movements and pace of interacting with the device. The 24-hour behaviour recordings not only successfully expose the environmentally significant behaviour, but also evoke design solutions to real problems rather than to the assumed user needs. Disregarding the luxury and entertaining features (e.g. LCD screen built into the fridge door) (section 7.4.2.2), more useful and sustainable design innovations could be created when designers are provided with the insights below:

- Users have to check every drawer in the freezer before shopping (section 7.4.2.2);

- Users often leave the doors open during quick tasks (section 7.4.1.1 and 7.4.1.3);

- Much time is wasted for loading things from the unpacking place, dining table and worktop into the fridge and freezer (section 7.4.3.2).
Observational studies play an important role in understanding the user needs in order to prevent undesirable features and design user friendly objects that are also the most basic principles of reducing costly side effects of product use.

9.2.2.2 Multi-methods approaches to revealing the determinant of behaviour change

The collection and analysis of empirical data from multiple sources are helpful to make sense of phenomena and to interpret the reasons behind them. The case study of household cold appliances involved observational studies and supplementary data collection methods, such as questionnaires and semi-structured interviews. Responses from the questionnaires and interviews extend the traditional user centred design by focusing on the user’s values and intentions behind their daily practice and beyond their needs that could not be gleaned from the photographs and video recordings.

Multiple data collection methods allow the designer to decide which determinant(s) influence behaviour change and select the applicable intervention approaches for sustainable use. For example, the observational studies showed that the “eco-button” (sections 7.4.2.2 and 7.4.4.1) and “alarm” (section 7.4.2.2) features on the fridge were not always accepted by the users and caused unexpected behaviour for lower temperature setting and longer opening. Further data analysis agreed that the use patterns of the household cold appliance could not be simply improved by behaviour intervention approaches at the level of “guiding” energy conservation, since users supposed that changing use behaviour of their cold appliance “(it) is not a big issue” (MUS-F01). The intentional factors, such as knowledge, belief and emotion are not the major forces in developing environmental friendly routines for household cold appliance use. Comparing the visual data with the data from questionnaires and interviews indicated that users are not fully aware of the extent to which they, as individuals, are impacting the environment. A good illustration of this is the wife of MUS-F04 in Main Study (Chapter 7), commenting on her existing usage of the cold appliance as (section 7.4.6.2): “no, I do not think that I need to change anything” (MUS-F04). However, the video of her behaviour revealed a number of things, such as leaving the fridge door open for 68 seconds while she transferred items between the worktop and the fridge (section 7.4.1.1), chatting with family members while forgetting to add foods into the fridge and looking for the frozen items in shopping bags (section 7.4.1.2); as well as storing hot leftovers into fridge (section 7.4.1.2).
In drawing out the reasons behind this, it was partially due to the connection between the seemingly trivial and habitual nature of the fridge and freezer use behaviour and the other, related household activities, such as cooking and food shopping. It has been shown that there is a disparity between the user’s actual behaviour and their knowledge, their intention or willingness. The results of the post-intervention questionnaires (section 7.4.6.1) and other studies (e.g. Thogersen, 1996; DEFRA, 2007b) confirmed that if they are given the proper information and opportunities, most people are willing to take actions if it benefits the environment. However, in daily life there are a great deal of routine things, once established, which seem resistant to persuasive design interventions. Partially, it is because operating household appliances in an environmentally friendly manner, such as the cold appliance, is not a priority to users. In this case, design becomes “a conversation between desired outcomes and unwanted side effects” (Beale, 2007, p. 21). It may be the “time” to tell the user what they should do and what they should not by better designed products and services/systems instead of simply fulfilling the user’s need. For example, Eco-steer shapes and restricts a user to a specific action; Clever Design makes the unsustainable operation impossible to perform.

9.2.2.3 In-depth user focused study for generating effective design solutions

User centred design is “grounded in the user’s own current behaviour, which is often less than optimal” (Beale, 2007, p. 22). Traditional research techniques are no longer sufficient in capturing underlying customer needs (Fletcher et al., 2001; Evans et al., 2002) and there is also a requirement for designers to engage with the issues more than the usability to make things work properly. Unlike conventional user centred design, a further detailed use/interaction study attaches more importance to the user experience, desirability, intention and value, as well as conflicts between these issues and the sustainability concerns. In the design case, the habitual nature of fridge and freezer use behaviour directed the design interventions towards the second level of “maintaining the change” and building the energy conversation with force. A range of ideas employing the “Eco-spur” and “Eco-steer” approaches were created in order to fulfil user’s needs and wishes, or to address wider goals than the users might have. Taking the idea of the breakfast food drawer, for example (Figure 8.15), in designing a drawer container instead of a shelf is encouraging the user to remove all the items, e.g. for their breakfast, in one go rather than sorting through the items on a shelf. This makes the behaviour constraint less offensive. The solutions based on detailed use studies seem
more timely and more effective on actual behaviour than those eco-setting features resulting from the conventional user centred research.

9.2.2.4 Qualitifying the requirement for Design for Sustainable Behaviour

Among the recent behaviour impact studies, Elias et al. (2008b; 2008c) collected quantitative data on energy demands and the frequency of user's interaction with the household electrical appliances. For example, a video recording covering a two period was made of the refrigerator in a multiple occupancy student house, to give quantifiable data to a particular action in terms of the time, the duration and the frequency of refrigerator door openings. By quantifying the impact of the studied behaviours, a designer can attempt to mitigate the energy losses through a better technological understanding and design practice.

Compared with the work of Elias et al. (2008c), the outcomes from the author's practice-based design case show that it is more useful for industrial designers to go to the “field” and collect various types of qualitative information, in order to construct a fully understanding of the users (chapters 7 and 8). This helps designers to “meet” the potential users and the real problems in context rather than to respond to the secondary literature, such as the phenomena, the consequence or the figures from the quantitative assessment. With rich and descriptive information, an overall map of household cold appliance usage patterns could be created with the themes drawn from the user studies, including usability of the fridge and freezer (section 7.4.2), the relevant household activities (section 7.4.1), the wider use context (kitchen plan) (section 7.4.3) and the related items design (food packaging) (section 7.4.5), as well as the timeline of product usage and user life (section 7.4.4). The qualitative data not only allows the designer to access anomalies and regularities in product usage and derive user's desires, but could also detect reasons behind the behaviour. This will have the effect of shifting the design to a new level of performance from the sustainable perspective, on far wider issues than just matching the usability needs.

This matches well with other studies (Sherwin, 2000; Lofthouse, 2001) which also stressed that industrial designers need more informative and specific data to inspire their use scenario building while design engineers require information to support the product design. Therefore, Elias’ study is valuable to clarify the seriousness of the issue
as complementary information for industrial designers and improves the energy efficiency of product use from an engineering point of view.

9.3 Applying Social-Psychological Theory and Model to Design for Sustainable Behaviour

Reviewing models and theories from social psychology, three sets of elements of behaviour change which appear highly relevant in the context of designing sustainable behaviour were assembled to offer a basic framework of the “behaviour part” in the model (section 2.6). The elements collectively illustrate the possible drivers and the moderators of individual behaviour change in product use and consumption, acting as an ideal catalyst through which to direct the designers towards the applicable behaviour intervention approaches. The next section will reflect how the “behaviour part” (behavioural change elements) and the Design Behaviour Intervention Model (DBIM) can help in the household cold appliance design project, including the user studies undertaken, the design process adopted, the behaviour intervention applied and the success factors identified. Finally, the generalisability of these experiences in other product types, contexts and user types are discussed.

9.3.1 Applying Behavioural Change Elements in Design for Sustainable Use of Household Cold Appliance

Evaluating the studied behaviour through the detailed use/interaction study and integrating the model into the design development process allows the testing of some topics or solution opportunities early on in the design project. This enables designers to prioritize, reconsider and address the issues that are of real importance to users rather than something interesting only to the designers. In addition, the behavioural change elements and the model, aid the designers to tackle the problems more effectively and efficiently. Through an overall picture of problems and possible solutions, the designers could see how the work at the front-end of the project could become an opportunity at the end of the design development process. The design case demonstrated how the behaviour part can offer a fertile ground for new ideas to provide effective and efficient behaviour interventions.

Figure 9.2 summaries the system thinking process from data collection preparation (1) (product analysis and use context analysis), the use/interaction study design to data collection and analysis (2) and shows how behavioural change factors affect the design
decision making (3), signifying its importance relative to the other design phase and ultimately (4, 6, 7, 8, 9) to the acceptability and effectiveness of the design concepts. The data analysis of the pilot and main study has found that the fridge and freezer usage is habitual behaviour (6) (section 6.4 and 7.4.2.1) involved in a simple operating process (4) with some basic functioning requirements, such as to prevent bacteria multiplying and to keep food fresh (section 7.4.2.1). Therefore, it was decided that those heuristic and persuasive design approaches (5) for building energy conversation (in the Design Behaviour Intervention Model) are not sufficient to generate concepts to lead the radical change in the fridge use patterns (9).

It can be seen from the design case that incorporating these theory-based tenets into a behaviour intervention design project has optimised the design process in the following aspects:

- Designing a comprehensive user study: to facilitate the design of a structured and purposive use/interaction study to explicate user’s needs and the issues hidden in their usage patterns or beyond their needs;

- Collecting natural and realistic data: to ensure an appropriate order of the use/interaction activities conducted in the user study to obtain the most natural and realistic responses;

- Analysing the behaviour and its context: to offer systematic thinking and analysis to appreciate the interconnectivity of the issues that lie within the user and system interactions.

- Responding to problems: to assist the designers to select the most effective and efficient design approaches to secure a lasting change in usage patterns.
Figure 9:2: The Design Behaviour Intervention Model assisted system thinking process for design for sustainable use of household fridge
9.3.2 Generalisability of the Model for Other Product Types

This research focused on the application of the model developed to reduce the environmental impact of household consumption. To ensure effectiveness, for a given period of time, the scope of this investigation was narrowed down to one household appliance group, cold appliances. The household cold appliance design project is a valuable case to fill the gap in the new research area of Design for Sustainable Behaviour. It may be possible to employ the Design Behaviour Intervention Model and design experience gained from the design case to other product types. Two issues should be taken into account when assessing the generalisability of the findings.

Fully understanding the user is vital to the success of improving the environmental performance of product use. An appropriate user study could inspire designers to generate more effective and more acceptable design solutions. The diversity in the user and system interaction processes should be considered in the development of sustainable design interventions of other appliances, where the focus and the practices can be different from the design of household cold appliances. For example, some appliances with a complicated interface will involve a long declarative stage and knowledge compilation stage. As shown in Figure 9.3, it is interesting to see how users make efforts to learn to operate the washing machine. To mitigate under-loading resulting in excessive use of detergent, water and energy, the countermeasures could be an “intelligent machine” that could “automatically adjust water and detergent doses according to the load” (Jelsma and Knot, 2002, p.125). The design solutions could also build an energy conversation by inserting “Eco-information”, “Eco-choice” or “Eco-feedback”, where the user has a choice, facilitating the learning and decision-making process and empowering users to take responsible actions.

Figure 9.3: Users make the efforts to learn to operate the washing machine
A further issue is the application of social-psychological theory into the behaviour intervention design project. The literature showed that more complicated behavioural factors and external issues may be involved when designing environmentally conscious behaviour for other products or systems. It could be illustrated by two examples: cars and heating equipment. The former's usage patterns can be more related to social factors and affect, as Gatersleben and Velk (1998) found that the car provides people with the feelings of maintaining social relationships, doing their job, experiencing pleasure, having privacy, freedom and control over people’s lives and saving time for leisure. The latter examples may not only be determined by internal factors (e.g. habit, emotion, attitude), but also by external socio-economic constraints (e.g. income levels, type of dwelling, tenure, household composition and rural/urban location) (Milne and Boardman, 2000; Druckman and Jackson, 2008).

In conclusion, the Design Behaviour Intervention Model could be applied to promote sustainable use behaviour of any product or system which requires energy, resources and consumables (i.e. ink or paper used for the ink jet printer). This includes household electrical products and industrial plant equipment. The investigation of introducing the social-psychological theory to the sustainable design domain and integrating the model into the Design for Sustainable Behaviour project is just beginning. The findings have the potential to be of value and are applicable to other product types, contexts and industries. A number of areas that emerge out of this research for further study will be detailed in section 10.6.

9.4 Effectiveness and Acceptability of the Behaviour Intervention Approach in Practice

Seven design approaches were identified from three intervention levels to influence user behaviour (Chapter 4). Within this thesis, there has been a lot of discussion regarding how to get the balance between the effectiveness of the behaviour interventions and the users’ acceptability and ethical considerations (sections 4.2, 4.4, 8.3.6 and 8.5). The literature review showed that a number of studies have been conducted to evaluate the impact of the materials and strategies relating to energy conversation on energy consumption behaviour. “Consequence strategies”, providing real-time feedback of a specific performance, have been proved to be more effective than antecedent strategies which offer information to increase the knowledge about consumption (Abrahamse et al., 2005; 2007; Darby, 2006). However, in the Design
Behaviour Intervention Model (Figure 4.3), the heuristic and persuasive approaches are located towards the user end, such as Eco-information, and are the least intrusive behaviour intervention but likely to have the least effect on prolonged changes in behaviour. This approach attempts to inform or educate the users through visualizing the energy and resources or providing users with the opportunities to experience the energy and resources they have used. Due to its non-coercive nature, Eco-information is considered to a heuristic approach to guide the autonomous behaviour change. To the energy force approaches on the axis of power of decision-making between the user and interventions, Eco-technology and Clever design, retain the greatest degree of control and intrusiveness, as do the certainty and effectiveness on sustainable improvement. Four reasons have been stressed in section 4.2 to explain why they are not considered as an acceptable solution to reduce the impact of product use as they reduce the risk of the failure by automatically overriding any decision making by the users. Therefore, the central question in this debate is: is there any ethically acceptable way that has the potential to achieve the expected results of reducing the environmental stresses and engaging user participation in sustainable behaviour?

The second level of the Design Behaviour Intervention Model has provided some potential approaches to afford or steer the behaviour towards more environmentally conscious actions without overruling the users. This study has tested, through the practice-based design project of household cold appliances, the user's tolerance of behaviour changing concepts by adopting the approaches mainly from the mid level. This offered an example of the application of behaviour spurring and steering approaches to change behaviour without lessening the users' ability to choose how to interact. It also filled the gap identified in the literature by Lilley (2007) recognising that industrial designers need tangible illustrations to make the approaches more understandable and applicable, and users should be engaged in the Design for Sustainable Behaviour project. Four design concepts selected from varying levels of intervention and different design categories have been evaluated by the users, revealing the critical point of the acceptability of the design intervention. Four principles of behaviour intervention design were identified to obtain a good trade-off between the effectiveness and acceptability: needs fulfilment, balanced exchange, tailored segmentation and reasonable force.
9.4.1 Needs Fulfilment

The feedback obtained from the user testing (Chapter 8) demonstrated that the behaviour changing concepts designed for fulfilling the user's needs are regarded with great favour. The “switching off” option of the Modular FRiDGE (section 8.3.4.2 and 8.3.5.3) met the underlying user need of having a full fridge between the shopping trips or when away on holidays. Placing the fridge at the right height (section 7.5.2.2 and 8.3.3) allowed users to access the items with ease and minimal effort. These are non-intrusive solutions because they achieved a more sustainable result by adapting the products better to the actual way people use them (Rodriguez and Boks, 2005; Wever et al., 2008). Designing sustainable interventions for “needs fulfilment” also referred as “functionality matching” by Wever et al. (2008) is considered as the most basic principles of reducing costly side effects of product use (section 9.2.2). In summary, the most user desirable behaviour change design solution could be to minimise the environmental and social effects of use by:

- Eliminating the mismatching between the delivered functionalities and the desired functionalities (Wever et al., 2008);
- Realising the sustainability goals perceived by users;
- Eliciting user articulated and latent needs in accessibility, usability and functionality.

9.4.2 Balanced Exchange

“Balanced exchange” is a principle when looking for design solutions to improve the less optimal use/interaction. Particularly, sustainable energy consumption patterns are less than desirable or are sometimes competing with users’ goals and values. For example, the prescribed environmental friendly use patterns are inconsistent with the user's desired way of product use or restrict his/her freedom in use. To limit the energy intensive actions, designing a behaviour spurring or steering intervention for sustainable change which purposely affords a certain action or diminishes aspects of accessibility or usability, is like making a deal with users. The success of Eco-spur and Eco-steering is based on a “win-win” formula. It means to induce or seduce users into compliance with the sustainable behaviour intervention by the provision of user benefits in aspects of usability or functionality. In the fridge design case, comparing the removal of items from the shelves and the removal of the breakfast food drawer (Figure 8.14) or the condiment tray (Figure 8.19 and Figure 8.20), the latter designs
intentionally reduced options or activities available to the user. Although the number of fridge door openings for breakfast would be decreased, it would also be less easy to access (users have to take the drawer and the tray out for load things in). However, the feedback from user testing (Chapter 8) showed that they were popular “behaviour inventions” as they helped with food organising and consuming (section 8.3.5.3). The behaviour restrictions are generally inoffensive but offer added convenience, comfort, time/labour savings, fun and flexibility in use, as a compensation or reward to users who are willing to transfer some of the freedom of usage.

9.4.3 Tailored Segmentation
A premise in design behaviour spurring and steering is that as the activity restrictions increase, these solutions become less usable and appealing to all users in terms of accessibility, usability and functionality. In accordance with Lilley’s reasoning (2007), to enhance the effectiveness and acceptance, the behaviour spurring and steering should be tailored for the specific customer segments who share similar characteristics. Concept 3 Weekly Meal PlannER (section 8.3.5.3) is a good example to expose the users’ limit of the behaviour design intervention. In the user testing focus group, it was considered as a very favourable food organiser in a single/diet/very organised kitchen, while it was a little too restrained on behaviour for households with children. Therefore, tailoring the behaviour intervention to customer segments is a means to allow for user acceptance of behaviour change concepts that employ the coercive approaches, such as Eco-steer, Eco-technology, and Clever Design. To address the needs of the widest possible audience, irrespective of age or ability, it is important to carry out the detailed user study. This enables designers to extend their knowledge when designing behaviour change concepts for user segments with different capabilities, values, experiences, needs and lifestyles.

9.4.4 Reasonable Force
The use of coercive approaches is based on the severity of the consequence derived from the user actions and righteousness of the design intent behind the design concept. It has been found that the forceful interventions, known as Architectures of Control (Lockton, 2005b), have been employed into products, software, physical environments and in the other fields which limit the scope of behaviours afforded to the user. For safety reasons, microwave ovens do not work until the door is closed (Lockton et al., 2009); for keeping order in public, park benches with central armrests are designed to prevent individuals sleeping on them (Lockton, 2005b); for arguably commercial
purposes, ink cartridges that are unable to be refilled (Lilley, 2007). As Lilley (2007) identified, it could be easier for manufacturers and designers to justify to adopt a behaviour force approach, if the target behaviours are legislated against, widely reasoned as socially unacceptable or illegal. In this context, these behaviour interventions appear well intentioned and more readily accepted by users.

