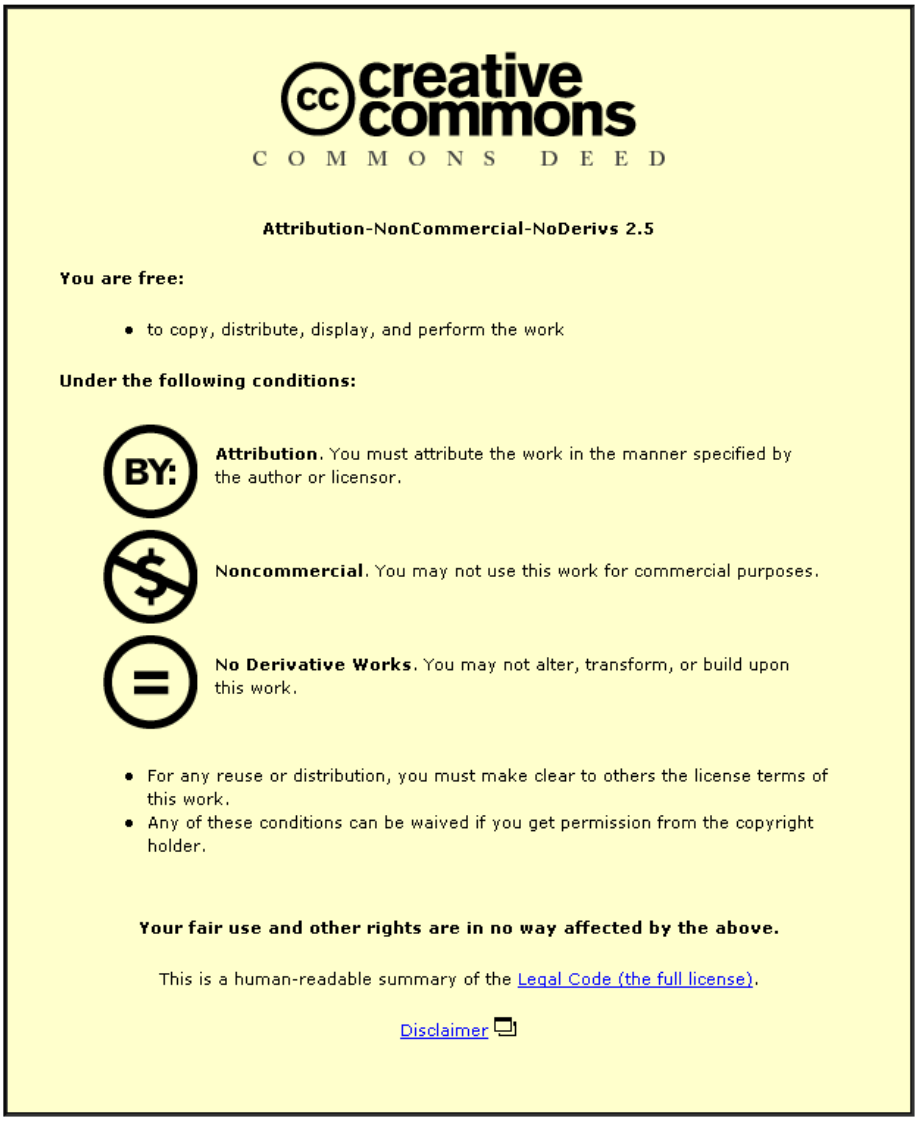

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Improving Energy Efficiency of Product Use: An Exploration of Environmental Impacts of Household Cold Appliance Usage Patterns

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Abstract

This report presents the findings from a qualitative study investigating how product design can be used to change consumer behaviour to reduce the household energy consumption. A fundamental aspect of this aim is to fill the gap in existing research by understanding the product use behaviour and its impacts on the environment. Household cold appliances were chosen as a case to explore the capacity of designer-conducted user studies to identify unsustainable aspects of product use. User-centred research techniques [1, 2] including questionnaires, semi-structured interview and Product-in-Use observations 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. Eighteen British families were involved in this qualitative study. This paper presents the methods and process for extracting design oriented information from the behaviour study in the early phases of energy efficient products development. It concludes that usage patterns study can offer resources to assist manufacturers and designers minimise environmental impacts product use. Also it discusses the implications for the future design of household cold appliances.

Introduction

During the use phase, a significant proportion of a product's energy demand is determined by the consumer's behaviour. In studies from the United States, the Netherlands and the UK, cited by Wood and Newborough [3], it is estimated that resident's behaviour is responsible for 26–36% of in-home energy use. Therefore, in addition to improving the technological efficiency of domestic appliances, a fundamental change in user behaviour is required to achieve the reduction in residential energy consumption. Product manufacturers and designers are ideally placed to plan and to shape the way in which operation occurs: how these appliances are perceived, learned, and used. A better understanding of what users do and how they interact with products as well as the hidden factors behind daily decision-making process should be gained in order to encourage more sustainable daily actions.