For design for sustainable behaviour, Eco-technology and Clever design are classified as the most coercive approaches and placed at the end of the power axis to avoid the illegitimate application of the forceful interventions. They correspond to control for behavioural change. The power axis of influencing between a user and a product (service/system) and the three levels of intervention offer a framework for manufacturers and designers to justify the magnitude of behaviour enacted and the strength of intervention applied. In this design case study, due to the habitual nature of the target behaviour, Eco-spur and Eco-steer approaches are mainly used and technological innovation is employed in the specific design context for improving energy efficiency of the fridge use. As discussed in section 5.3.2.3, DAC (Divide and Cool) - Divisible Cooling Technology from Arçelik (Beko) (2009) has provided the technical possibility for further reduction in behavioural energy use of the module designed fridge, Concept 4 Modular FRIDGE (section 8.3.4.2 and 8.3.5.3). Integrating this technology into the service design solution served as a good example of where designers build in Eco-spur and Eco-steer to fit the user usage pattern and limit the “rebound effect” of purely technological innovation. The modular nature of cooling systems and the flexible service mechanism were welcome ideas in the user testing focus group as they are tailored to meet the changing needs of the user, with regard to the volume of the fridge, during their different life stages. It is possible to see how “doubled” energy efficiency could be gained from a more efficient refrigerator compressor (Arçelik, 2009) and a running fridge unit that is full up.

However, the extent of the behaviour interventions that affect behaviour and the acceptance by users are dependent on the specific context. With regard to the disadvantages of behaviour force interventions discussed in section 4.2, it is suggested to employ the approaches from the second level of the model and to engage the user in the concept development and testing when designing interventions to motivate user behaviour towards a greater sustainable practice.
9.5 Designing Behaviour Intervention

This section presents a Guide (Figure 9.4) for Design for Sustainable Behaviour, which is based on the review of the literature, methods and the design case. By describing a particular practiced-based design case that has proved useful to other designers (Lofthouse, 2001; Lilley and Lofthouse, 2009), it aims to give inspiration and a stepwise strategy to actively integrate Design for Sustainable Behaviour considerations into product/service/system development process.
Figure 9.4: Guide: give steps towards Design for Sustainable Behaviour
9.5.1 Design for Sustainable Behaviour in five steps

The following five-step strategy is developed to help researchers and designers undertaking a Design for Sustainable Behaviour project:

- Get an overview of the product/service/system environmental effects;
- Apply the behavioural change elements and gain insight into the detailed use/interaction context concerning the environmental and social impacts of the product/service/system use; and identify the problems by classifying the behaviour type and internal and external drivers for behavioural change;
- Frame the problems and the design briefs for concept generation;
- Incorporate the behaviour intervention approaches in the solutions and concepts development process that lead to sustainable improvements in use;
- Test the acceptance of behaviour intervention with the target users.

When it comes to a specific design project, the strategy works best by ensuring that all the important decisions are made before design starts.

Involving the users in the concept development process should be the first step toward seeking design solutions to minimise environmental impacts of household consumption. Firstly, it increases the success of the design interventions in creating lasting sustainable change in behaviour. Doing a Design for Sustainable Behaviour project, the development of the brief should be based on the detailed user study. With insightful behaviour data designers could spot the core problems and any important issues for consideration for the concept development process. Secondly, the in-depth use/interaction study and the user testing encourage useful and effective design innovations by dismissing vague speculations and breaking down barriers and prejudices. What is more, understanding user behaviour helps to clarity the influence(s) (intention, habits and control in the “behaviour part” in the model) of the behavioural change and choose the appropriate behaviour intervention approach(es). The nature of the behaviour or habit determines the selection of the design approaches. For example, when the user still maintains a sense of awareness and consideration of their actions, his/her behaviour is in the declarative stage (Anderson, 1982) that is also the early stage of habit formation. The intention is the main factor of behaviour
changing. Eco-information and Eco-feedback can be used to guide the user's actions in this stage. When user behaviour exhibits the habitual and routine nature as discussed in section 2.6.3.5, or when the eco-mode (Eco-choice) and alarm (Eco-feedback) have less effects on the user behaviour as in the fridge use study (section 7.4.2.2), Eco-spur and Eco-steer could be employed to influence and maintain the change. To change habitual routines in the procedural stage (Anderson, 1982) or to prevent people from making errors, more coactive solutions could be used.

The five-step strategy is an approach for steering the sustainable behaviour project from start to finish. It is also possible to apply this strategy in stages, incorporating the Design for Sustainable Behaviour inputs into a design project. The general understanding of the Design Behaviour Intervention Model (sections 4.2 and 4.3) is a requirement for a Design for Sustainable Behaviour project or to make various entry points to the other design task. The subsequent considerations will contribute to a successful behaviour intervention:

- It is important that the environmental impacts are assessed before commencing with the creation of solutions for sustainable behaviour change. For example, the resource consumption for use stage, i.e. the theoretical minimum energy for functioning and intrinsic losses, should be examined by LCA.

- The household cold appliance design case has shown (Figure 6.1) how the “Before \(\rightarrow\) Mid \(\rightarrow\) After Use” approach was used to analyse the interaction between the user and studied product. For designing sustainable use of the device with a complicated interface and interaction process as discussed in section 9.3.2, the flowcharting technique is suggested to be employed in use and intervention analysis (Hossein, 2004). A procedural flow chart allows the designer to break the process down into individual activities or stages, and show the task or multiple tasks available to the user and the logical relationships between the decisions and actions. Displaying the interaction process in shorthand form promotes better understating of the operation processes. This may help designers to seek the opportunity to insert design interventions into the consumer learning or decision making process.

- In terms of techniques for dealing with the qualitative data, motion detection software or systems could be used to circumvent the large amount of fragmented or irrelevant data. An overall map with the themes drawn from the user study could be built to address the problems.
- “5W and 1H” questions frameworks (section 8.3.2) are helpful to translate the segmented facts into the design briefs that the designers understand.

- During the conceptualisation stage, seven behaviour intervention approaches at varying levels of intervention and three design categories give the inspiration and space for innovation by focusing on creating radical change in user behaviour.

- To test the acceptance and effectiveness of the devices, the design outcomes (or the prototype of the product/service/system) must be tested with the users. Focus groups could be run to gain initial feedback from users by presenting the use scenario with 2D and 3D images or a 3D demo. Testing the prototype product/service/system in the real world use conditions would lead to a more in-depth research result.
10 CONCLUSIONS AND FUTURE WORK

This chapter sums up the research project and findings. It shows that the research aim and objectives have been met and reflects upon the limitations of this research and the contribution to knowledge made by this study. Suggestions for further work are outlined.

10.1 Meeting the Aim and Objectives

The initial aim of the research was to investigate how designers can influence user behaviour strategically through design interventions to reduce the environmental impact of household appliances during use. As illustrated in Table 10.1, this aim was realised through carrying out the research activities to meet the objectives set out in Chapter 1.

Table 10-1: Meeting the research objectives

<table>
<thead>
<tr>
<th>Objective</th>
<th>Chapter(s)</th>
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<tbody>
<tr>
<td>1. To critically review substantial literatures and the secondary sources</td>
<td>Chapter 2</td>
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<td>in relation to:</td>
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<td>- the driving forces of consumption and household energy consumption;</td>
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<td>- the barriers and enablers to pro-environmental behaviour;</td>
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<td>- the determinants of behavioural change in social-psychological theory;</td>
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<td>- the current methods of moderating user behaviour;</td>
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<td>- the behavioural change determinants for application in a design context.</td>
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<td>2. To investigate the potential design interventions for sustainable</td>
<td>Chapter 4</td>
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<td>behaviour, linking existing theories and behaviour models to sustainable</td>
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<td>product design;</td>
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<tr>
<td>3. To identify the relationship between household appliance consumption</td>
<td>Chapter 5</td>
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<td>and its environmental impact, selecting a household appliance group as</td>
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<td>a case for further exploration;</td>
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<tr>
<td>4. To examine environmental impact resulting from the use of the selected</td>
<td>Chapter 6 and Chapter 7</td>
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<tr>
<td>case (household cold appliance) and the capacity of a designer-conducted</td>
<td></td>
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<td>user study to identify environmental problems of product use;</td>
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<td>5. To redesign the selected case, the fridge, to explore how design</td>
<td>Chapter 8</td>
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<td>behaviour intervention could influence user behaviour to reduce the</td>
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<td>environmental impact of use through:</td>
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<td>- investigating the effects of the more detailed observational methods</td>
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<td>on the design outcomes;</td>
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<td>- exploring the effects of the more detailed behaviour intervention</td>
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<td>approaches on designing behavioural change;</td>
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<tr>
<td>- evaluating the effectiveness and the acceptance of the selected design</td>
<td></td>
</tr>
<tr>
<td>concepts on behavioural change with target users;</td>
<td></td>
</tr>
<tr>
<td>- documenting the design process, techniques adopted and design</td>
<td></td>
</tr>
<tr>
<td>outcomes for the subsequent analysis and generating the design case as</td>
<td></td>
</tr>
<tr>
<td>illustrative examples of how design behaviour interventions could</td>
<td></td>
</tr>
<tr>
<td>reduce the use impacts on environment;</td>
<td></td>
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<tr>
<td>6. To develop guidance to assist designers in implementing Design for</td>
<td>Chapter 9</td>
</tr>
<tr>
<td>Sustainable Behaviour strategically in future design processes.</td>
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</tbody>
</table>
The literature review (Chapter 2) addressed objective 1 by exploring the current knowledge across many different fields, such as social sciences, energy engineering, technology studies and computing technology. Reviewing the literature of consumption behaviour and domestic energy consumption uncovered the driving forces of consumption and the barriers to sustainable energy consumption behaviour. The theories are compiled into behaviour and habit models in order to learn the psychological factors behind household energy consumption. The potential application of the current knowledge of behavioural determinants in a design context was recognised, laying down a firm foundation for further studies.

In fulfilment of objective 2, through introducing social-psychological theories and behaviour models to the sustainable product design domain, the breakthrough points that potentially enable design to change the individual behaviour and habits were identified. In Chapter 4, seven design approaches illustrated with design case studies were described. Accordingly, these interventions are divided into three levels from “building the conversation” to “blocking the behaviour” to ensure the occurrence of behavioural and habitual change in the complicated energy and resource consumption situation. Furthermore, three design categories and the degree of power for decision-making between users and interventions were classified to help designers to take a balanced and ethical approach to limiting the impacts of use. The Design Behaviour Intervention Model, connecting the determinants of behaviour change with design approaches, was developed and taken forward for application and evaluation.

Objective 3 was achieved in Chapter 5. Through the analysis of the consumption meanings and the environmental impact of household appliance use, a case was selected to formulate the specific user focused study and to explore the ways in which household cold appliances could be improved to shape the user behaviour to a more sustainable outcome.

The behaviour studies of the selected case reported in Chapters 6 and 7 fulfilled objective 4. The pilot and main user studies explored the capacity of a designer-conducted user study to identify the “actual” and “assumed” needs, the diversity in use context, the unsustainable and sustainable use patterns and the hidden factors behind the usage. It exemplified methods and processes for extracting design oriented information from the behaviour study in the early phases of energy efficient product
development. The results of these user research activities informed the development of
the practice-based design project in Chapter 8.

Objective 5 was realised by conducting two design activities to reduce the
environmental impact of household fridge use, presented in Chapter 8. One was to
investigate how designers tackle designing for sustainable behaviour by applying
traditional user centred research techniques. The other (Design Study 2) was a more
detailed practice-based design project, conducted by the researcher as the designer. By
comparing the design process of the two design studies, it was apparent that the
specific behaviour study and the Design Behaviour Intervention Model, when applied,
could offer productivity and efficiency in the design solution generating process, with
the aim of reducing the impacts of use. The outcomes from Design Study 2 were
evaluated in a user focus group to investigate the users’ acceptance of these concepts, as
well as the behaviour changing approaches applied. These studies offered the evidence
to support the feasibility of design-led solutions to make a difference to user behaviour.

Chapter 9 presented the guide and principles developed for fulfilling objective 6, to
assist designers in implementing Design for Sustainable Behaviour strategically in
future design projects. Suggestions were made about how designers could employ the
Design Behaviour Intervention Model, and transfer the research and design experience
gained from the case study to other product types to shift behavioural change,
achieving a reduction in the impacts of product use.

10.2 Conclusions from the Thesis

The steady rise in household energy consumption (section 2.3) has resulted in calls for
an interdisciplinary approach to increasing public participation in conservation
behaviour beyond user education campaigns and technological innovations. This
research has worked on both theoretical and practical levels to verify the viability of
changing user behaviour through design to reduce the environmental impact of product
use.

At a theoretical level, this research has addressed the gap in current behavioural change
measures through distinguishing and linking indirect and direct energy use,
consumption behaviours as well as respectively relevant existing theories and research
(section 2.8.2). The need for a better grasp of the household energy consumption levels
where both users and designers can make significant contributions to sustainable
consumption was highlighted. It was identified that, unlike the other stages in the user goods life cycle, energy consumption during use was an undeveloped area in sustainable design and stood at the crossroads between the field of sustainable design and social psychological studies (section 2.8.1).

The Design Behaviour Intervention Model (Chapter 4) was proposed to give a snapshot of the possible drivers and the moderators of individual behaviour, directing designers towards applicable behaviour intervention approaches to tackle the problems more effectively and efficiently. “Intention”, “habit” and “control”, the three psychological variables which appeared to be most strongly related to design-led interventions, were extracted to establish the behaviour context for the Design for Sustainable Behaviour project. Seven behaviour intervention approaches for guiding design practice were defined with existing product and conceptual case studies. The contribution of the model was the support of understanding and shaping the consumption practice in an analytic and reflective way, which was tested by carrying out a product specific case study. It encouraged the designers to take the moral and ethical issues into consideration at the beginning of the design project and to create design ideas from three categories: single product solutions, system and service solutions, to obtain more sustainable benefits.

On the practical level, the findings from the case study of household cold appliance use (Chapter 6 and 7) emphasised that understanding user behaviour could be the preliminary step for seeking solutions to minimising environmental impact of household consumption through improving product design. The pilot studies (Chapter 6) not only uncovered the different ways of using the product and its unnecessary energy and food consumption, but also identified the gap between environmental awareness and real action, and the reasons underpinning this gap. Firstly, the results showed a lack of user awareness of the link between personal behaviour and the direct impact on the environment and energy use. Secondly, the routine practice and habitual activities ingrained in the use patterns of energy-using products were performed with little deliberation. The findings of the main use study (Chapter 7) have provided an insight into the type of information required by designers to deal with the Design for Sustainable Behaviour challenge and the appropriate formats for conveying this information. It uncovered the way in which the product is used and its unnecessary energy use, interrelated factors affecting the usage and “triggers” for sustainable behaviours. The critical role product design played in daily routines was also evident. By understanding the limitations with current designs and the effects they have on user behaviour, a real potential was identified to enable design to create “better” user
behaviour to reduce environmental impact. It was concluded that to successfully integrate energy conscious concerns into daily routine and to make this process repeatable, appropriate products must be developed.

In terms of the research techniques adopted for gaining insights into users, evidence has been drawn upon to support the use of observational research techniques to capture the actual habitual behaviour in its context. Combining questionnaires, in-depth interviews and everyday observations in one study revealed the difference between people’s thoughts and their actual actions. Concealing the research objectives from the participants at the beginning of the study through a “cover story” (please refer to section 6.2.2.1), minimised the unnatural factors affecting behavioural responses generally. Running consecutive research activities allowed participants to elaborate on different aspects of their behaviour and discuss the reasons for the particular behaviour and its environmental impact. The qualitative and flexible design of this user study allowed the researcher to validate and adjust the process according to the individual cases. This is not just a good example of dealing with a habitual behaviour study, but they have been actively seeking ways of turning potential issues into practical design opportunities.

The contributions of the in-depth use study and the Design Behaviour Intervention Model for Design for Sustainable Behaviour were evident from the comparison of the two design activities in Chapter 8. A series of innovative design concepts was created in Design Study 2, with the aim of making a radical immediate and lasting change in the use pattern of the household fridge. It demonstrated how the wealth of rich data obtained from the behaviour study has been translated into design concepts. The concrete data on the behaviour in situ and in-depth elaboration on reasons behind the daily use routes resulted in numerous novel design concepts. The Design Behaviour Intervention Model set up the vision and strategy for Design for Sustainable Behaviour prior to designing. It gave the designer the ability to classify the behaviour type and construct the working space more actively, and to identify the design directions and bring up corresponding countermeasures more effectively. More importantly, it enabled the designer to have an appropriate estimation of the user acceptance and effectiveness of the design concepts in the concept development process.

The critical points of acceptability of the behaviour changing concepts for sustainable use of household fridges (section 8.5) were disclosed by testing the four combined design concepts selected from varying levels of intervention and different design
categories with the target users. Subsequently, four principles (section 9.4) of designing general behaviour interventions, to obtain a good trade-off between acceptability and effectiveness and between influencing and coercing, were identified as: needs fulfilment, balanced exchange, tailored segmentation and reasonable force.

Finally, a Guide (section 9.5) was synthesised from primary and secondary data to help researchers and designers undertaking a Design for Sustainable Behaviour project. It indicated that general understanding of the Design Behaviour Intervention Model would be required prior to designing to make various entry points in the concept generation process. The in-depth use/interaction study and the user testing could stimulate behaviour changing design innovations by breaking down barriers and prejudices, contributing to a successful behaviour intervention.

10.3 Limitations of this Research

This section reflects on the limitations of the research data, methodology and findings which shed light on the further work recommended in section 10.5.

Recognising the benefit of introducing the social-psychological theory into the design area, it is also possible to identify how the quality and applicability of this “first attempt” to develop the design intervention model could be improved. Providing designers with a useful tool for Design for Sustainable Behaviour, ideally, it should be developed further and re-tested to work towards a more complete and practical model for the design industry.

The limited time available for the research makes it impossible to study the impacts of the usage patterns of every household appliance group identified in Chapter 5. One group of household appliances, the cold appliance, was selected as the case study and the household fridge was redesigned to test the emergent approaches. It would have been more comprehensive to pursue a wider range of product types and explore the use impacts in both social and environmental dimensions.

The design outcomes generated were concerned with the possible effects of using design interventions in association with conceptual design rather than technological feasibility. Because of the time constraints for the thesis and the initial aim of the research, full consideration was not given to the environmental impact enacted by the manufacturing and the use of materials. Some of the behaviour changing concepts
would increase the use of materials and the energy for functioning. However, these
developed behaviour changing concepts were seen as practical narratives to spark the
debate and effective vehicles for testing user preferences and acceptance of design-led
solutions and the approaches applied. To solve the environmental problems of the
artefacts’ production and consumption, “behaviour changing” ideas must be prototyped
and tested with users in entirety in the real context.

It was recognised that the absence of an industrial collaborator in the design process
means deficiencies of expertise in prototyping or manufacturing and access to the
customer base. This was considered to be acceptable for the conceptual design
outcomes within the scope of this research project. To strengthen the practical
significance of this design work, more collaborators from industry should be involved
in the design process to remedy the deficiencies.

The research project focussed on collecting the qualitative data of usage patterns rather
than quantifying the behavioural impact of the product during use. Further quantitative
research on measuring the use impact of a wider range of product categories would be
useful to clarify the seriousness of the behavioural issue. It could work as
supplementary information for industrial designers and engineering designers to
improve the overall efficiency performance of devices.

10.4 Contribution to Knowledge

Design for Sustainable Behaviour has only recently become a specific subject in
academic research. The previous (Rodriguez, 2004; Rodriguez and Boks, 2005; Lilley,
2007) and ongoing design research projects (Elias et al., 2008b; 2008c; 2008a;
Pettersen and Boks, 2008; Lockton et al., 2009; Pettersen, 2009) have commonly been
investigating the design capability for sustainable behaviour, facilitating discussion
within the design community to inform theoretical debate about this growing area.

Most of this doctoral research project has focussed on not only the theoretical and
practical dimensions for designers to tackle the “behaviour change” challenge but also
the responses from the users regarding the effectiveness and acceptability of the design
concepts. This involved the establishment of the conceptual model for Design for
Sustainable Behaviour based on a comprehensive literature review from diverse
disciplinary fields, the investigation of the feasibility of applying the Design Behaviour
Intervention Model in a product specific case study and the evaluation of the
effectiveness and the acceptance of its implementation in new household appliance
design development with users. This research is novel as it aimed to involve the user
perspective in the generation process of both of the theory and design concepts.

The research led to a review of the literature in the fields of social sciences, energy
engineering and technology studies and sustainable design. These areas were
traditionally segmented fields, but the four elements combined reinforced the
foundation for this study. The research has therefore contributed to current knowledge
by bringing social-psychological theory and sustainable product design together to
develop a theoretical conceptual model for Design for Sustainable Behaviour. The
Design Behaviour Intervention Model would assist designers at a practical level to
understand and shift user behaviour in a systematic, projective and reflective way.

Previous research has often not been based on an empirical inquiry into Design for
 Sustainable Behaviour embedding the applied field within a concept development
 process. The developed methodology or strategies have been tested with designers,
researchers or design teams. These investigations have only included the design phase
and have not consider the user impacts on the behaviour changing concept designs.
This piece of research is unique because of the practice elements of the theory and
design concept development process. The researcher as practitioner undertook a design
project and adopted the Design Behaviour Intervention Model in the practical design
activity. The practice helped the researcher as designer to frame the complex situation
in identifying and solving some of the unforeseen problems that a design may have. It
also allowed the researcher to elaborate this theory based on the practical design
experience and the feedback from the users. The practice-based design activity verified
that a balanced behaviour intervention could be obtained between influencing and
coercing by adopting the middle ground of the behaviour intervention approaches.

The design processes and the outcomes of the practice-based design activity served as
the illustrative examples for applying these insights to inform design processes. These
theoretical and practical experiences have been integrated into a Guide, addressing
opportunities or difficulties which may arise in the Design for Sustainable Behaviour
project. The Design Behaviour Intervention Model bridged the gap in the current
knowledge, providing a framework on which future design projects can be based.
10.5 Recommendations for Further Work

In many respects, the research should be seen as a starting point for future investigation and research on Design for Sustainable Behaviour. The following sections propose some recommendations for further work, which have emerged out of this research study.

10.5.1 Prototyping the Design Outcomes

The most obvious area for future development is to prototype the “behaviour changing” concepts and to test the prototype with users in a real use environment. The outcomes of the practice-based design activity could be detailed and prototyped with the industrial collaborators. It would greatly contribute to this field of enquiry by offering tangible results of the effectiveness and acceptability of the design interventions. The actual behavioural energy savings would be measured from the interaction between users and improved product/service/system.

10.5.2 Designing for Reducing the Impact of Food Consumption

The household cold appliance use study, which focussed on energy reduction, also highlighted a number of insights into food waste, such as the effect of differing household size on food use and storage and the level of food preparation organisation at different meals. Some barriers to users maximising the length of time food stays fresh in the fridge were identified, such as the invisible nature of “cold”, and unawareness of the link between temperature and freshness. In response to these findings, future research projects would be to develop design interventions to minimise the environmental impact of food products post-retailing within a systems context, which aim to fulfil customer needs whilst attaining greater eco-efficiencies.

10.5.3 Investigating Design for Sustainable Behaviour in Other Appliance Groups

The development of the model for Design Behaviour Intervention and the guide for Design for Sustainable Behaviour was based on one design case. To consolidate and expand the achievements, further work could take the findings from this research and apply them to a wider range of the product groups. This would have enabled
comparisons to be made between product types with different user usage patterns, to validate and strengthen the theory developed.

10.5.4 Quantifying the Environmental Impact of Product Use
As shown in sections 5.1 and 5.2, little research has been carried out to quantify the environmental impact of the product during use. An area for development could include the collection of measurable data on behavioural impacts of the usage pattern of each product type. This would be with regard to direct energy consumption and quantitative assessment of variables of consumption meanings of the product relating to indirect energy consumption for example (sections 5.1 and 5.2). It would be interesting to give a full assessment of behavioural impacts of each product category during use. In conjunction with this, a more complete “profile” of behavioural potential, containing both qualitative and quantitative data, could be built up to support and to encourage design inspirations to improve the efficiency of product use.

10.5.5 Opportunity for Creativity and Innovation
It appears that Design for Sustainable Behaviour provides the opportunity for design innovation which has become the enabler for drawing out industrial interests in implementing sustainable design in practice. In the practice-based design project, 25 cooling solutions (Chapter 8) were inspired by conducting the in-depth use study (Chapter 6 and 7) and adopting the Design Behaviour Intervention Model (Chapter 4) in the design processes. This demonstrated the capability of Design for Sustainable Behaviour as a starting point in new product research and development. Additional, the further energy savings from the users’ interaction with the product, system and service were the “selling point” for users. This was also favoured by potential users thereby possibly increasing the market share. Further investigation could be undertaken into developing the methodology or strategy to integrate behavioural considerations into design processes, to increase the designers’ ability for creative thinking and to stimulate their passion for creation. This would promote the manufacturers’ and various stakeholders’ participation in Design for Sustainable Behaviour.
REFERENCES


DEFRA. (2007a) 2005 Experimental Carbon Dioxide Emission Statistics at Local Authority and Government Office Region Level DEFRA, UK.


Environmental Change Unit (1997) 2MtC - DECADE: Domestic Equipment and Carbon Dioxide Emissions, Oxford: Oxford University.


Sustainable Consumption Roundtable. (2006) I will if you will: Towards sustainable consumption, The National Consumer Council (NCC) and The Sustainable Development Commission (SDC), UK.


Appendix 1: Understanding consumer behaviour through social theories of consumption
Initially, the model emphasises the function of consumption in social discrimination. It supposes that there is a fixed, legitimated and widely-known hierarchy of possessions and practices which indicates a household’s position on a ladder of prestige (Shove and Warde, 1998). Consumption is the most efficient way to demonstrate the social status and prestige (Sanne, 2002) and a form of communication with the social class which people belong to (Campbell, 1994). The process of consumption is that the lower classes seek to imitate the practices of their superiors, implying that there will be no cessation of demand for particular goods until the lower class has the same possessions as the higher. The higher class will constantly be seeking new items to mark its social status and then perpetual demand for new products appears inevitable (Shove and Warde, 1997; 1998).

Nowadays, the stratified society is not a strict ladder society (Sanne, 2002). Culture is pluralism, which is too individualised and differentiated to classify. There is evidence of “trickle-up” as well as down (Shove and Warde, 1998). The distinction between “high” and “popular” culture is difficult to make. This contributes to significance for the volume of consumption. The omnivore will require not just recordings of opera but of jazz and reggae, not simply a kitchen cupboard containing native aromatics but the spices required for all the cuisines of the world (Shove and Warde, 1998). In this value, items are often thrown away not because they are worn out (Cooper, 2005), but because they are not pleasing, acceptable, compatible or storable, which is not a cycle of replacing (Shove and Warde, 1998).

Consumption as Identify
Consumers use goods to create and sustain a “self-identity” and people define themselves through the goods and practices they possess and display (Shove and Warde, 1997; 1998). People are defined not by what they do but by what they consume (Jackson, 2005), their lifestyle and visible attachment to a group. This model relates an individual to his/her own self-understanding; consumption is not a signal to the world but to own mind but the link between consumption of material goods and the construction and maintenance of personal identity. Personal identity, one of the most important elements in modern understandings of consumer behaviour (Jackson, 2005), means that there is a potential for inducing these kinds of behavioural change through hidden messages to do with colours, symbols, images and so on. Products are created to appeal to consumers’ psychological demand by projecting or embodying lifestyle they desire to be identified (Gordon, 2002).

Consumption as Meaning
People interact with things on the basis of the symbolic roles and displaced meanings those things have for them (Jackson, 2005). There are much more psychological sakes, such as communicating personal, social and cultural meaning, in the possession of material artefacts than its functional benefits (Jackson, 2005). The consumer goods carried and communicated cultural meanings are considered as “vessels for the preservation of the individuals’ hopes and ideals” (Koskijoki, 1997, p. 138). Therefore, to prolong product lifetime, designers should not only create useful things, but in which meaning is firmly anchored in the materiality (Verbeek and Kockelkoren, 1997), evoking the consumers’ emotional feeling and inspiring them to “define the objects as unexchangeable, unique and even in a sense ‘sacred’” (Koskijoki, 1997, p. 136). Relatively, people will care, appreciate and cherish the material possessions which will not be easily discarded and replaced” (Verbeek and Kockelkoren, 1997, p. 104).

Table 2: Ordinary Consumption

<table>
<thead>
<tr>
<th>Ordinary consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumption takes place inconspicuously as a part of the ordinary everyday decision-making. They are repetitive actions with little conscious thought following a specific route to work, e.g. buying a given brand of coffee, turning the light on, turning the television off and disposing of waste paper, paying for electricity (Jackson, 2005). It is not oriented particularly towards individual display but is about convenience, habit, practice, and individual responses to social norms and institutional contexts (Shove and Warde, 1998; Shove, 2003; Jackson, 2005). It has the following features: 1) Little display or status oriented (Jackson, 2005); 2) Invisible day-to-day experience (Shove and Warde, 1998; Jackson, 2005); 3) Low-cognitive effort (Jackson, 2005); 4) Locked-in. Far from being able to exercise free choice about what to consume and what not to consume, people often find themselves ‘locked in’ to consumption patterns which are unsustainable, either by social norms which lie beyond individual control, or else by the constraints of the institutional context within which individual choice is negotiated (Sanne, 2002; Jackson, 2005). This offers an explanation why although a high proportion of consumers express a strong preference for eco-friendly goods and services, there is still a considerable ‘value-action gap’-between people’s attitudes, which are often pro-environmental, and their everyday behaviours (Sustainable Consumption Roundtable, 2006).</td>
</tr>
</tbody>
</table>
Appendix 2

Appendix 2: Differences in the possession rates of household goods in different user group

<table>
<thead>
<tr>
<th>Household type</th>
<th>Age</th>
<th>Income</th>
<th>Education</th>
<th>Residential location</th>
</tr>
</thead>
<tbody>
<tr>
<td>More like to say they do about environment</td>
<td>Older</td>
<td></td>
<td>With degree</td>
<td></td>
</tr>
<tr>
<td>Regular cut down energy</td>
<td>45-64 do most</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conserve water</td>
<td>&gt;65 do most</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Everything</td>
<td>Families - possess more</td>
<td>Higher - possess more</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central heating system</td>
<td>Necessary to less than 50% household</td>
<td>Families with children -more necessary than without children</td>
<td>34-45-more necessary</td>
<td>More important to low income</td>
</tr>
<tr>
<td></td>
<td>Younger-less willing to turn down thermostat +insulate home</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bath +shower</td>
<td>smaller use more</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Largest evaluate more harmful to environmental than smaller</td>
<td>Youngest use most; oldest use most</td>
<td></td>
<td>Better-educated use more</td>
</tr>
<tr>
<td></td>
<td>larger-more willing to bath/shower less</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wash machine</td>
<td>Necessary to less than 50% household</td>
<td>Families with children -more necessary than without children</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dishwasher</td>
<td>Largest evaluate more harmful to environmental than smaller</td>
<td></td>
<td>Higher – use more</td>
<td></td>
</tr>
<tr>
<td>Clothes dryer</td>
<td>Necessary to less than 50% household</td>
<td>Families with children -more necessary than without children</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooker</td>
<td>Larger evaluate more harmful to environmental than smaller</td>
<td></td>
<td>Rural-more necessary</td>
<td></td>
</tr>
<tr>
<td>Microwave</td>
<td>Families with children -more necessary than without children</td>
<td>34-45-more necessary</td>
<td>Higher – use more</td>
<td>Rural-more necessary</td>
</tr>
<tr>
<td></td>
<td>Description</td>
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<td>-----------------------------------------------------------------------------</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Oven</td>
<td>Families with children - more necessary than without children</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Larger use more</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TV</td>
<td>Larger use more</td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td>Higher – possess more</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Better-educated use less</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rural-more necessary</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>More important to family without children</td>
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<tr>
<td></td>
<td>Higher – use less/day even possess</td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td>More important to low income</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Video recorder</td>
<td>Larger use more</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Oldest - least possess</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rural-more necessary</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>34-45-more necessary</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Oldest - least possess</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Computer</td>
<td>Larger use more</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Higher – use more</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Higher evaluate more harmful to environmental than lower</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rural-more necessary</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Larger evaluate more harmful to environmental than smaller</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personal computer</td>
<td>Oldest - least possess</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Better-educated more often posses + more necessary+</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>use more</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

**Age:** 1-19, 20-39, 40-64, 65+

**Level of education:** Low=primary and secondary school, mid=lower general, intermediate vocational or technical, high=higher general, high vocational, university
Appendix 3

Appendix 3: Estimated behavioural potential and impact in seven household appliance sectors
Table 1: Behavioural Potential in Space Heating Sector (Environmental Change Institute, 2005; Lockwood and Murray, 2005; Energy Saving Trust, 2006a; Utley and Shorrock, 2006; Druckman and Jackson, 2008)

<table>
<thead>
<tr>
<th>Behavioural Potential</th>
<th>Energy Intensive Behaviour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low temperature setting</td>
<td>Average household temperatures have been increased from around 12 to 18°C between 1970 and 2002; 22% of people in the UK turn up the thermostat instead of putting on extra clothing.</td>
</tr>
<tr>
<td>Eliminate unintended on-time</td>
<td>Nowadays, all rooms remain at one temperature rather than enforce differentials between living, sleeping and unoccupied rooms; 28% of UK households leave the heating on while the house is unoccupied; 83% in 1996 had some form of programmed heating, yet many of them do not fully understand how to operate controls efficiently with many preferring to use them as on-off switches.</td>
</tr>
<tr>
<td>Link the fuel cost to heat usage on the bill</td>
<td>17% of households in London spend more than 10% of their income on fuel; It is essential to provide the information to households to link the cost of fuel and the heat usage, since up to half UK households do not even look at their energy bills, especially those who pay by direct debit.</td>
</tr>
</tbody>
</table>

Table 2: Behavioural Potential in Lighting Sector (Environmental Change Unit, 1997; UNEP, 2002; Rodriguez and Boks, 2005; Energy Saving Trust, 2006a)

<table>
<thead>
<tr>
<th>Behavioural Potential</th>
<th>Energy Intensive Behaviour</th>
<th>Projected savings in 2010 (TWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eliminate unintended on-time</td>
<td>70% forget to turn lights off in unoccupied rooms</td>
<td>2.0</td>
</tr>
</tbody>
</table>

Table 3: Behavioural Potential in Cold Appliance Sector (Environmental Change Unit, 1997; ELIMA European Research Project, 2005; Elias et al., 2008a)

<table>
<thead>
<tr>
<th>Behavioural Potential</th>
<th>Energy Intensive Behaviour</th>
<th>Projected savings in 2010(TWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular defrosting clean condenser coil</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>Opening times for fridge door</td>
<td>8-19 seconds</td>
<td>2 weeks video recode for a refrigerator</td>
</tr>
<tr>
<td>Time (seconds)</td>
<td>Frequency</td>
<td></td>
</tr>
<tr>
<td>Leaving the doors open for searching</td>
<td>229</td>
<td>16</td>
</tr>
<tr>
<td>putting hot food in the appliance</td>
<td>2 weeks video recode for a refrigerator</td>
<td></td>
</tr>
<tr>
<td>Open door while taking out items</td>
<td>464</td>
<td>66</td>
</tr>
<tr>
<td>Open door while loading foods</td>
<td>289</td>
<td>65</td>
</tr>
<tr>
<td>Leaving the doors open during quick task</td>
<td>169</td>
<td>7</td>
</tr>
</tbody>
</table>
Table 4: Behavioural Potential in Wet Appliance Sector (Environmental Change Unit, 1997; McCalley, 2004; Energy Saving Trust, 2006a)

<table>
<thead>
<tr>
<th>Appliance</th>
<th>Behavioural potential</th>
<th>Energy Intensive Behaviour</th>
<th>Projected savings in 2010 (TWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet –</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>More efficient loading</td>
<td>Switch off standby</td>
<td>71% Leave appliances on standby</td>
<td>2.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Users’ understanding of “full” load the users is quite below the manufacturer’s stated maximum and they tend to underload their washing machines.</td>
<td></td>
</tr>
<tr>
<td>Washing machine/</td>
<td>Low temperature cycles</td>
<td>44% English wash clothes at 60 degrees; 15% Wash clothes at 90 degrees.</td>
<td></td>
</tr>
<tr>
<td>Dishwasher</td>
<td>Avoid unnecessary use</td>
<td>32% of users use the tumble dryer when the washing line could be used.</td>
<td></td>
</tr>
<tr>
<td>Tumble dryer</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5: Behavioural Potential in Cooking Appliance Sector (Energy Saving Trust, 2006a)

<table>
<thead>
<tr>
<th>Appliance</th>
<th>Behavioural potential</th>
<th>Energy Intensive Behaviour</th>
<th>Projected savings in 2010 (TWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric hob</td>
<td>put lids on saucepans</td>
<td></td>
<td>2.6</td>
</tr>
<tr>
<td></td>
<td>use pressure cookers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electric oven</td>
<td>use microwave instead</td>
<td>Microwaves save 80% of energy of using traditional ovens and around 13% of electric ovens</td>
<td></td>
</tr>
<tr>
<td></td>
<td>eliminate unnecessary pre-heating</td>
<td>5% of all ovens on-time is unnecessary pre-heating</td>
<td></td>
</tr>
<tr>
<td></td>
<td>turn off 10 min before the end of cooking</td>
<td>The food finishes cooking from the heat remaining in the oven</td>
<td></td>
</tr>
<tr>
<td>Microwave</td>
<td>switch off standby</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>eliminate reboiling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kettle</td>
<td>minimum water</td>
<td>67% of the user boil more water than needed; The kettle only needs to be half full on 50% of the occasions</td>
<td></td>
</tr>
</tbody>
</table>

Table 6: Behavioural Potential in Consumer Electronics Sector (Environmental Change Unit, 1997; Rodriguez and Boks, 2005; Energy Saving Trust, 2006b)

<table>
<thead>
<tr>
<th>Appliance</th>
<th>Behavioural potential</th>
<th>Energy Intensive Behaviour</th>
<th>Projected savings in 2010 (TWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumer electronics -</td>
<td>switch off standby</td>
<td>50% of the appliances with standby function are never turned off</td>
<td>1.1</td>
</tr>
<tr>
<td>Remote control (consuming 18% of energy in this sector)</td>
<td>switch off remote control</td>
<td>The remote controls are also becoming the barriers for 40% of users to switch off the devices, although the remote control is created to remove the need of a manual on/off switch.</td>
<td></td>
</tr>
</tbody>
</table>
80% of users have a combination of the following appliance turned on at the same time, at least one hour a day: computer and TV; computer, stereo and TV, stereo and TV; 90% have the TV on at some point only to hear the sound ranged from 5min to over an hour a day; 40% want to hear the news while using computer.