In the home, there are very few pieces of equipment that use energy 24 hours a day 365 days a year. Fridges and freezers are two such products and account for around one-fifth of domestic energy consumption [4] and 25% of the average household bill [5]. The Energy Saving Trust [4] 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 [5]. The UK Government Energy White Paper [6] identified the need for further reductions in the energy used by cold appliances [7]. To reduce environmental impacts in this cold sector, most solutions have focused on technological innovations. However, about half the efficiency gains have been offset by the "rebound effect" [4]. The rebound effect is liked to the supply side. Manufacturers are providing bigger volume cold appliances. According to the Environmental Change Institute [8], the average size of cold appliances on the market was increased by 15% between 1995 and 2001. This has resulted in the fact that revealed that manufacturers are not selling appliances with lower overall energy consumption [9]. On the demand side, it is reported that every household at least own one cold appliance often with two or more [8]. A survey by Mintel [10] shows that in 2007, the sales in this sector grew by 8% compared with 2005. Recently, consumers are enthusing about larger and more energy hungry appliances, such as, American style fridge freezers containing integrated LCDs or ice producers. Over the lifetime, an American style fridge and freezer consumes 1800 KWh more than the typical average sized A-rated appliance. Increasing consumer expectation for comfort, convenience, speed and security as well as the social and psychological contexts within which cold appliance consumption behaviours exist are challenging the energy gains of technological improvements of reducing the

impact of product use. The current energy label test is criticised by consumer bodies and experts for not reflecting actual energy consumption of home use. In research of the real-life usage, the consumer surveys on actual energy consumption have given the following results (see Table 1). 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. Fridges and freezers, the 'must-have' products in the household, are widely used by a variety of user groups in a range of habitual use behaviours and routine activities. Research to date indicates that the everyday product use behaviour and its evnrionmental impacts have not yet been clearly addressed.

Table 1, difference in electricity consumption of fridge and/or freezer between actual and the label provided by research from different countries [7, 11, 12, 13, 14].

Energy Consumption Research community	Effects of actual energy consumption
Food Refrigeration and Process Engineering Research Centre (FRPERC) report	The effect of door opening is 1-2% The influence of warm food is 4-10%
Mennink et al. (1998) tested a 200 litre refrigerator	The effect of door opening is 8% (2.2W) The influence of Adding food at room temperature is 11% (3.1W)
Refrigerators and Freezers, product case 5, Methodology Study Eco-design of Energy-using Products (MEEUP) for European Commission	Ice-up of the evaporator deteriorate the efficiency by 10-20% 1°C difference in temperature causes a 4% difference in energy consumption.
ECUEL project SAVE (1999) in France used metered appliances in around 98 households for one month between January and July 1998 to monitor	Keeping a cold appliance in a non-heated storeroom rather than a kitchen gives an average energy saving of 36%. On average, freezers were operating at 3.1°C colder than the recommended temperature (-18°C), leading to 17.6% more energy use.
In Japan, the surveys on Actual Energy Consumption of Top-Runner Refrigerators of Jyukankyo Research Institute (2006) monitored over 100 refrigerators in household for one year	Average annual actual electricity consumption was 65% larger than the JIS test value (Japan Industrial Standards test in 1999)

Rather than a quantitative energy monitoring study, the qualitative study of the fridge and freezer use provided an insight into the type of information required by designers to reduce the energy consumption in operating the product. To collect qualitative 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, a combined research techniques have been conducted in eighteen British families. By analysing the use of the fridge and freezer, the areas with the potential for achieving improvements by energy efficient product design were identified. The final section discusses the implications for future design of household cold appliances. Some design briefs are outlined as an example of how design solutions can be used to change consumer behaviour to reduce the household energy use.

Data Collection and Analysis

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. Table 2 summaries the composition of the households involved in this study.

Table 2 the composition of the participants involved;

Age	Had owned fridge/ freezer for	Family Size Person/ Household	Single	Two	Three	Four	Five
25-65	4months - 16years		1	4	3	7	5

Methods of study

Qualitative methods would be applied to uncover and understand what lies behind the everyday use of the fridge and freezer in order to "give the intricate details of phenomena that are difficult to convey with quantitative methods" [15]. As shown in Table 3, a combination of user-centred research techniques [4, 5] was employed for this study to capture opportunities for design to help consumers to use their fridge and freezer more efficiently.