Table 7: Behavioural Potential in Consumer Electronics Sector (Energy Saving Trust, 2006b)

<table>
<thead>
<tr>
<th>Behavioural Potential</th>
<th>Energy Intensive Behaviour</th>
</tr>
</thead>
<tbody>
<tr>
<td>switch off standby</td>
<td>Although the stand-by power consumption of a single mobile phone charger only averages 1 watt, the combined stand-by usage of approximately 25 million (a conservative estimated of approximately one active phone per household) of these items adds up very quickly to 25 megawatts (MW). This adds up to 219 GWh consumed per annum, which is enough to power the electricity needs of 66,000 homes for one year.</td>
</tr>
<tr>
<td>unplug recharger</td>
<td>65% of the users leave electrical charger plugged in; The exploration of the rechargeable products (e.g. mobile phone, MP3 player and digital camera) reduces impacts of disposable batteries on the environment, however, the method of recharging result in constant energy demand if the recharging unit is left plugged in and switched on at the socket.</td>
</tr>
</tbody>
</table>
Appendix 4: Current energy efficient policies and activities in the cold appliance sector
Current Energy Efficient Policies and Activities in the Cold Appliance Sector (Council of the European Union, 2005; Environmental Change Institute, 2005; Lockwood and Murray, 2005; Energy Saving Trust, 2006b; Market Transformation Programme, 2007b)

<table>
<thead>
<tr>
<th>Policies / Activities</th>
<th>Content</th>
<th>In force/target date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy-using products directive (EuP)</td>
<td>EuP establishes parameters for designing products that use energy, though not all energy-using products will have obligations under the framework. Manufacturers will have to look at the whole life cycle of their product including the use stage.</td>
<td>11/08/2007</td>
</tr>
<tr>
<td>EU energy label</td>
<td>Introduces A+ (EEI=42-30) and A++ (EEI&lt;30) classes</td>
<td>01/01/2005</td>
</tr>
<tr>
<td>Minimum standard</td>
<td>C (E for chest freezers)</td>
<td>03/09/99</td>
</tr>
<tr>
<td>Industry agreement</td>
<td>Fleet average of EEI of 52</td>
<td>2006</td>
</tr>
<tr>
<td>Energy+</td>
<td>European scheme aims to encourage the production of the most energy efficient cold appliances and demonstrate the potential for improved levels of performance. It is run as a competition and winning products could promote their Energy+ status. It helps to demonstrate possibilities for the review of the Energy Label classes.</td>
<td>The min requirement for Energy+: EEI = 42 (using the calculation in directive 94/2/EC).</td>
</tr>
<tr>
<td>Energy Saving Recommended (ESR)</td>
<td>An Energy Saving Trust scheme highlights products that demonstrate best practice in terms of energy efficiency, allowing users to identify products more easily. To manufacturers, products meeting set criteria are able to display the ESR logo at point of sale and in promotional material. The scheme aims to review the criteria as the efficiency of appliances improves to maintain ‘best practice’ recognition for recommended appliances.</td>
<td>Current criteria for cold appliances: A+ (from 1st July 2004).</td>
</tr>
<tr>
<td>Energy Efficiency Commitment (EEC)</td>
<td>EEC encourages the purchasing of more efficient cold appliances through retailer, manufacturer and energy supplier agreement and induce greater energy efficiency in the domestic sector - via referrals from local authorities, street-by-street door knocking, social enterprises, or direct mailing and information on the back of bills</td>
<td></td>
</tr>
</tbody>
</table>

EEI= Energy Efficiency Index
Appendix 5

Appendix 5: Technological improvements of selected cold appliance brands
Table 1: A Brand Map of Selected Cold Appliance Brands and Their Parent Company (Mintel, 2007c).

<table>
<thead>
<tr>
<th>Parent company</th>
<th>Brand names</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arçelik</td>
<td>Beko</td>
</tr>
<tr>
<td>Electrolux Group</td>
<td>AEG, Electrolux, Frigidaire, Zanussi</td>
</tr>
<tr>
<td>Indesit Company</td>
<td>Indesit, Hotpoint</td>
</tr>
<tr>
<td>BSH Home Appliances</td>
<td>Bosch, Siemens, Viva</td>
</tr>
</tbody>
</table>

Table 2: Technological Improvements of Selected Cold Appliance Brands

- CFC/HCFC-free Refrigerants: many products that have removed CFCs have replaced them with hydrochlorofluorocarbons (HCFCs or HFCs), a Class II chemical which considered to be 5% ozone depleting and are also a danger to the Earth’s vital ozone layer. HCFCs were prohibited for use in certain applications in household prohibited from January 2001 (Sustainable Development Unit, 2005). Norfrost, being a specialist in the manufacture of chest freezers, claims to be the first to mass-produce CFC-free and later HCFC-free chest units in the world (Mintel, 2007c). And all Electrolux fridges and freezers, for example, have used only natural gases, such as R600a - the only ones that have zero impact on ozone layer depletion and the greenhouse effect, since 1993, many years before it became compulsory (Electrolux, 2005);

- Vacuum insulated panels (VIPs): delivering at least twice the level of insulated of current methods and reducing around fifth of the average cold appliance consumption (Environmental Change Institute, 2005; Mintel, 2007c). The Panasonic NR-F462U claims a 67% energy reduction compared to a 1993 model (Market Transformation Programme, 2007b). In 1994, the Blomberg CT1300A from the Arçelik, a Turkish company that won the 2004 European Energy+ award for a two-door domestic refrigerator. This achieved an EEI of 19.81 using only around 27% of the energy used by an average European cold appliance of comparable size and type. “Exception of Beko (Arçelik company), the market leader in the UK market (Mintel, 2007c), none of other major British brands or their parent companies is known to have invested in VIP technology for demonstration or production models” (ibid). The cost and some technical problems (weaknesses in insulation at edges and seals) of VIPs may be the current barriers for manufacturers to use them widely in production models (ibid);

- Energy efficient compressor: decreasing compressor size (larger one using more energy); employing variable speed compressors (twice the price of a conventional one); using oscillating compressors (lack of incentive from compressor manufacturers’ research and development) (Cold II 2000 in: Market Transformation Programme, 2007b);

- Energy efficient fan: automatic fan cut-out avoids wasting energy when the door is opening. Large capacity evaporator (Eartheasy, 2007);

- More precise temperature sensor (Eartheasy, 2007);

- Thickening of insulated walls: an optimum level to balance wall thickness and usable internal walls;

- Safe and responsible disposal, which takes account of the implications of the Waste, Electrical and Electronic Equipment (WEEE) Directive and the restriction of hazardous waste (ROHS)
legislation. To this end, Samsung has built a Hazardous Substances Management System (e-HMS) to promptly and systematically manage hazardous substances in whole parts of the product that comes from whole cooperating companies at the raw material selection stage (Samsung, 2006);

Marking for components recycle: Electrolux and Samsung, as the examples, have marked most of the components used in fridge and/or freezer to facilitate disposal and recycling at the end of their working lives (Electrolux, 2005; Samsung, 2006);

Reducing material weight while using more recyclable materials (Miele, 2007);

Taking a life cycle assessment (LCA) to identify the environmental impact: Samsung Electronics has applied LCA and DfX(Design for Assembly / Disassembly / Recycle / Service) supporting product development since 1995 (Samsung, 2006);

Antibacterial surfaces for preserving health and hygiene: anti-bacterial protection feature of Bosch and LG, for example, offers silver natural elements within the lining of the fridge section for protection against bacteria, microorganism and algae growth (Bosch, 2006; LG, 2006).
Appendix 6: User guideline from purchase to disposal stages for avoiding behavioural energy waste from manufacturers and related government departments.

**Purchase**
- Choose products that use CFC/HCFC-free gasses and an insulation system with energy label;
- Assess consumption - two prices: An essential assessment that must be made before buying a fridge or freezer is its consumption. Ignoring the purchase price, what will mostly affect the overall cost of the appliance is energy consumption during its life cycle;
- Assess capacity energy can also be wasted if the fridge capacity is not properly assessed: having a large fridge-freezer, even a highly efficient one, always half empty means wasting energy; considering that a medium capacity fridge consumes around 300 kWh per year, whether it is full or empty, and that monthly consumption increases by 10-20 kWh for every 100 litres of further capacity. Because a fridge is always on, even a small difference in consumption between the various models can make a big difference to the annual electricity bill;
- Select types: Chest freezers are usually more efficient than upright freezers that are better insulated and cod air does not spill out when the door is opened;
- The importance of defrosting: Manual defrosts refrigerators are generally more efficient than auto defrost models but only if they are properly maintained.

**Use**
- Proper installation: To position the refrigerator away from a heat source or direct sunlight from a window; To allow air to circulate around the condenser coils, leave a space between the wall or cabinets and the refrigerator or freezer and keep the coils clean; Do not cover fridge and/or freezer with material and it will prevent air flowing around the cabinet side;
- Adjustable thermostats: It is good practice to keep the thermostat on a half-way position: lower temperatures are not necessary to preserve food better, but they increase energy consumption by 10-15%; Check refrigerator setting by placing a thermometer in a jar of water and leaving in refrigerator overnight and in the morning the temperature should read 5 ºC and freezer should be -18 ºC;
- The anti-sweat switch should be on during the summer and off during the winter;
- Minimise door openings time and times;
- Keeping refrigerators at least three quarters full: Do not over stock but full retains cold better than an empty one;
- Never put warm or hot food straight into the fridge or freezer;
- Cover all liquids stopping food picking up taints and uncovered foods release moisture and make the compressor work harder; Replace paper wrappings on food items with aluminum foil or plastic wrap since paper is an insulator;
- Defrosting frozen food in the refrigerator;
- Where to place it: The coldest area is usually the lowest one; Glass is a universal material and is ideal also for cooked food, dishes containing oil or fat, and sauces and leave a small space at the back.

**Maintenance**
- Check the gaskets: Keeping them clean and checking periodically that they are not detached or split contributes considerably to limiting energy consumption;
- Clean the condenser and cabinet walls: The condenser works best when it is dust-free;
- Besides daily cleanliness, the appliance should be cleaned at least once a month;
- Periodic defrosting: every time it exceeds a thickness of 5 mm. The freezer should be defrosted if ice buildup is thicker than 1/4 inch.
Disposal

- An energy efficient fridge freezer uses nearly a third of the energy to do the same job as a 10-year-old appliance – that's a saving of up to £35 a year. Buying an energy efficient fridge freezer to replace your inefficient one could cut carbon dioxide emissions produced indirectly by your home up to 228Kg a year
Appendix 7

Appendix 7: Participant information sheet, informed consent form and kitchen user profile questionnaire
User Study-Understanding the Relationship between User and Kitchen

Participant Information Sheet

Before agreeing to participate in this research study, it is important that you read the following explanation.

Explanation of Procedures

The research study is designed to learn more about what you think of the appliances you use and the life in the kitchen. Participation in the study involves completion of a short demographic data collection sheet, two observations and an interview.

Data collected will include asking for some personal information; age, working status, and food shopping and cooking habits.

The first observation of how you store your food into the kitchen after shopping will be carried out for 10-20 minutes. The second observation of how you prepare your meals in a normal day. A video camera will be set on the appliance to record its use for 24 hours. The camera will be used for recording your motion only around the appliance without recording voice.

The interview will last for approximately one hour and be audiotaped by the researcher then later transcribed. In the interview you have the option of giving any views about the kitchen appliance usability, perceptions and expectations of kitchen appliances and your opinions on a range of products purchase, use and its impacts.

Confidentiality and Freedom to Withdraw

ALL information provided by you will remain strictly confidential and you will not be personally identified. Also you are free to withdraw from this study at any point without needing to provide a reason.
User Study-Understanding the Relationship between User and Kitchen

INFORMED CONSENT FORM
(to be completed after Participant Information Sheet has been read)

The purpose and details of this study have been explained to me. I understand that this study is designed to further scientific knowledge and that all procedures have been approved by the Loughborough University Ethical Advisory Committee.

I have read and understood the information sheet and this consent form.

I have had an opportunity to ask questions about my participation.

I understand that I am under no obligation to take part in the study.

I understand that I have the right to withdraw from this study at any stage for any reason, and that I will not be required to explain my reasons for withdrawing.

I understand that all the information I provide will be treated in strict confidence.

I agree to participate in this study.

Your name

Your signature

Signature of investigator

Date
KITCHEN STUDY

USER PROFILE QUESTIONNAIRE

This questionnaire is a part of research project at Loughborough University, to understand the relationship between the users and the kitchen (household; food; etc.).

Appliance Information (Please tick all boxes that apply)

<table>
<thead>
<tr>
<th>Question</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Which of the following appliances do you use most frequently in your</td>
<td>A ☐ Cooker</td>
</tr>
<tr>
<td>kitchen?</td>
<td>B ☐ Fridge and / or freezer</td>
</tr>
<tr>
<td></td>
<td>C ☐ Dishwasher</td>
</tr>
<tr>
<td></td>
<td>D ☐ Boiler</td>
</tr>
<tr>
<td></td>
<td>E ☐ Microwave</td>
</tr>
<tr>
<td></td>
<td>F ☐ Other (please specify) _________</td>
</tr>
<tr>
<td>2. Which of the following description is proper and accurate for your</td>
<td>A ☐ Very small</td>
</tr>
<tr>
<td>kitchen?</td>
<td>B ☐ Small</td>
</tr>
<tr>
<td></td>
<td>C ☐ Just right</td>
</tr>
<tr>
<td></td>
<td>D ☐ Large</td>
</tr>
<tr>
<td></td>
<td>E ☐ Very large</td>
</tr>
<tr>
<td>3. Which of the following descriptions are proper and accurate for your</td>
<td>A ☐ Busiest room in my house</td>
</tr>
<tr>
<td>kitchen?</td>
<td>B ☐ Heart of my home</td>
</tr>
<tr>
<td></td>
<td>C ☐ I spend as much time as possible</td>
</tr>
<tr>
<td></td>
<td>D ☐ I spend as less time as possible</td>
</tr>
<tr>
<td></td>
<td>E ☐ Other (please specify) _________</td>
</tr>
<tr>
<td>4. Did you buy your kitchen appliances?</td>
<td>A ☐ All of them</td>
</tr>
<tr>
<td></td>
<td>B ☐ Some of them (please specify)</td>
</tr>
<tr>
<td></td>
<td>C ☐ None</td>
</tr>
</tbody>
</table>

Shopping Habits (Please tick all boxes that apply)

<table>
<thead>
<tr>
<th>Question</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. How do you do your main food shopping?</td>
<td>A ☐ Everyday</td>
</tr>
<tr>
<td></td>
<td>B ☐ Twice or three times a week</td>
</tr>
<tr>
<td></td>
<td>C ☐ Once a week</td>
</tr>
<tr>
<td></td>
<td>D ☐ Twice a month</td>
</tr>
<tr>
<td></td>
<td>E ☐ Once a month</td>
</tr>
<tr>
<td></td>
<td>F ☐ Whenever need</td>
</tr>
<tr>
<td></td>
<td>G ☐ Other (please specify) _________</td>
</tr>
<tr>
<td>6. Where do you shop for food most often?</td>
<td>A ☐ Supermarket</td>
</tr>
<tr>
<td></td>
<td>B ☐ Discount store</td>
</tr>
<tr>
<td></td>
<td>C ☐ Market</td>
</tr>
<tr>
<td></td>
<td>D ☐ Through the internet-delivery</td>
</tr>
<tr>
<td></td>
<td>E ☐ Grocery on the way to work / home</td>
</tr>
<tr>
<td></td>
<td>F ☐ Daily-delivery</td>
</tr>
<tr>
<td></td>
<td>G ☐ Other (please specify) _________</td>
</tr>
</tbody>
</table>
Cooking Habits (Please tick all boxes that apply)

7. How do you feel about cooking?
   A ☐ I love to do it and I spend as much time as possible on it
   B ☐ I have to do it
   C ☐ I hate to do it, I spend little time on it
   D ☐ I always have time to do
   E ☐ I have not enough time to do
   F ☐ Other (please specify) __________

8. When cooking a dinner at home, which of these statements, apply to you?
   A ☐ Most ready-meals or chilled prepared meal
   B ☐ Combination of ready meals and fresh ingredients
   C ☐ Mostly fresh ingredients

9. How many meals do you have at home per week?
   Times
   Breakfast 0 1 2-3 4-6 7
   Lunch
   Evening meal

10. Which on is your main meal?
   A ☐ Breakfast
    B ☐ Lunch
    C ☐ Evening meal

User Information (Please tick all boxes that apply)

11. Age __________

12. Occupation ________________

13. Working status
   A ☐ Full - time
   B ☐ Part - time
   C ☐ Not working

14. Household income (Optional)
   A ☐ < 20K
   B ☐ 20K – 40K
   C ☐ > 40K

15. Living status
   A ☐ Multi person non-family household
   B ☐ Single person household
   C ☐ Family/partner/friend without children at home
   D ☐ Family/partner/friend with children
   ➔ If D, how many children do you have? __________
   Please tick the appropriate age group(s) of your child(ren)
   A ☐ 0-2 Number __________
   B ☐ 3-4 Number __________
   C ☐ 5-11 Number __________
   D ☐ 12-18 Number __________
   E ☐ 18+ Number __________

If you would be willing to take part in a future study, please leave your contact information.

Email ____________________________ Address ____________________________
Tel NO. ____________________________
Appendix 8

Appendix 8: Observation (Product-in-Use) task -1
# OBSERVATION (Product in Use) TASK-1

## Appliance information

1. Make and model of the separated fridge / freezer or combined fridge-freezer:

<table>
<thead>
<tr>
<th></th>
<th>Product model</th>
<th>Style</th>
<th>Make</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>fridge-freezer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Separate freezer</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Location of the fridge-freezer:

<table>
<thead>
<tr>
<th></th>
<th>Where</th>
<th>Kitchen</th>
<th>Living Room</th>
<th>Utility Room</th>
<th>Garage</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>P2</td>
<td>fridge-freezer</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Separate freezer</td>
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</tbody>
</table>

<table>
<thead>
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<th>Distance</th>
<th>Top</th>
<th>Left</th>
<th>Right</th>
<th>Back</th>
</tr>
</thead>
<tbody>
<tr>
<td>P3</td>
<td>fridge-freezer</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Separate freezer</td>
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</tbody>
</table>

2a Does it stand close to radiators or in a heated room?

2b Do other household appliances stand next to it?

<p>| | | | | | |</p>
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</thead>
<tbody>
<tr>
<td></td>
<td>Oven</td>
<td>Dishwasher</td>
<td></td>
<td>Washing machine</td>
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</table>

3. Size

<table>
<thead>
<tr>
<th></th>
<th>Overview</th>
<th>shelves</th>
<th>drawers</th>
<th>racks</th>
<th>bins</th>
<th>trays</th>
</tr>
</thead>
<tbody>
<tr>
<td>P4</td>
<td>fridge-freezer</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Separated freezer</td>
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<td></td>
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<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Over-filling?</th>
<th>Air-circulation?</th>
<th>Special context?</th>
</tr>
</thead>
<tbody>
<tr>
<td>P5</td>
<td>fridge-freezer</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Separated freezer</td>
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</tbody>
</table>

4. Interface

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<td>P6</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Temperature</th>
<th>Setting range</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Interface display</th>
</tr>
</thead>
<tbody>
<tr>
<td>P7</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>New features</th>
</tr>
</thead>
<tbody>
<tr>
<td>P8</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Distance of the work counter or tables</th>
</tr>
</thead>
<tbody>
<tr>
<td>P9</td>
<td></td>
</tr>
</tbody>
</table>

5. Others

<table>
<thead>
<tr>
<th></th>
<th>Anything interesting?</th>
<th>Take picture of the filled fridge and freezer</th>
</tr>
</thead>
<tbody>
<tr>
<td>P10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix 9: Pilot study, observation (food storage + preparation) task -2, semi-structured interview
FRIDGE-FREEZER USERS PILOT STUDY
OBSERVATION (Food Storage+Food Preparation) TASK-2
Semi - STRUCTURED INTERVIEW

Food storage
1. What kind of foods did the subject buy? (Video)
   Unrefrigerated; Refrigerated; Frozen
2. How do they put them into the fridge-freezer? (Video)
   Be organised according to products type - open once or less time
   If not - open more time?
3. Where did they put what types of products into the fridge-freezer? (Video)
   Inside the fridge-freezer
   Top                     Shelves?
   Bottom                  Drawers?
   Front                   Door Bins?
   Back                    Bottle racks?
4. Did the subject adjust the temperature setting or use super cool function after putting a lot of things in the fridge-freezer?

Q1 How do you decide what need to put into the fridge-freezer and what need not to?
   a) according to cooking plan
   b) package of the foods
   c) want them to keep fresh for longer
   d) keep good quality of the food (e.g. fruits/bread can keep in the ambient temp)
   e) for safety issues
   f) because of fridge-freezer design (e.g. eggs trays? Fruit drawer?)

Q2 How do they decide where to put what types of products into the fridge-freezer?
   a) because of fridge-freezer design (e.g. eggs trays? Fruit drawer?)
   b) for the temperature differences in the fridge-freezer (e.g. back / bottom is cooler)

Q3 Do you store food for cooling at other places?
   a) at a cool place in the house (like the garage, basement, pantry, etc...)
   b) outside the house (like balcony, terrace, etc...)

Q3a Why do not store foods e.g. bread/ fruits/ eggs at the ambient temperature?
   a) lack of storage space
   b) high indoor temperature

Cooking Habits
5. How did they take things out of the fridge-freezer? (Video)
   What did they take out of the fridge-freezer? (Video)
   How many times did they open the fridge and / or freezer? (Video)

Q4 How many people do you usually cook for?
Q5 Do your kids use fridge? What type of products do they often take out?
Q6 Do you often drink chilled water or drinks?

THANK YOU VERY MUCH FOR YOUR COOPERATION.
Appendix 10: Pilot study, post-intervention questionnaire
FRIDGE-FREEZER USERS PILOT STUDY
Post-INTERVENTION QUESTIONNAIRE

This questionnaire is a part of research project at Loughborough University, to understand the householder's behaviour and attitudes towards fridge-freezer use.

Product Information

1. Please select the style of your fridge and/or freezer and write the mark(s):

   a) Combined top freezer
   b) Combined bottom freezer
   c) Combined side by side
   d) Separate fridge
   e) Separate freezer

2. How long have you had your fridge and/or freezer?

   a) Combined fridge-freezer
   b) Separated fridge
   c) Separated freezer

3. Relation to your main fridge and/or freezer, have you deliberately made it last longer by doing any of the following? (tick the appropriate boxes)

   a) Changed components
   b) New door seals
   c) Cleaned the evaporators and condenser/ fan blades and guard
   d) Others (please specify)

4. How long do you think a fridge and/or freezer should last?

Use Context

5. Use status of your fridge and/or freezer: (tick the appropriate boxes)

   a) Family/Cohabiting use
   b) One person use
   c) Shared fridge-freezer

THANK YOU VERY MUCH FOR YOUR COOPERATION.
11. When using a fridge, freezer or combined fridge-freezer, which of these statements apply to you? (tick the appropriate boxes )

<table>
<thead>
<tr>
<th>Always</th>
<th>Sometimes</th>
<th>Never</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) I cool the prepared food / the leftover before I put them into the fridge</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>b) I find the fridge/freezer door left open</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c) I cover liquids before I put them into the fridge.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>d) I replace the paper wrappings on items before putting them into the fridge</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>e) When I feel hungry I open the fridge and/or freezer to decide to eat</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>f) Before I do the main food shopping, I open the fridge and freezer then decide what I need to buy</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>g) I forget what I want to take out from the fridge and/or freezer after opening it</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>h) I leave the fridge and/or freezer open when I am unpacking the shopping</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>i) Other using habits (please specify)</td>
<td></td>
<td></td>
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<tr>
<td></td>
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</tr>
</tbody>
</table>

12. What do you particularly like of your fridge and/or freezer?

| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

13. What do you particularly dislike of your fridge and/or freezer?

| | | |
| | | |
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| | | |
| | | |

THANK YOU VERY MUCH FOR YOUR COOPERATION.
Appendix 11: Pilot study, semi-structured interview
### Fridge-Freezer Information

7. Why did you put fridge-freezer in the ....?  
   
a) according to the instruction  
b) fit for the space in the ... (kitchen)  
c) easy for take out/ put in foods

8a. How did you decide the size / volume when choosing your fridge-freezer?  
   
a) the bigger, the better  
b) how much capacity is need (according to previous one)  
c) accepted the salver's advice  
d) according to the space in fitted kitchen

8b. Is your fridge always with this full?  
   
a) on the shopping day, it is pretty full  
b) some times completed full and for some time less filled  
c) more or less half full all the time  
d) often only marginal full

8c. How often do you load more / less loads in your fridge / fridge than usual?  
   
a) in different seasons (summer? winter?)  
c) in holiday  
c) when inviting friends  
d) after / before kids left home

9. Do you have a second fridge and/or freezer running? Where is it? When do you use it?

10a. Why did you set the temperature of the fridge-freezer at ... °C?  
   
a) according to the instruction  
b) the lower then better

10b. Have you changed the temperature setting of your fridge and/or freezer?  

When and for what reason?  
   
a) according to the charge  
b) according to the type of food  
c) according to the outside temperature  
d) by intuition, habit

10c. Do you have other comment about temperature setting ( Control/ LCD readout/ Control Panel/ Digital Panel)?

---

THANK YOU VERY MUCH FOR YOUR COOPERATION.
Environmental Responsibility

11. What do you consider to be the environmentally responsible behaviour when using a fridge-freezer?

12. What do you consider to be the negative environmental impacts of using fridge-freezers?

13. As the user, do you feel that it is your responsibility for the environmental impacts of using fridge-freezers?

14. Do you think the manufacturer's should design fridge-freezers to reduce the environmental impacts?

15. How would you like to change your behaviour to be less environmental impacts when using fridge-freezers?

16. How could the fridge-freezers be changed to enable users to be more environmentally responsible when using fridge-freezers?

THANK YOU VERY MUCH FOR YOUR COOPERATION.
17. According to the fridge-freezer features, ask the following questions.

<table>
<thead>
<tr>
<th>Feature</th>
<th>A) Use every day</th>
<th>B) Use once or twice a week</th>
<th>C) Use only in summer/or winter</th>
<th>D) Use several times after buying</th>
<th>E) Don't use at all</th>
<th>F) Don’t know how to use</th>
<th>G) Useless, features to be reassessed</th>
<th>H) Other: Please give your reason(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fridge</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Chiller drawer</td>
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<td></td>
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<td></td>
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<tr>
<td>Integrated vacuum system</td>
<td></td>
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<tr>
<td>CoolSelect zone drawer</td>
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<td></td>
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<tr>
<td>Humidity controller</td>
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<tr>
<td>Super (quick) cool</td>
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<tr>
<td>Eco-setting</td>
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<tr>
<td>I care-intelligent refrigeration</td>
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<td></td>
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<tr>
<td>Ice &amp; cold water dispenser</td>
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<tr>
<td>In-door drink express (get chilled drinks in record time)</td>
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<tr>
<td>Home bar/beverage station</td>
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<td></td>
<td></td>
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<tr>
<td>LCD screen</td>
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<tr>
<td>DVD player</td>
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<tr>
<td>Remote Controller</td>
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<tr>
<td>Freezer</td>
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<td></td>
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<tr>
<td>Ice care(out-door ice hole)</td>
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<td></td>
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<tr>
<td>Shallow freezer drawer(individual fruit)</td>
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<tr>
<td>Cool-care zone (temp. for specific items)</td>
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</tbody>
</table>
Appendix 12

Appendix 12: Modified version information sheet and user profile questionnaire
User Study-Understanding the Relationship between User and Kitchen

Participant Information Sheet

Before agreeing to participate in this research study, it is important that you read the following explanation.

Explanation of Procedures

The research study is designed to learn more about what you think of the appliances you use and the life in the kitchen. Participation in the study involves completion of a short demographic data collection sheet, two observations and an interview.

Data collected will include asking for some personal information; age, working status, and food shopping and cooking habits.

The first observation of how you store your food into the kitchen after shopping will be carried out for 10-20 minutes. The second observation of how you prepare your meals in a normal day. A video camera will be set on the appliance to record its use for 24 hours. The camera will be used for recording your motion only around the appliance without recording voice.

The interview will last for approximately one hour and be audiotaped by the researcher then later transcribed. In the interview you have the option of giving any views about the kitchen appliance usability, perceptions and expectations of kitchen appliances and your opinions on a range of products purchase, use and its impacts.

Confidentiality and Freedom to Withdraw

ALL information provided by you will remain strictly confidential and you will not be personally identified. Also you are free to withdraw from this study at any point without needing to provide a reason.
User Study-Understanding the Relationship between User and Kitchen

INFORMED CONSENT FORM
(to be completed after Participant Information Sheet has been read)

The purpose and details of this study have been explained to me. I understand that this study is designed to further scientific knowledge and that all procedures have been approved by the Loughborough University Ethical Advisory Committee.

I have read and understood the information sheet and this consent form.

I have had an opportunity to ask questions about my participation.

I understand that I am under no obligation to take part in the study.

I understand that I have the right to withdraw from this study at any stage for any reason, and that I will not be required to explain my reasons for withdrawing.

I understand that all the information I provide will be treated in strict confidence.

I agree to participate in this study.

Your name
________________________________________

Your signature
________________________________________

Signature of investigator
________________________________________

Date
________________________________________
KITCHEN STUDY

USER PROFILE QUESTIONNAIRE

This questionnaire is a part of research project at Loughborough University, to understand the relationship between the users and the kitchen (household; food; etc.).

Appliance Information (Please tick all boxes that apply)

1. Which of the following appliances do you use most frequently in your kitchen?
   A [ ] Cooker
   B [ ] Fridge and / or freezer
   C [ ] Dishwasher
   D [ ] Boiler
   E [ ] Microwave
   F [ ] Other (please specify) ________

2. Which of the following description is proper and accurate for your kitchen?
   A [ ] Very small
   B [ ] Small
   C [ ] Just right
   D [ ] Large
   E [ ] Very large

3. Which of the following descriptions are proper and accurate for your kitchen?
   A [ ] Busiest room in my house
   B [ ] Heart of my home
   C [ ] I spend as much time as possible
   D [ ] I spend as less time as possible
   E [ ] Other (please specify) ________

4. Did you buy your kitchen appliances?
   A [ ] All of them
   B [ ] Some of them (please specify) ________
   C [ ] None

Shopping Habits (Please tick all boxes that apply)

5. How do you do your main food shopping?
   A [ ] Everyday
   B [ ] Twice or three times a week
   C [ ] Once a week
   D [ ] Twice a month
   E [ ] Once a month
   F [ ] Whenever need
   G [ ] Other (please specify) ________

6. Where do you shop for food most often?
   A [ ] Supermarket
   B [ ] Discount store
   C [ ] Market
   D [ ] Through the internet-delivery
   E [ ] Grocery on the way to work / home
   F [ ] Daily-delivery
   G [ ] Other (please specify) ________
   ______________________________________________________________________
Cooking Habits (Please tick all boxes that apply)

7. How do you feel about cooking?
   A □ I love to do it and I spend as much time as possible on it
   B □ I have to do it
   C □ I hate to do it, I spend little time on it
   D □ I always have time to do
   E □ I have not enough time to do
   F □ Other (please specify) __________

8. When cooking a dinner at home, which of these statements, apply to you?
   A □ Most ready-meals or chilled prepared meal
   B □ Combination of ready meals and fresh ingredients
   C □ Mostly fresh ingredients

9. How many meals do you have at home per week?
   Times
   Breakfast 0 1 2-3 4-6 7
   Lunch
   Evening meal

10. Which one is your main meal?
    A □ Breakfast
    B □ Lunch
    C □ Evening meal

User Information (Please tick all boxes that apply)

11. Age __________
12. Occupation ______________

13. Working status
    A □ Full - time
    B □ Part - time
    C □ Not working

14. Household income (Optional)
    A □ $20K
    B □ $20K - $40K
    C □ $40K

15. Living status
    A □ Multi person non-family household
    B □ Single person household
    C □ Family/partner/friend without children at home
    D □ Family/partner/friend with children
      ➔ If D, how many children do you have? __________
          Please tick the appropriate age group(s) of your child(ren)
          A □ 0-2 Number __________
          B □ 3-4 Number __________
          C □ 5-11 Number __________
          D □ 12-18 Number __________
          E □ 18+ Number __________

If you would be willing to take part in a future study, please leave your contact information.

Email ___________________________ Address ___________________________
Tel NO. ___________________________ ___________________________
Appendix 13

Appendix 13: Main user study, post-intervention questionnaire
FRIDGE-FREEZER USERS STUDY

Post-INTERVENTION QUESTIONNAIRE

This questionnaire is a part of research project at Loughborough University, to understand the householder's views on purchase and use of fridge-freezer and a range of issues about environment.

Product Information (Please tick all boxes that apply)

1. Please select the style of your fridge and/or freezer and write down the mark(s) A Combined top freezer ________
   B Combined bottom freezer ________
   C Combined side by side ________
   D Separate fridge ________
   E Separate freezer ________

2. How long have you had your fridge and/or freezer? Year(s)
   A Combined fridge-freezer ________
   B Separate fridge ________
   C Separate freezer ________

3. Relation to your main fridge and/or freezer, have you deliberately made it last longer by doing any of the following?
   A Changed components ________
   B New door seals ________
   C Cleaned the evaporators and condenser/ fan blades and guard ________
   D Others (please specify) ________

4. How long do you think a fridge and/or freezer should last? ________ Year(s)

Use Context (Please tick all boxes that apply)

5. Use status of your fridge and/or freezer:
   A Family/Cohabiting use ________
   B One person use ________
   C Shared fridge-freezer ________

6. How often do you put the following items into the fridge?

<table>
<thead>
<tr>
<th>Item</th>
<th>Always</th>
<th>Sometimes</th>
<th>Never</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meat products</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dairy products</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetables</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fruits</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bakery/bread</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cake</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eggs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drinks</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leftover</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
7. How often do you use the following functions of the fridge and/or freezer? If your fridge and/or freezer does not have the features, please tick N/A.

<table>
<thead>
<tr>
<th>Bottle racks</th>
<th>Ice trays</th>
<th>Quick freezing</th>
<th>Temperature setting</th>
<th>Child lock</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Always</td>
<td></td>
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<tr>
<td>Seasonal use</td>
<td></td>
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<tr>
<td>When inviting friends to dinner</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Used only a few times</td>
<td></td>
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<tr>
<td>Never (indicate why)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>a) Do not remember to use</td>
<td></td>
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<tr>
<td>b) Useless feature to me</td>
<td></td>
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</tr>
<tr>
<td>c) Others. Please specify</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

8. Which of the following have you done in the last 3 years?
A [ ] Purchased a fridge-freezer or a separated fridge/freezer as a replacement
B [ ] Upgraded to an energy-efficient fridge-freezer or separated fridge/freezer
C [ ] Purchased a fridge-freezer or a separated fridge/freezer when setting up the home
D [ ] Considered how the old can be disposed
E [ ] Considered to remaining a working parts of the old one (please specify the reasons) __________________________________________

9. When choosing a fridge-freezer, which of the following things would you say influenced you? (Please tick the number of each statement which correspond most closely to your desired response)

- Appearance: Unimportant -- 1 -- 2 -- 3 -- 4 -- 5 -- Very important
- Size: Unimportant -- 1 -- 2 -- 3 -- 4 -- 5 -- Very important
- Separated style: Unimportant -- 1 -- 2 -- 3 -- 4 -- 5 -- Very important
- Combined style: Unimportant -- 1 -- 2 -- 3 -- 4 -- 5 -- Very important
- Price: Unimportant -- 1 -- 2 -- 3 -- 4 -- 5 -- Very important
- Energy-efficient model: Unimportant -- 1 -- 2 -- 3 -- 4 -- 5 -- Very important
- Well-known brand: Unimportant -- 1 -- 2 -- 3 -- 4 -- 5 -- Very important
- Previous fridge brand: Unimportant -- 1 -- 2 -- 3 -- 4 -- 5 -- Very important
- Additional functions: Unimportant -- 1 -- 2 -- 3 -- 4 -- 5 -- Very important
- Refrigerant with less environmental impacts: Unimportant -- 1 -- 2 -- 3 -- 4 -- 5 -- Very important

10. How would you say you use your fridge or freezer?
A [ ] When shopping for food, I stock up my fridge
B [ ] When shopping for food, I stock up my freezer
C [ ] I often store food for later use
D [ ] I often freeze food for later use
E [ ] I use my fridge-freezer to help plan my weekly meals
F [ ] I have limited space in my fridge to store food
11. When using a fridge, freezer or combined fridge-freezer, which of these statements apply to you?