Table 3 Research methods used for the main study

Research Activity	Time	Equipment	Participant	Aim (h=hour, m=minute)
Questionnaire: User profile; Participant Information Sheet; Informed Consent Form	10m		Wife and/or Husband	To brief the research, its significance, the use of the data & 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 & the researcher.
Observation: Food Unpacking Recording	15-30m	Hand-held digital camcorder	Wife and/or Husband	To uncover the habits &principles of unpacking grocery shopping.
Observation: Fridge & Freezer Use Condition, Use Environment	10m	Digital camera and digital camcorder	Researcher	To gain insight of the fridge and freezer use and reasons for particular use behaviour
Observation: 24 Hours Behaviour Record	24.5 h	Fixed camera, laptop & motion detected software	Family member(s)	To adequately capture a range of behaviours related to the everyday use of fridge & freezer,
Post-intervention Questionnaire	15m		Wife and/or Husband	To identify individual's knowledge & attitudes towards energy & resource efficiency & eco-friendly purchasing &performance of environmental behaviour; To ascertain the links between intentions & daily use behaviour of the fridge & freezer.
Semi-structured Interview, Explanations to 24-hour record	30-40m	Voice recorder	Wife and/or Husband	To discover the attitudes in relation to environment & energy use of fridge & freezer; To entice users' true opinions & promote substantive discussions about the reasons for their particular behaviour, the users' environmental responsibility & the changes that should be made to the fridge & freezer design.

Observation

Miles and Huberman [16] identified that focusing solely on individual behaviour without attending to contexts runs a serious risk of misunderstanding the meaning of events. The visual recordings enable researchers to capture people's behaviour in real-life contexts [1] and to look at the interaction between people and their environment [17], offering more detailed and more accurate source of daily practices and routines [18]. It is an interactive and naturalistic [1] method to record behaviours which people may not be able to articulate when asked [19]. Also it helps the observer to identify true opinions and actions as people often say one thing but think or do another [20]. As Daut commented, video enables the researcher to capture both visual and audible information providing a rich source of data about people's ordinary lives [21].

In this study, the interaction between the user and the product assessed the environmental consequences from three stages - before use (selection and purchase), mid-use (operation and maintenance) and after use (disposal or recycle). Mid-use is 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.

Questionnaire and Semi-structured Interview

It was felt that no technique used independently can give a representative picture of fridge and freezer use, but multiple methods built a sufficient profile of users' values and intentions behind the daily practice. Self-completion questionnaires and semi-structured interviews clearly offered an advantage in supplementary data collection. These two techniques were used to investigate what consumers thought about their fridge and freezer and the environmental impacts of their use. They helped to reduce the risk that the conclusion would reflect any limitations of a specific method.

A self-completion questionnaire, a series of pre-established questions with a limited set of response categories, was designed for respondents to evaluate themselves. The results allow the assessment of current respondents' environmental attitudes and action in different environmental subject areas, including energy efficiency and waste recycling. The use of open ended questions provides respondents with an opportunity to respond to the "like" and "dislike" issues about cold appliance in more detail. The face to face interviews resulted in insightful information about users, which consisted mainly of descriptions of the routine practice ingrained in the fridge and freezer use patterns. The face to face interview provided the opportunity to modifying the 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" [22]. Using a pre-prepared agenda of issues enabled discussions around specific issues, avoiding irrelevant or useless content and making the comparisons of responses with other interviewees' easily. All the activities conducted in this study were recorded by notes, photos and video recordings which assisted more detailed analysis to extract, compare and collate similarities and differences.

Data Analysis

The qualitative nature of the data collected throughout the study has informed the data analysis process. Three main analysis methods, coding, matrix and mapping and clustering, were adopted, undertaking three analysis activities data reduction, data display and conclusion drawing and verification [16]. The coded information was compressed into maps, to enable reviewing and unscrambling of the research data. Themes were drawn from the data. Finally, the objects that had similar characteristics were clustered to build theory [16].

Results

Through analysing the data of the real use of domestic cold appliances, the householders' real needs and its environmental impacts were identified and divided into five 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. The first two of these are outlined in more detail in the following sections

Use Scenarios of the Household Fridge and Freezer

The video footage illustrated the flow, order and disorder of "everyday life" in eighteen households regarding the use of cold appliances. It exposed that the use impacts with the refrigerator 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 use of the domestic refrigerator. The analysis was focussed on three areas of intensive work with the

fridge and freezer: “morning”, “evening meal” and “unpacking grocery shopping” to identify the sequence of routinising use. In this paper only morning activities will be discussed.

Morning

In the households where members were out at work or school during the weekday, a flurry of activities conducted with the fridge needed to be done for the day ahead in the early morning. Unsustainable use patterns of 15 fridges during the breakfast preparation in a normal weekday were selected as samples. It revealed two most damaging behaviours of fridge use in the morning: “high frequency of door opening” and “left door open”. Combined with the demographic information from user profile questionnaires, a more detailed analysis of the factors influencing the fridge use was produced. It suggested that “rushers” were heedless of the time of opening of the fridge door, as all the tasks got achieved with the largest amount of conveniences and the least amount of effort.