<table>
<thead>
<tr>
<th></th>
<th>Always /Sometimes/Never</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>I find the fridge/freezer door left open</td>
</tr>
<tr>
<td>B</td>
<td>I cover liquids before I put them into the fridge.</td>
</tr>
<tr>
<td>C</td>
<td>I cool hot dish e.g. for least 1.5h before I put them into the fridge</td>
</tr>
<tr>
<td>D</td>
<td>I find food is not rotated and old food at back often goes out of date</td>
</tr>
<tr>
<td>E</td>
<td>I replace the wrappings on items before putting them into the fridge</td>
</tr>
<tr>
<td>F</td>
<td>When I feel hungry I open the fridge and/or freezer to decide what to eat</td>
</tr>
<tr>
<td>G</td>
<td>Before I do the main food shopping, I open the fridge and/or freezer then decide what I need to buy</td>
</tr>
<tr>
<td>H</td>
<td>I forget what I want to take out from the fridge and/or freezer after opening it</td>
</tr>
<tr>
<td>I</td>
<td>I leave the fridge and/or freezer open while transferring items</td>
</tr>
<tr>
<td>J</td>
<td>Other using habits (please specify)</td>
</tr>
</tbody>
</table>

12. What do you particular like of your fridge and/or freezer?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

13. What do you particular dislike of your fridge and/or freezer?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
Life Values (Please tick all boxes that apply)

14. Next, please show how much you agree or disagree with the statements below.
It’s important my family thinks I’m doing well
Definitely disagree — 1 — 2 — 3 — 4 — 5 — Definitely agree

I don’t want responsibility, I’d rather be told what to do
Definitely disagree — 1 — 2 — 3 — 4 — 5 — Definitely agree

I want to get to the very top in my career
Definitely disagree — 1 — 2 — 3 — 4 — 5 — Definitely agree

How I spend my time is more important than the money I make
Definitely disagree — 1 — 2 — 3 — 4 — 5 — Definitely agree

I consider myself to be a spiritual person
Definitely disagree — 1 — 2 — 3 — 4 — 5 — Definitely agree

I would be willing to volunteer my time for a good cause
Definitely disagree — 1 — 2 — 3 — 4 — 5 — Definitely agree

I like to keep up with the latest fashion
Definitely disagree — 1 — 2 — 3 — 4 — 5 — Definitely agree

I never seem to have enough time to get things done
Definitely disagree — 1 — 2 — 3 — 4 — 5 — Definitely agree

People come to me for advice before buying new things
Definitely disagree — 1 — 2 — 3 — 4 — 5 — Definitely agree

In general I feel very positive about myself
Definitely disagree — 1 — 2 — 3 — 4 — 5 — Definitely agree

Resource Efficiency (Please tick all boxes that apply)

15. Does your household buy, or is your household seriously considering buying its electricity on a Green Tariff?
A ☐ Yes – already buy
B ☐ Yes – seriously considering
C ☐ No - neither
D ☐ Don’t know
16. Do you have a water meter, so that you are billed based on how much water you use
   A □ Yes  B □ No  C □ Don’t know

17. a) IF HAVE WATER METER: Did you request to have a water meter fitted?
   A □ Yes  B □ No  C □ Don’t know

17. b) IF DON’T HAVE WATER METER: Are you seriously considering asking for one to be installed?
   A □ Yes  B □ No  C □ Don’t know

18. Please indicate how often you **personally** do each of the following.
   (1—Always/Very often, 2—Quite often, 3—Sometimes, 4—Occasionally, 5—Never)

   Leave your TV on standby overnight
   Always/Very often — 1 — 2 — 3 — 4 — 5 — Never □ Not applicable □ Don’t know

   Leave the lights on in rooms that aren’t being used
   Always/Very often — 1 — 2 — 3 — 4 — 5 — Never □ Not applicable □ Don’t know

   Leave a mobile phone charger switched on at the socket when not in use
   Always/Very often — 1 — 2 — 3 — 4 — 5 — Never □ Not applicable □ Don’t know

   Fill the kettle with more water than you are going to use
   Always/Very often — 1 — 2 — 3 — 4 — 5 — Never □ Not applicable □ Don’t know

   Keep the tap running while you brush your teeth
   Always/Very often — 1 — 2 — 3 — 4 — 5 — Never □ Not applicable □ Don’t know

   Leave the heating on when you go out for a few hours
   Always/Very often — 1 — 2 — 3 — 4 — 5 — Never □ Not applicable □ Don’t know

   When there is a choice, have a bath rather than a shower
   Always/Very often — 1 — 2 — 3 — 4 — 5 — Never □ Not applicable □ Don’t know

   Put more clothes on when you feel cold, rather than putting the heating on or turning it up
   Always/Very often — 1 — 2 — 3 — 4 — 5 — Never □ Not applicable □ Don’t know

   Throw away food because it has gone off
   Always/Very often — 1 — 2 — 3 — 4 — 5 — Never □ Not applicable □ Don’t know

   Decide not to buy something because you feel it has too much packaging
   Always/Very often — 1 — 2 — 3 — 4 — 5 — Never □ Not applicable □ Don’t know

   Take your own shopping bag when shopping
   Always/Very often — 1 — 2 — 3 — 4 — 5 — Never □ Not applicable □ Don’t know
Re-use things like empty bottles, tubs or jars, envelopes or paper
Always/Very often — 1 — 2 — 3 — 4 — 5 — Never □ Not applicable □ Don’t know

Learn what you do to help solve environmental problems
Always/Very often — 1 — 2 — 3 — 4 — 5 — Never □ Not applicable □ Don’t know

Buy second hand goods
Always/Very often — 1 — 2 — 3 — 4 — 5 — Never □ Not applicable □ Don’t know

Give things you no longer want to charity or to friends and family
Always/Very often — 1 — 2 — 3 — 4 — 5 — Never □ Not applicable □ Don’t know

Check where fruit and vegetables were grown before buying
Always/Very often — 1 — 2 — 3 — 4 — 5 — Never □ Not applicable □ Don’t know

Try not to buy products from a company whose ethics you disagree with
Always/Very often — 1 — 2 — 3 — 4 — 5 — Never □ Not applicable □ Don’t know

19. As far as you know, which of these can you put outside for a council recycling or composting collection?
A □ Paper/Newspapers/magazines  H □ Food waste
B □ Glass bottles/jars/glass I □ Garden waste
C □ Tins/Cans/Foil J □ Other items (Specify) ____________
D □ Cardboard
E □ Clothes K □ None of these
F □ Shoes L □ Don’t know
G □ Plastic bottles/plastic packaging

20. Which of these do you normally put outside for recycling or composting collection?
A □ Paper/Newspapers/magazines  H □ Food waste
B □ Glass bottles/jars/glass I □ Garden waste
C □ Tins/Cans/Foil J □ Other items (Specify) ____________
D □ Cardboard
E □ Clothes K □ None of these
F □ Shoes L □ Don’t know
G □ Plastic bottles/plastic packaging

21. Is there a bottle bank or recycling bank in your area where you can take things like bottles, cans or paper to recycle?
A □ Yes
B □ No
C □ Don’t know

21.a) IF YES, Do you [or your household] ever use these facilities?
A □ Yes
B □ No
C □ Don’t know
22. What, if anything, stops you recycling more than you do at the moment?  
Please TICK ALL THAT APPLY.
A □ Lack of doorstep collection  
B □ Lack of recycling facilities locally
C □ Cannot get to local recycling facilities/recycling centre
D □ Lack of space to store recyclables
E □ Do not know what I can/cannot recycle/unclear labeling
F □ Not enough time
G □ Too much effort
H □ Recycling is unhygienic
I □ Not interested
J □ No-one else around here recycles
K □ No point in doing it
L □ Nothing – already recycle everything I can
M □ Other (Specify) __________
N □ Don’t know

23. Which, if any, of these products have you heard of?
A □ Fair trade products
B □ Fish certified by Marine Stewardship Council/Fish from sustainable sources
C □ Timber products certified by Forestry Stewardship Council/ Timber from sustainable sources
D □ Red tractor meat
E □ Freedom food
F □ LEAF marquee food
G □ None of these
H □ Don’t know

24. Which, if any, of these do you (does your household) buy on a regular basis?  
TICK ALL THAT APPLY.
A □ Recycled toilet paper
B □ Recycled kitchen roll
C □ Free range eggs
D □ Free range poultry
E □ Organic food
F □ Eco-friendly products
G □ Other recycled products (specify)
H □ None of these
I □ Don’t know

25. What, if anything, stops you from making more environmentally friendly choices in the food and groceries you buy? CODE ALL THAT APPLY.
A □ Nothing–already buy all that I can
B □ Too expensive
C □ Not such good quality
D □ Not available where I shop
E □ Not enough labelling/information
F □ Too much effort
G □ Not enough time
H □ Does not help the environment
I □ Don’t see the point/not interested
J □ More important things to think about
K □ Just don’t think about it/No particular reason
M □ Other (Specify) __________
N □ Don’t know

26. Please indicate how much you agree or disagree with each statement

I would favour a system that rewarded me if I recycled everything I could and penalised me if I didn’t
Definitely disagree — 1 — 2 — 3 — 4 — 5 — Definitely agree
I wouldn’t sacrifice my home comforts to save energy
Definitely disagree — 1 — 2 — 3 — 4 — 5 — Definitely agree

I would like to make an effort to save energy in order to save money
Definitely disagree — 1 — 2 — 3 — 4 — 5 — Definitely agree

I would like to make an effort to save energy to help environment
Definitely disagree — 1 — 2 — 3 — 4 — 5 — Definitely agree

I don’t really give much thought to saving energy in my home
Definitely disagree — 1 — 2 — 3 — 4 — 5 — Definitely agree

I don’t pay much attention to the amount of water I use at home
Definitely disagree — 1 — 2 — 3 — 4 — 5 — Definitely agree

If I was buying a kitchen appliance like a freezer or oven, I would only choose one
with a high energy efficiency rating, even if it cost more
Definitely disagree — 1 — 2 — 3 — 4 — 5 — Definitely agree

People have a duty to reduce electricity use of household appliance
Definitely disagree — 1 — 2 — 3 — 4 — 5 — Definitely agree

I would be prepared to pay more for environmentally friendly products
Definitely disagree — 1 — 2 — 3 — 4 — 5 — Definitely agree

**Attitudes in Relation to the Environment** (Please tick all boxes that apply)

| 27. How much, if anything, would you say you know about the following terms? |
|-----------------------------|-----------------------------|
| **Climate Change**          | **Global Warming**          |
| A lot                       | A lot                       |
| A fair amount               | A fair amount               |
| Just a little               | Just a little               |
| Nothing—have only heard of  | Nothing—have only heard of  |
| the name                    | the name                    |
| Nothing – have never heard  | Nothing – have never heard  |
| of it                       | of it                       |

| **Carbon footprint**        | **CO2 or Carbon dioxide emissions** |
| A lot                       | A lot                       |
| A fair amount               | A fair amount               |
| Just a little               | Just a little               |
| Nothing—have only heard of  | Nothing—have only heard of  |
| the name                    | the name                    |
| Nothing – have never heard  | Nothing – have never heard  |
| of it                       | of it                       |
I find it is difficult to do things above, since there is lack of facilities
Definitely disagree --- 1 --- 2 --- 3 --- 4 --- 5 --- Definitely agree

I would favour a system that rewarded me if I do everything I could and
penalised me if I didn't
Definitely disagree --- 1 --- 2 --- 3 --- 4 --- 5 --- Definitely agree

I wouldn't sacrifice my comforts of fridge and freezer use to save energy
Definitely disagree --- 1 --- 2 --- 3 --- 4 --- 5 --- Definitely agree

30. Which of these best describes how you feel about your current lifestyle and
the environment?
A  I'm happy with what I do at the moment
B  I'd like to do a bit more to help the environment
C  I'd like to do a lot more to help to environment
D  Don't know
Appendix 14: Main user study, semi structured interview
<table>
<thead>
<tr>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Food storage</strong></td>
</tr>
<tr>
<td>1. What kind of foods did the subject buy? (Video)</td>
</tr>
<tr>
<td>Unrefrigerated; Refrigerated; Frozen</td>
</tr>
<tr>
<td>2. How do they put them into the fridge-freezer? (Video)</td>
</tr>
<tr>
<td>Be organised according to products type: open once or less time</td>
</tr>
<tr>
<td>If not - open more time?</td>
</tr>
<tr>
<td>3. Where did they put what types of products into the fridge-freezer? (Video)</td>
</tr>
<tr>
<td>Inside the fridge-freezer</td>
</tr>
<tr>
<td>Top</td>
</tr>
<tr>
<td>Bottom</td>
</tr>
<tr>
<td>Front</td>
</tr>
<tr>
<td>Back</td>
</tr>
<tr>
<td>Shelves?</td>
</tr>
<tr>
<td>Drawers?</td>
</tr>
<tr>
<td>Door Bins?</td>
</tr>
<tr>
<td>Bottle racks?</td>
</tr>
<tr>
<td>4. Did the subject adjust the temperature setting or use super cool function after putting a lot of things in the fridge-freezer?</td>
</tr>
<tr>
<td>Q1 How do you usually pack stuff into your shopping bag in the supermarket?</td>
</tr>
<tr>
<td>Q2 How do you unpack your shopping?</td>
</tr>
<tr>
<td>Q3 How do you decide what need to put into the fridge-freezer and what need not to?</td>
</tr>
<tr>
<td>a) according to cooking plan</td>
</tr>
<tr>
<td>b) package of the foods</td>
</tr>
<tr>
<td>c) want them to keep fresh for longer</td>
</tr>
<tr>
<td>d) keep good quality of the food (e.g. fruits/bread can keep in the ambient temp)</td>
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<tr>
<td>e) for safety issues</td>
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<tr>
<td>f) because of fridge-freezer design (e.g. eggs trays? Fruit drawer?)</td>
</tr>
<tr>
<td>Q4 How do you decide where to put what types of products into the fridge-freezer?</td>
</tr>
<tr>
<td>a) because of fridge-freezer design (e.g. eggs trays? Fruit drawer?)</td>
</tr>
<tr>
<td>b) for the temperature differences in the fridge-freezer (e.g. back / bottom is cooler)</td>
</tr>
<tr>
<td>Q5 Do you store food for cooling at other places?</td>
</tr>
<tr>
<td>a) at a cool place in the house (like the garage, basement, pantry, etc...)</td>
</tr>
<tr>
<td>b) outside the house (like balcony, terrace, etc...)</td>
</tr>
<tr>
<td>Q6 Why do not store foods e.g. bread/ fruits/ eggs at the ambient temperature?</td>
</tr>
<tr>
<td>a) lack of storage space</td>
</tr>
<tr>
<td>b) high indoor temperature</td>
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<tr>
<td><strong>Cooking Habits</strong></td>
</tr>
<tr>
<td>Q7 How many people do you usually cook for?</td>
</tr>
<tr>
<td>Q8 Do your kids use fridge? What type of products do they often take out?</td>
</tr>
<tr>
<td>Q9 Do you often drink chilled water or drinks?</td>
</tr>
<tr>
<td>5. How did they take things out of the fridge-freezer? (Video)</td>
</tr>
<tr>
<td>What did they take out of the fridge-freezer? (Video)</td>
</tr>
</tbody>
</table>
### Fridge-Freezer Information

10. Why did you put fridge-freezer in the ...?  
   a) according to the instruction  
   b) fit for the space in the ... (kitchen)  
   c) easy for take out/ put in foods  

11. How did you decide the size / volume when choosing your fridge-freezer?  
   a) the bigger, the better  
   b) how much capacity is need (according to previous one)  
   c) accepted the salver’s advice  
   d) according to the space in fitted kitchen  

12. How often do you load more / less loads in your fridge / fridge than usual?  
   a) in different seasons (summer? winter?)  
   c) in holiday  
   c) when inviting friends  
   d) after / before kids left home  

13. Do you have a second fridge and/or freezer running? Where is it? When do you use it?  

14a. Why did you set the temperature of the fridge-freezer at ... °C?  
   a) according to the instruction  
   b) the lower then better  

14b. Have you changed the temperature setting of your fridge and/or freezer?  
When and for what reason?  
   a) according to the charge  
   b) according to the type of food  
   c) according to the outside temperature  
   d) by intuition, habit  

14c. Do you have other comment about temperature setting ( Control/ LCD readout/ Control Panel/ Digital Panel)?

### Environmental Responsibility

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>15. What do you consider to be the environmentally responsible behaviour when using a fridge-freezer?</td>
<td></td>
</tr>
<tr>
<td>16. What do you consider to be the negative environmental impacts of using fridge-freezers?</td>
<td></td>
</tr>
<tr>
<td>17. As the user, do you feel that it is your responsibility for the environmental impacts of using fridge-freezers?</td>
<td></td>
</tr>
<tr>
<td>18. Do you think the manufacturer’s should design fridge-freezers to reduce the environmental impacts?</td>
<td></td>
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<tr>
<td>19. How would you like to change your behaviour to be less environmental impacts when using fridge-freezers?</td>
<td></td>
</tr>
<tr>
<td>20. How could the fridge-freezers be changed to enable users to be more environmental responsible when using fridge-freezers?</td>
<td></td>
</tr>
</tbody>
</table>
why the previous fridge-freezer was discarded? How did you dispose them (it)?

**Prompting questions for the Semi-structured Interview**

- How often do you use this...?
- Why was this ... abandoned?
- How did you form this routine of .../habit of ...?
- Do you family members have the same habit/do the same thing as you?

- Why was this ... located here?
- How did you arrive at this idea?
- Did you consider...? / have any ideas on...?
- Why is that important?
<table>
<thead>
<tr>
<th>Feature</th>
<th>Use every day</th>
<th>Use once or twice a week</th>
<th>Use once only in summer/winter</th>
<th>Use once after buying</th>
<th>Never use, indicate why</th>
<th>D) Don't remember to use</th>
<th>E) Other Please give your reason(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fridge</td>
<td></td>
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<td>Chiller drawer</td>
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<td>Integrated vacuum system</td>
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<td>CoolSelect zone drawer</td>
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<td>Humidity controller</td>
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<td>Super (quick) cool</td>
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<td>Seasonal temp setting</td>
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<td>Eco-setting</td>
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<tr>
<td>I care-intelligent refrigeration</td>
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<td>Ice &amp; cold water dispenser</td>
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<td>In-door drink express (get chilled drinks in record time)</td>
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<td>Home bar/beverage station</td>
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<tr>
<td>LCD screen</td>
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<td>DVD player</td>
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<td>Remote Controller</td>
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<tr>
<td>Freezer</td>
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<tr>
<td>Ice care(out-door ice hole)</td>
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<tr>
<td>Shallow freezer drawer(individual fruit)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cool-care zone (temp. for specific items)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Hello,

I am a second year PhD student in the Department of Design and Technology at Loughborough University. I am currently looking for some people to help me with my project which aims to understand the relationship between users and kitchen appliances.

To be eligible for the study you or your family members need to do food shopping and cooking and be the owners of the appliances in your kitchen.

The research is about what you think of the appliances you use and life in the kitchen. You will be asked to fill out a questionnaire and also answer some interview questions. An observation of how you put food away in your kitchen after shopping will be carried out for 10-20 minutes. Finally, a video camera will be set on the fridge to record its use over 24 hours.

All information provided by you will remain strictly confidential and you can withdraw at any point in the study.

If you would like further information or are interested in taking part in the study, please contact:

E-Mail : T.Tang@lboro.ac.uk
Mobile phone : 07912044***.

Thank you for your time and I hope to hear back from you,

Best wishes,

Tang Tang
PhD Student
Department of Design & Technology
Appendix 16: Coding system of main user study
<table>
<thead>
<tr>
<th>User code</th>
<th>Age Group</th>
<th>Working Status</th>
<th>Living status</th>
<th>Times of food shopping</th>
<th>Food shopping place</th>
</tr>
</thead>
<tbody>
<tr>
<td>MUS-F01</td>
<td>35-39</td>
<td>Part-Time/housewife</td>
<td>4-person family with two children aged (5-11; 3-4)</td>
<td>2-3/Week</td>
<td>Supermarket</td>
</tr>
<tr>
<td>MUS-F02</td>
<td>25-39</td>
<td>Full-Time</td>
<td>2-person household without children</td>
<td>2/Month</td>
<td>Supermarket</td>
</tr>
<tr>
<td>MUS-F03</td>
<td>25-29</td>
<td>Full-Time</td>
<td>1-person household without children</td>
<td>1/ Week</td>
<td>Supermarket</td>
</tr>
<tr>
<td>MUS-F04</td>
<td>45-49</td>
<td>Part-Time/housewife</td>
<td>4-person family with two children aged (2/12-18)</td>
<td>2-3/ Week</td>
<td>Supermarket</td>
</tr>
<tr>
<td>MUS-F05</td>
<td>45-49</td>
<td>Part-Time/housewife</td>
<td>3-person family with one child aged (12-18)</td>
<td>2-3/ Week</td>
<td>Supermarket</td>
</tr>
<tr>
<td>MUS-F06</td>
<td>30-34</td>
<td>Full-Time</td>
<td>2-person household without children</td>
<td>2/ Month</td>
<td>Internet</td>
</tr>
<tr>
<td>MUS-F07</td>
<td>40-44</td>
<td>Full-Time</td>
<td>4-person family with two children aged (5-11;12-18)</td>
<td>2-3/ Week</td>
<td>Supermarket</td>
</tr>
<tr>
<td>MUS-F08</td>
<td>45-49</td>
<td>Full-Time</td>
<td>3-person family with one child aged (18+)</td>
<td>2-3/ Week</td>
<td>Supermarket</td>
</tr>
<tr>
<td>MUS-F09</td>
<td>60-64</td>
<td>Part-Time/housewife</td>
<td>2-person household without children</td>
<td>1/ Week</td>
<td>Supermarket</td>
</tr>
<tr>
<td>MUS-F10</td>
<td>50-54</td>
<td>Unemployed-Housewife</td>
<td>4-person family with two children aged (2/12-18)</td>
<td>2-3/ Week</td>
<td>Supermarket</td>
</tr>
<tr>
<td>MUS-F11</td>
<td>45-49</td>
<td>Part-Time/housewife</td>
<td>4-person family with two children aged (2/12-18)</td>
<td>1/ Week</td>
<td>Internet</td>
</tr>
<tr>
<td>MUS-F12</td>
<td>40-44</td>
<td>Part-Time/housewife</td>
<td>5-person family with three children aged (3/5-11)</td>
<td>1/ Week</td>
<td>Supermarket</td>
</tr>
<tr>
<td>MUS-F13</td>
<td>30-34</td>
<td>Full-Time</td>
<td>2-person household without children</td>
<td>Whenever need</td>
<td>Supermarket + Daily-Delivery(milk)</td>
</tr>
<tr>
<td>MUS-F14</td>
<td>40-44</td>
<td>Unemployed-Housewife</td>
<td>4-person family with two children aged (2/5-11)</td>
<td>1/ Week</td>
<td>Supermarket + Local farm</td>
</tr>
<tr>
<td>MUS-F15</td>
<td>45-49</td>
<td>Part-Time/housewife</td>
<td>4-person family with two children aged (2/12-18)</td>
<td>1/ Week</td>
<td>Internet</td>
</tr>
<tr>
<td>MUS-F16</td>
<td>45-49</td>
<td>Full-Time</td>
<td>3-person family with one child aged (18+)</td>
<td>2-3/ Week</td>
<td>Supermarket</td>
</tr>
<tr>
<td>MUS-F17</td>
<td>45-49</td>
<td>Unemployed-Housewife</td>
<td>5-person family with three children aged (2/12-18;18+)</td>
<td>Whenever need</td>
<td>Internet</td>
</tr>
<tr>
<td>MUS-F18</td>
<td>45-49</td>
<td>Full-Time</td>
<td>5-person family with three children aged (3/12-18)</td>
<td>1/ Week</td>
<td>Internet</td>
</tr>
</tbody>
</table>
Full Coding System of the Visual Data (Video Data and Data from Product-in-Use Photograph)

<table>
<thead>
<tr>
<th>ACTION</th>
<th>CODE</th>
<th>FAMILY MEMBER</th>
<th>CODE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open door</td>
<td>Op→Op-do</td>
<td>Wife</td>
<td>W</td>
</tr>
<tr>
<td>Leave Open</td>
<td>Lv-Op</td>
<td>Husband</td>
<td>H</td>
</tr>
<tr>
<td>Not closed completely</td>
<td>N-clo-com</td>
<td>Daughter</td>
<td>D</td>
</tr>
<tr>
<td>Throw away</td>
<td>Thr-away</td>
<td>Son</td>
<td>S</td>
</tr>
<tr>
<td>Overfill</td>
<td>OVRFIL</td>
<td>Guest</td>
<td>G</td>
</tr>
<tr>
<td>Habitual behaviour</td>
<td>Habitual-Bh</td>
<td>Young generation</td>
<td>You-gen</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PLACE</th>
<th>CODE</th>
<th>PLACE</th>
<th>CODE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Back of 3rd shelf (from top)</td>
<td>Bac-3-sh</td>
<td>Original Place</td>
<td>Original</td>
</tr>
<tr>
<td>Front of 2nd shelf</td>
<td>Fro-2-sh</td>
<td>Not Original Place</td>
<td>N-Orig</td>
</tr>
<tr>
<td>Bottom glass shelf</td>
<td>Bot-gla-sh</td>
<td>Habitual place</td>
<td>Habitual</td>
</tr>
<tr>
<td>Middle door bin</td>
<td>Mid-do-bin</td>
<td>For special user</td>
<td>Pla-4- user</td>
</tr>
<tr>
<td>Bottom door bin</td>
<td>Bot-do-bin</td>
<td>Place in design feature</td>
<td>Des-ftr</td>
</tr>
<tr>
<td>Bottom drawer</td>
<td>Bot-dra</td>
<td>place for space</td>
<td>Pla-4- spa</td>
</tr>
<tr>
<td>left Bottom drawer</td>
<td>Bot-dra-le</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right Bottom drawer</td>
<td>Bot-dra-r</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bottle rack</td>
<td>Rack</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>STATE</th>
<th>CODE</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Pile up (Bh-Trs) (boxes)</td>
<td>PILE-UP</td>
<td>Special-content</td>
<td>Spe-con</td>
</tr>
<tr>
<td>Laid-down (bottle) on shelf</td>
<td>La-dow</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PURPOSE</th>
<th>CODE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1. Take out item(s)</td>
<td>Out</td>
</tr>
<tr>
<td>1-2. Nothing</td>
<td>Noth</td>
</tr>
<tr>
<td>2-1. Bring back item(s)</td>
<td>Bac</td>
</tr>
<tr>
<td>2-2. Bring back hot item(s)</td>
<td>Bac-hot</td>
</tr>
<tr>
<td>3-1. Load new item(s)</td>
<td>Loa-new</td>
</tr>
<tr>
<td>3-2. Load new item(s) for chill</td>
<td>Loa-new-chil</td>
</tr>
<tr>
<td>3-3. Load frozen item for defrost</td>
<td>Loa-fro-dfr</td>
</tr>
<tr>
<td>3-4. Loading where there is the place-have not got plan, disorganised</td>
<td>LOA-SPA</td>
</tr>
<tr>
<td>4-1. Searching</td>
<td>Ser</td>
</tr>
<tr>
<td>4-2. Searching space at back</td>
<td>SER-BAC</td>
</tr>
<tr>
<td>5. Sorting</td>
<td>Sor</td>
</tr>
<tr>
<td>5-1. Sorting items between shelves</td>
<td>SOR-BET</td>
</tr>
<tr>
<td>5-2. Sorting items to fit in-too full</td>
<td>SOR-FIT</td>
</tr>
<tr>
<td>6. Transferring items between worktop &amp; fridge</td>
<td>Tra</td>
</tr>
<tr>
<td>7. Making room</td>
<td>Mak-rum</td>
</tr>
<tr>
<td>7-1. Making room at last taking out</td>
<td>MAK-RUM-OUT</td>
</tr>
<tr>
<td>8. Move just put-in items to make space for new items</td>
<td>Mov-new-for-new</td>
</tr>
<tr>
<td>9. Deciding</td>
<td>Dec</td>
</tr>
<tr>
<td>10. Consider where to put</td>
<td>CON</td>
</tr>
<tr>
<td>11. Checking foods</td>
<td>Che</td>
</tr>
<tr>
<td>11-1. Checking expired date</td>
<td>Che-dat</td>
</tr>
<tr>
<td>11-2. Checking expired date of yogurt</td>
<td>Che-dat-yog</td>
</tr>
<tr>
<td>12. Picking up item fell down to floor from fridge with the door open</td>
<td>Pic</td>
</tr>
<tr>
<td>13. Doing something unrelated + ?</td>
<td>Unr</td>
</tr>
<tr>
<td>14. Forget what wanted</td>
<td>For</td>
</tr>
<tr>
<td>15. Could not find items that are going into fridge</td>
<td>not-FIND</td>
</tr>
<tr>
<td>16. items out of date</td>
<td>OOD</td>
</tr>
<tr>
<td>Principles of locating items</td>
<td>Expired date of food: move out old items to front, put new purchased items at the back of the fridge (back/bottom of in drawer or shelf)</td>
</tr>
<tr>
<td>------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Fridge design</td>
<td>Order-Counter fridge -Open first - squat down-look for space- put items in...</td>
</tr>
<tr>
<td></td>
<td>Order-over counter fridge-bend down-put items in...</td>
</tr>
<tr>
<td></td>
<td>Order-over counter fridge/freezer-items on the nearest floor open door-bend down pick up-put items in...</td>
</tr>
<tr>
<td></td>
<td>Pull un-(transparent) drawer out to check</td>
</tr>
<tr>
<td></td>
<td>Fail to put in-space (shelf height / bin width) is not big enough.</td>
</tr>
<tr>
<td>Fridge/package design</td>
<td>Put in packed tinned drinks? but how they take out? With door open, tear up the plastic wrap, take one out?</td>
</tr>
<tr>
<td></td>
<td>Tear package off leaving door open</td>
</tr>
<tr>
<td>Delivery → fridge</td>
<td>More open time and times than usual</td>
</tr>
<tr>
<td></td>
<td>Overfill- Buy more than need, struggling to find space</td>
</tr>
<tr>
<td></td>
<td>Waitrose?- Less time used for classifying food in the fridge, frozen and cupboard</td>
</tr>
<tr>
<td>POSTURE</td>
<td>Code</td>
</tr>
<tr>
<td>1. too high to reach</td>
<td>Hi-to-rea</td>
</tr>
<tr>
<td>2. counter fridge - squat down;</td>
<td>Cou-Squ-dow;</td>
</tr>
<tr>
<td>2.1. squat; search carefully</td>
<td>Squ;</td>
</tr>
<tr>
<td>3. bend to see the back in fridge</td>
<td>Ben-; Ben-bac;</td>
</tr>
<tr>
<td>4. kneel down; search carefully</td>
<td>Kne;</td>
</tr>
<tr>
<td>5. design effect different user’s posture</td>
<td>Des-eff-user-potr</td>
</tr>
<tr>
<td>Habitual Behaviour of Ease Use</td>
<td>Code</td>
</tr>
<tr>
<td></td>
<td>Putting the things that are going to the same place together in shopping bag</td>
</tr>
<tr>
<td></td>
<td>Putting the items near the place where they are going before sorting items into storage</td>
</tr>
<tr>
<td></td>
<td>Take whole drawer out of the fridge to organize the vegetables, ...items</td>
</tr>
<tr>
<td>KITCHEN DESIGN</td>
<td>Code</td>
</tr>
<tr>
<td>Kitchen layout design effect behavior</td>
<td>KITC-des-EFF</td>
</tr>
<tr>
<td>Modern kitchen needs 2nd fridge and /or freezer</td>
<td>KITC-des-EFF-2nd FRI+/FRE</td>
</tr>
<tr>
<td>Modern kitchen needs built-in style</td>
<td>KITC-des-EFF-BUI-IN</td>
</tr>
<tr>
<td>Have to locate cold appliance in “wrong” place-e.g. near to the oven</td>
<td>KITC-des-EFF-WRO-LOC</td>
</tr>
<tr>
<td>Location of fridge and unpacking</td>
<td>KITC-des-EFF-LOC-FRI-UNP</td>
</tr>
<tr>
<td>Have to transfer items into fridge one by one</td>
<td>KITC-des-EFF-TRA-1-BY-1</td>
</tr>
<tr>
<td>---------------------------------------------</td>
<td>---------------------------</td>
</tr>
<tr>
<td>Locating fridge in kitchen is easy to check food</td>
<td>KITC-des-EFF-EAS-CHE</td>
</tr>
<tr>
<td>Cooking triangle</td>
<td>KITC-des-EFF-COO-TRI</td>
</tr>
<tr>
<td>High temperature in kitchen</td>
<td>KITC-des-EFF-HIG-TEM</td>
</tr>
<tr>
<td><strong>STATE</strong></td>
<td><strong>CODE</strong></td>
</tr>
<tr>
<td>Special? Use</td>
<td>Spe-use</td>
</tr>
<tr>
<td>Behaviour of transferring</td>
<td>Bh-Trs</td>
</tr>
<tr>
<td><strong>User's capability to adaptation</strong></td>
<td><strong>CODE</strong></td>
</tr>
<tr>
<td>Added container</td>
<td>UCTA-ADD-CON</td>
</tr>
<tr>
<td>rearrange</td>
<td>UCTA-REA</td>
</tr>
<tr>
<td>adaptation</td>
<td>UCTA-ADA</td>
</tr>
<tr>
<td>Creating “for new” use</td>
<td>UCTA-CRE-NEW</td>
</tr>
</tbody>
</table>
Complete Coding System of Eighteen Households’ Responses to the Semi-structured Interview in the Main User Study

**PACKING AND UNPACKING**

<table>
<thead>
<tr>
<th>Reason</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pack the heavy ones first, the lighter one can go on the top</td>
<td>PAC-ORD</td>
</tr>
<tr>
<td>Pack cold things together; frozen things together; yogurt, butter, cheese together; vegetables together</td>
<td>PAC-ORD</td>
</tr>
<tr>
<td>Put stuffs that sort of looks like similar shape together</td>
<td>PAC-ORD</td>
</tr>
<tr>
<td>Pack ready to unpack-One bag for fridge; one bag for freezer; one bag for cupboard</td>
<td>PAC-ORD</td>
</tr>
<tr>
<td>Do not have particular rules</td>
<td>UNP-ORD</td>
</tr>
<tr>
<td>Put where they were going</td>
<td>UNP-ORD</td>
</tr>
</tbody>
</table>

**FOODS NEED TO PUT IN THE FRIDGE**

<table>
<thead>
<tr>
<th>Reason</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keep fresh</td>
<td>FOO-FRI</td>
</tr>
<tr>
<td>Keep longer</td>
<td>FOO-FRI</td>
</tr>
<tr>
<td>Keep chilled, like the taste</td>
<td>FOO-FRI</td>
</tr>
<tr>
<td>Lock-in modern lifestyle, it is convenient to put everything in</td>
<td>FOO-FRI</td>
</tr>
<tr>
<td>Food always in</td>
<td>FOO-FRI</td>
</tr>
<tr>
<td>Depending on space</td>
<td>FOO-FRI</td>
</tr>
<tr>
<td>Never put in</td>
<td>FOO-FRI</td>
</tr>
<tr>
<td>Medicines have to be kept at certain temperature</td>
<td>FOO-FRI</td>
</tr>
<tr>
<td>Have no plan, just load in and then have a plan after</td>
<td>FOO-FRI</td>
</tr>
<tr>
<td>Have one fridge so, put drink (wine, beer) in beforehand</td>
<td>FOO-FRI</td>
</tr>
</tbody>
</table>

**LOADING PRINCIPLES**

<table>
<thead>
<tr>
<th>Reason</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expired date of food</td>
<td>FOO-FRI</td>
</tr>
<tr>
<td>Food packaging</td>
<td>FOO-FRI</td>
</tr>
<tr>
<td>Food hygiene</td>
<td>FOO-FRI</td>
</tr>
<tr>
<td>Weight of the items</td>
<td>FOO-FRI</td>
</tr>
<tr>
<td>User of food and drinks</td>
<td>FOO-FRI</td>
</tr>
<tr>
<td>Temperature distribution in the fridge</td>
<td>FOO-FRI</td>
</tr>
<tr>
<td>Fridge design</td>
<td>FOO-FRI</td>
</tr>
<tr>
<td>Frequency of use</td>
<td>FOO-FRI</td>
</tr>
<tr>
<td>Habitual place for certain food and drinks</td>
<td>FOO-FRI</td>
</tr>
<tr>
<td>Put where there is space</td>
<td>FOO-FRI</td>
</tr>
<tr>
<td>Learn food organising habit from family home</td>
<td>FOO-FRI</td>
</tr>
<tr>
<td>Learn food organising habit from friends</td>
<td>FOO-FRI</td>
</tr>
<tr>
<td>Learn food organising habit from media</td>
<td>FOO-FRI</td>
</tr>
<tr>
<td>Family members’ routine of putting foods in</td>
<td>FOO-FRI</td>
</tr>
<tr>
<td>Putting things away is a kind of exercise</td>
<td>FOO-FRI</td>
</tr>
<tr>
<td>Put back in original/right place</td>
<td>FOO-FRI</td>
</tr>
<tr>
<td>Know where everything is, but do not put back in original/right place</td>
<td>FOO-FRI</td>
</tr>
<tr>
<td>Children are not high enough to reach</td>
<td>FOO-FRI</td>
</tr>
<tr>
<td>FULL STATE OF FRIDGE and FREEZER</td>
<td>STA-FUL</td>
</tr>
<tr>
<td>-----------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>Related to frequency of shopping</td>
<td>STA-FUL-SHO-DAY</td>
</tr>
<tr>
<td>On the shopping day, the householder does the shopping, the fridge and freezer are always full</td>
<td>STA-FUL- PAR</td>
</tr>
<tr>
<td>When we have a party, if we were entertaining, having visitors-</td>
<td></td>
</tr>
<tr>
<td>At Christmas, Somebody’s birthday</td>
<td></td>
</tr>
<tr>
<td>Always that much</td>
<td>STA-FUL- ALW</td>
</tr>
<tr>
<td>Change in life-we need a big one after we have children</td>
<td>STA-FUL-CHI</td>
</tr>
<tr>
<td>Change in life-we had a less full fridge since we had been leading a healthier lifestyle</td>
<td>STA-FUL-UNH-LIF</td>
</tr>
<tr>
<td>Related to work pattern</td>
<td>STA-FUL-WOR-PAT</td>
</tr>
<tr>
<td>Related to distance between home and shops;</td>
<td>STA-FUL-DIS-HOM-SHO</td>
</tr>
<tr>
<td>Freezing vegetables from garden</td>
<td>STA-FUL-GRO-GAR</td>
</tr>
<tr>
<td>Less full before going holiday</td>
<td>STA-LES-FUL-HOI</td>
</tr>
<tr>
<td>Less full after children left home</td>
<td>STA-LES-FUL-CHI-LEF</td>
</tr>
<tr>
<td>Empty before going holiday, but leave it on</td>
<td>STA-EMP-HOI-LEA-ON-UNS-USA</td>
</tr>
<tr>
<td>Make space for drinks and water in the summer</td>
<td>STA-FUL-SEA-SUM</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>USE OF FREEZER</th>
<th>FRE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Save it for future-bread</td>
<td>FRE-FUR-BRE</td>
</tr>
<tr>
<td>Save it for future-milk</td>
<td>FRE-FUR-MIL</td>
</tr>
<tr>
<td>For future-ready meal</td>
<td>FRE-FUR-REA-MEA</td>
</tr>
<tr>
<td>For future-Big portions-homemade ready meal</td>
<td>FRE-FUR-HOM-REA-MEA</td>
</tr>
<tr>
<td>Cook more than need</td>
<td>FRE-COO-MOR</td>
</tr>
<tr>
<td>Sell by date</td>
<td>FRE-SEL-BY-DAT</td>
</tr>
<tr>
<td>Special offer/reduced</td>
<td>FRE-RED</td>
</tr>
<tr>
<td>For future-Raw ingredients</td>
<td>FRE-FUR-RAW-ING</td>
</tr>
<tr>
<td>For future-Stuff that we are going to use later in the week</td>
<td>FRE-FUR-USE-LAT</td>
</tr>
<tr>
<td>For party</td>
<td>FRE-FUR-PAR</td>
</tr>
<tr>
<td>Freezer always that full</td>
<td>FRE-ALW-FUL</td>
</tr>
<tr>
<td>Problems-manual defrost, ice-up</td>
<td>FRE-PRO-MAN-DEF</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>OTHER PLACE FOR STORING FOOD</th>
<th>OP-4-SF</th>
</tr>
</thead>
<tbody>
<tr>
<td>When-</td>
<td>OP-4-SF-WHE</td>
</tr>
<tr>
<td>Busy time;</td>
<td>OP-4-SF-WHE-BUS</td>
</tr>
<tr>
<td>Christmas;</td>
<td>OP-4-SF-WHE-CHR</td>
</tr>
<tr>
<td>Party</td>
<td>OP-4-SF-WHE-PAR</td>
</tr>
<tr>
<td>Where</td>
<td>OP-4-SF-WHER</td>
</tr>
<tr>
<td>Garage</td>
<td>OP-4-SF-WHER-GAR</td>
</tr>
<tr>
<td>Porch</td>
<td>OP-4-SF-WHER-POR</td>
</tr>
<tr>
<td>Dining room</td>
<td>OP-4-SF-WHER-DIN</td>
</tr>
<tr>
<td>Toilet</td>
<td>OP-4-SF-WHER-TOI</td>
</tr>
<tr>
<td>Larder</td>
<td>OP-4-SF-WHER-LAR</td>
</tr>
<tr>
<td>Pantry</td>
<td>OP-4-SF-WHER-PAN</td>
</tr>
<tr>
<td>Second fridge and/or freezer</td>
<td>OP-4-SF-WHER-2nd FR+/FRE</td>
</tr>
<tr>
<td>Why-</td>
<td>OP-4-SF-WHY</td>
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</table>

<table>
<thead>
<tr>
<th>SECOND FRIDGE and/or FREEZER</th>
<th>2nd FR+/FRE</th>
</tr>
</thead>
<tbody>
<tr>
<td>When main one becomes too full</td>
<td>2nd FR+/FRE-MAI-FUL</td>
</tr>
<tr>
<td>Do not get out often</td>
<td>2nd FR+/FRE-NOT-USE-OFT</td>
</tr>
<tr>
<td>Drinks we want to chill</td>
<td>2nd FR+/FRE-DRI-TAS</td>
</tr>
<tr>
<td>When we are going to be very busy</td>
<td>2(^{nd}) FRI+/FRE-BUS</td>
</tr>
<tr>
<td>When we have party or a lot of visitors</td>
<td>2(^{nd}) FRI+/FRE-PAR</td>
</tr>
<tr>
<td>Came with the house</td>
<td>2(^{nd}) FRI+/FRE-WIT-HOU</td>
</tr>
<tr>
<td>Our fridge in our old house</td>
<td>2(^{nd}) FRI+/FRE-OLD-HOU</td>
</tr>
<tr>
<td>Use it as a larder, keep extra things</td>
<td>2(^{nd}) FRI+/FRE-KEE-ETR</td>
</tr>
<tr>
<td>From my friends</td>
<td>2(^{nd}) FRI+/FRE-FRO-FRI</td>
</tr>
<tr>
<td><strong>CHILDREN</strong></td>
<td>CHI</td>
</tr>
<tr>
<td>Special setting for children</td>
<td>CHI-SPE-SET</td>
</tr>
<tr>
<td>Food for children</td>
<td>CHI-FOO</td>
</tr>
<tr>
<td>Use by children</td>
<td>CHI-USE</td>
</tr>
<tr>
<td>Unsustainable use behaviour of the young generation</td>
<td>CHI-UNS-YOU-GEN</td>
</tr>
<tr>
<td>Change in lifestyle-Children effect on usage</td>
<td>CHI-EFF-USA</td>
</tr>
<tr>
<td>Children are not high enough to reach</td>
<td>CHI-NOT-REA</td>
</tr>
<tr>
<td>Change in life-we need a big one after we have children</td>
<td>STA-FUL-CHI</td>
</tr>
<tr>
<td><strong>GROWING VEGETABLES IN THE GARDEN</strong></td>
<td>GRO-GAR</td>
</tr>
<tr>
<td>Difference in loads and use of fridge-summer</td>
<td>GRO-GAR-SUM-FRI</td>
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<tr>
<td>Difference in loads and use of freezer-winter</td>
<td>GRO-GAR-SUM-FRE</td>
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<tr>
<td><strong>FRIDGE DESIGN</strong></td>
<td>FRI-DES</td>
</tr>
<tr>
<td>Temperature setting</td>
<td>FRI-DES-TEM-SET</td>
</tr>
<tr>
<td>Never change since purchase, Recommended setting</td>
<td>FRI-DES-TEM-SET-NEV</td>
</tr>
<tr>
<td>Change since items go bad</td>
<td>FRI-DES-TEM-SET-CHA-GO-BAD</td>
</tr>
<tr>
<td>Keep colder, freshness</td>
<td>FRI-DES-TEM-SET-KEE-COL</td>
</tr>
<tr>
<td>Colder for better taste</td>
<td>FRI-DES-TEM-SET-TAS</td>
</tr>
<tr>
<td>Freeze things so change</td>
<td>FRI-DES-TEM-SET-TOO-COL</td>
</tr>
<tr>
<td>Change older during holiday</td>
<td>FRI-DES-TEM-SET-HOL</td>
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<tr>
<td>Chill drinks</td>
<td>FRI-DES-TEM-SET-DRI</td>
</tr>
<tr>
<td>Lack of knowledge/ information</td>
<td>FRI-DES-TEM-SET-INF</td>
</tr>
<tr>
<td>Useless feature</td>
<td>FRI-DES-USELESS-FEA</td>
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<tr>
<td>Behaviour control</td>
<td>FRI-DES-BEH-CON</td>
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<tr>
<td><strong>FRIDGE LOCATION</strong></td>
<td>FRI-LOC</td>
</tr>
<tr>
<td>Kitchen</td>
<td>FRI-LOC-KITC</td>
</tr>
<tr>
<td>Utility room</td>
<td>FRI-LOC-UTI</td>
</tr>
<tr>
<td>Style effect the location</td>
<td>FRI-LOC-STY-EFF</td>
</tr>
<tr>
<td><strong>KITCHEN DESIGN</strong></td>
<td>KITC-des-EFF</td>
</tr>
<tr>
<td>Lack of space for food in kitchen</td>
<td>KITC-des-EFF-LAC-SPA-4-FOO</td>
</tr>
<tr>
<td>Old pantry needed</td>
<td>KITC-des-EFF-PAN</td>
</tr>
<tr>
<td><strong>RESPONSIBILITY FOR USER IMPACTS</strong></td>
<td>RES-4-USE-IMP</td>
</tr>
<tr>
<td>User’s responsibility</td>
<td>RES-4-USE-IMP-USER</td>
</tr>
<tr>
<td>Manufacture’s responsibility</td>
<td>RES-4-USE-IMP-MANU</td>
</tr>
<tr>
<td>Both</td>
<td>RES-4-USE-IMP-BOT</td>
</tr>
<tr>
<td><strong>ENVIRONMENTAL RESPONSIBLE BEHAVIOUR</strong></td>
<td>ENV-RES-BEH</td>
</tr>
<tr>
<td>Need more knowledge/Information</td>
<td>ENV-RES-BEH-INF</td>
</tr>
<tr>
<td>Do not leave door open</td>
<td>ENV-RES-BEH-NOT-LV-OP</td>
</tr>
<tr>
<td>Disposal of old fridge</td>
<td>ENV-RES-BEH-DIS</td>
</tr>
<tr>
<td>Pile on near to the fridge first</td>
<td>ENV-RES-BEH-PIL-NEA-USU-USA</td>
</tr>
<tr>
<td>Try to plan when open the fridge</td>
<td>ENV-RES-BEH-PLAN</td>
</tr>
</tbody>
</table>
Have the freezer quite full  ENV-RES-BEH-FRE-FUL
Do not stuff too full  ENV-RES-BEH-NOT-TOO-FUL
A-rated  ENV-RES-BEH-A-RAT
Do not put hot food in  ENV-RES-BEH-NOT-HOT-FOO
Right size  ENV-RES-BEH-RIG-SIZ
Set at right temperature  ENV-RES-BEH-RIG-TEM

NEGATIVE ENVIRONMENTAL IMPACT  NEG-ENV-IMP
Using energy  NEG-ENV-IMP-ENE
End of life/Disposal  NEG-ENV-IMP-DIS
Do not put things in that need not to  NEG-ENV-IMP-PUT-FOO-NEE
One size  NEG-ENV-IMP-ONE-SIZ

CHANGE YOUR BEHAVIOUR  CHA-BEH
No willing to change-  CHA-BEH-NO
It is not a big issue  CHA-BEH-NO-NOT-BIG
Have done good enough  CHA-BEH-NO-ENO
Can not change my lifestyle-lock-in  CHA-BEH-NO-LOC-IN-LIF
We do not waste food, preserve food  CHA-BEH-NO-NOT-WAS
Depends on what would make difference before making chances  CHA-BEH-DEP-DIF
Willing to change-  CHA-BEH-WIL
Have done a lot, but would like to do more  CHA-BEH-WIL-DO MOR
Plan in advance  CHA-BEH-WIL-PLAN
If I know what to do, need more information  CHA-BEH-WIL-INF
If it was not too inconvenient  CHA-BEH-WIL-CONV
Want to act immediately  CHA-BEH-WIL-IMM
Want to change but it is not easy-busy life  CHA-BEH-WIL-BUS
Want to change but is not easy-habit difficult to change  CHA-BEH-WIL-HAB
Economic benefit-Service design-Payback period of replacing vs. electricity cost  CHA-BEH-WIL-ECO-BEN
Environmental sense?-Appliance life-electricity saving of efficient mode vs. cost of manufacturing a new product  CHA-BEH-WIL-ENV-SEN

CHANGES TO PRODUCT DESIGN  CHA-DES
Do not know whether it is possible  CHA-DES-NOT-KNO
Efficient temperature setting  CHA-DES-EFFI-TEM-SET
Need information about power  CHA-DES-INF
Need education  CHA-DES-EDU
Communicating more  CHA-DES-COM
Reminder  CHA-DES-REM
Separate temperature zone/control  CHA-DES-SEP-TEM-CONT
More doors  CHA-DES-MOR-DO
Space for bottle  CHA-DES-SPA-4-BOT
Be modular  CHA-DES-BE-MOD
a kit of parts  CHA-DES-KIT
Shelf-like drawer  CHA-DES-SHE-DRA
Wastage of space on the shelf  CHA-DES-SHE-WAS
Designers lack of knowledge about what would actually make difference and could design something around that  CHA-DES-LAC-KNO
<table>
<thead>
<tr>
<th>DISPOSAL</th>
<th>DIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gave away</td>
<td>DIS‐GAV‐AWA</td>
</tr>
<tr>
<td>Sold</td>
<td>DIS‐SOL</td>
</tr>
<tr>
<td>Recycled</td>
<td>DIS‐REC</td>
</tr>
<tr>
<td>Do not what to do with it</td>
<td>DIS‐NOT‐KNO</td>
</tr>
<tr>
<td>COMMUNITY</td>
<td>COM</td>
</tr>
<tr>
<td>Give things away to neighbours, live in friendly street</td>
<td>COM‐LEF‐NEI</td>
</tr>
<tr>
<td>SUSTAINABLE USAGE</td>
<td>USU‐USA</td>
</tr>
<tr>
<td>UNSUSTAINABLE WAY of ENERGY consumption</td>
<td>UNS‐USA</td>
</tr>
<tr>
<td>DIFFERENCE BETWEEN AWARENESS (INTENTION) AND USE</td>
<td>DIF</td>
</tr>
<tr>
<td>Difference between they awareness and the feature of their fridge</td>
<td>DIF‐AWA‐FEA</td>
</tr>
<tr>
<td>Difference between they what say and what they do</td>
<td>DIF‐SAY‐DO</td>
</tr>
</tbody>
</table>
Appendix 17

Appendix 17: Design study 1: MSc design brief
07DTP860 SUSTAINABILITY & DESIGN:
DESIGNING BEHAVIOURAL CHANGE

BACKGROUND

• “All design has social, ecological and environmental consequences” (Papanek, 1995).
• The most significant environment impact of most electronic products occurs during use, and is often a result of user behaviour;

• Government & NGOs rely on user education & incentives.
  o Can be effective, but changes are often short-lived
  o Actions prescribed by campaigns must be convenient, supported by infrastructure and constantly reinforced to maintain changes.

• Manufacturers implement Eco-efficiency measures to reduce resource use & waste but these are dependant on customer compliance.

• The role of the designer is evolving; designers are in the position to plan and to shape the way in which consumption occurs and to bridge the considerable the intention and behaviour gap between environmental values and user everyday action.

Research indicates that to be effective, design for behavioural change approaches should;
  o make resource use & resulting waste visible and accessible
  o provide feedback in real-time to make the links between action & consequence tangible
  o be varied in frequency & type to ensure spontaneity & reduce predictability or irritation,
  o use predominately positive rather than negative reinforcement,
  o be coupled with eco-efficiency improvements,
  o avoid competing with other values,
  o evolve & adapt to cope with unpredictable changes in behaviour,
  o be, as far as possible, ethical in their intent and outcomes.

Reported behaviours people display when using fridges;

• Leave door open while transferring items to worktop,
  o Electrolux fridges, for example, are fitted with "door ajar" alerts

• Do not locate fridge correctly,
  o keeping in a non-heated room rather than a kitchen = av. energy saving of 36% (MTP, 2006)

• Set temperature too high,
  o fridge should operate at about 3 - 5°C

• Overfill the fridge – so cold air can't circulate properly, but they should keep the fridge at least three quarters full – retains cold better than an empty one,

• Food is not rotated and old food at back often goes out of date,

• Put hot food straight into fridge,
  o the fridge not designed to cool hot food.
  o dish should be allowed to cool (around 1½ hours after cooking)
THE BRIEF

Your challenge is to redesign a FRIDGE to influence the user’s behaviour towards reducing waste or reducing energy use (or both),

TASK 1 – RESEARCH AND DEVELOPMENT (20%)

• Observe and record in your logbook – using images, photos and words - how people use fridges and consider what possible environmental impacts could result from these different types of behaviour,
• Use questionnaire and/or interview to find out people’s perception about the environmental problems of fridge use

TASK 2 – RE-DESIGN (50%)

• Sketch some design ideas that would influence the user’s behaviour towards conserving energy or reducing waste.
• Choose and detail one final concept.

TASK 3 – PRESENTATION (30%)

• Choose one final concept and prepare a 15 minute PowerPoint presentation
• Clearly describe how your design would change the user’s behaviour.

HAND IN AND PRESENTATIONS:
14th March, Time to be confirmed
<table>
<thead>
<tr>
<th>ASSESSMENT CRITERIA</th>
</tr>
</thead>
</table>
| **07DTP860**  
Sustainability & Design  
Name: |  
**TASK 1 – R&D (20%)**  
- Produced quality user centred research on fridge use  
- Related observed user behaviour to wider environmental impacts  
- Analyzed users’ perception about environmental impacts |  
/20 |
| **TASK 2 - (50%) RE-DESIGN**  
- Applied results of research to product designs generated  
- Demonstrated good understanding of design-led intervention  
- Applied this understanding in product design ideas  
- Demonstrated iterative designing process  
- Produced quality design output |  
/50 |
| **TASK 3 – (30%) PRESENTATION**  
- Demonstrated development of concept  
- Clearly articulated in presentation how this concept addresses environmental issue(s) identified  
- Explained design solution clearly both visually and verbally in presentation  
- Delivered high quality presentation  
- Able to discuss design ideas with others and respond to questions asked |  
/30 |
| **TOTAL MARK** |  
/100 |
Appendix 18: User testing focus group: presentation boards