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

- Number of family members: In a 5-person household, 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 2-person families only opened it 5-6 times mainly for a drink during breakfast.

- Age of children: adults got up early to prepare and had breakfast with their younger children; while in the family with the teenage children, older children had independent breakfast and the fridge was used more.

- 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, always was taken out repeatedly.

- Different types of drinks: the variety of drinks for breakfast increased the number of times doors were opened. Also, if two of family members drank different juices, in the behavioural records, they usually opened for two kinds of drinks out and 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 the fridge more*.*

- The preparation of the fruit bags and lunch boxes for work and school.

It can be found that “rushers” often intended to get “quick tasks” done with the door opening, such as, checking expired date of the items, pouring drinks for breakfast (Figure 1), searching for vegetables in the bottom drawers, making lunch boxes and fruit bags and transferring items between worktop and fridge one by one. For example, *the wife spent 68s transferring foods for breakfast between worktop and fridge and the son left door open for 70s to make sandwiches (MUS-F04)* (see Figure 2).

Figure 1: pouring milk for breakfast with door open (MUS-F17)

Figure 2: left door open for 70s to make sandwiches (MUS-F04)

Householders who were knee-deep in morning chaos failed to be organised during the breakfast preparation. Firstly, they were not planning in advance. The wife opened the fridge 5 times 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 during breakfast time (MUS-F15); and twice in 2 persons household within 5 minutes (MUS-F02).

Fridge and Freezer in Use and Fridge and Freezer Design

The findings from the Product-in-use observations and interviews indicated that there existed a variety of use patterns of fridge and freezer 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.

Use content

The interviewees pointed out that the main functions of the domestic refrigerator were to: prevent bacteria multiplying; keep food fresh; maintain and chill food and drink as well as provide a sensible storage for the food and drink. The divergences in the opinions lay egg storage and individual preference for cold food and drinks. Some of the participants stressed the need for chilling certain food and drinks. In some households there was a second fridge particularly for keeping wine cool. Load conditions also affected the energy efficiency can be seen in the following three aspects: having the refrigerator overcrowded or too empty and placing food in a mess represented in Figure 3. There are several issues influencing overfilling including: having parties or visitors, the frequency of shopping affected by work patterns and the distance between the shops/supermarket and home, the life stage of the users affected by having children and having a healthier diet. Going on holiday is the time for users to use up or throw away the food to ensure the fridge as empty as possible. Leaving the empty fridge running then became one of the harmful use behaviours which should draw the designers' concerns.

Figure 3: overfilled fridge; "empty" fridge; food placed in a mess

Linking the interview and the observation, the data showed that consumers also located items because of: "Frequency of the use" - for easy access; "Routinising practice", habitual place; "Where there is space"; "Fridge design". On reflection, these examples strongly supported the argument for three perceptive elements of daily practice model [23]. When householders interacted with the refrigerators, they oscillated between:

1. Keeping in control with intentions and understandings constituted through a more or less conscious assessment of existing practice, for example, "frequency of the use" and knowledge learnt from past experience and others, such as, family home, friends and media including magazines, cookery magazines, TV and radio.

2. Routinising behaviour without awareness - a habit that is "highly automated" [24] 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 refrigerator while they could not make themselves clearly for why they do in that manner in the interview.

3. Lacking of principles without plans - letting things go in a disorganized 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 locating principle of “Where there is space” and interestingly “fridge design” might offer the possible solutions to this problem caused by user behaviour.

Another issue about environmental intentions and actual behaviour is evident in the user study. Users who considered themselves environmental friendly could not integrate energy conscious behaviour into every part of their daily routines. Whilst element 1 of the daily practice model embodied the agreement among the real action and intention and desire for “being green people”, element 3 symbolised “being out of control” and “lock-in the daily practice”. Observing routines indicated practitioners’ shift from element 1 to element 3. For instance, MUS-F02’s daily interaction with the fridge, such as, placing food inside the fridge, food preparation, was a lot more “relaxed” than putting away her grocery shopping.

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 purchased in the future. However, it was reported that the space left for the refrigerator was the main restriction of the purchase of American side by side style or bigger size refrigerator.

Observing use routines of the fridge and/or freezer exposed how these were tied up with bodily movement, with the design of the appliance and users’ capability of adaptation to the design as well as with the use impacts on environment. 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 fridge had to always bend, squat or kneel down to reach the back and bottom of the fridge for search for the desired item and sort out content. Figure 4 illustrates this in more detail.

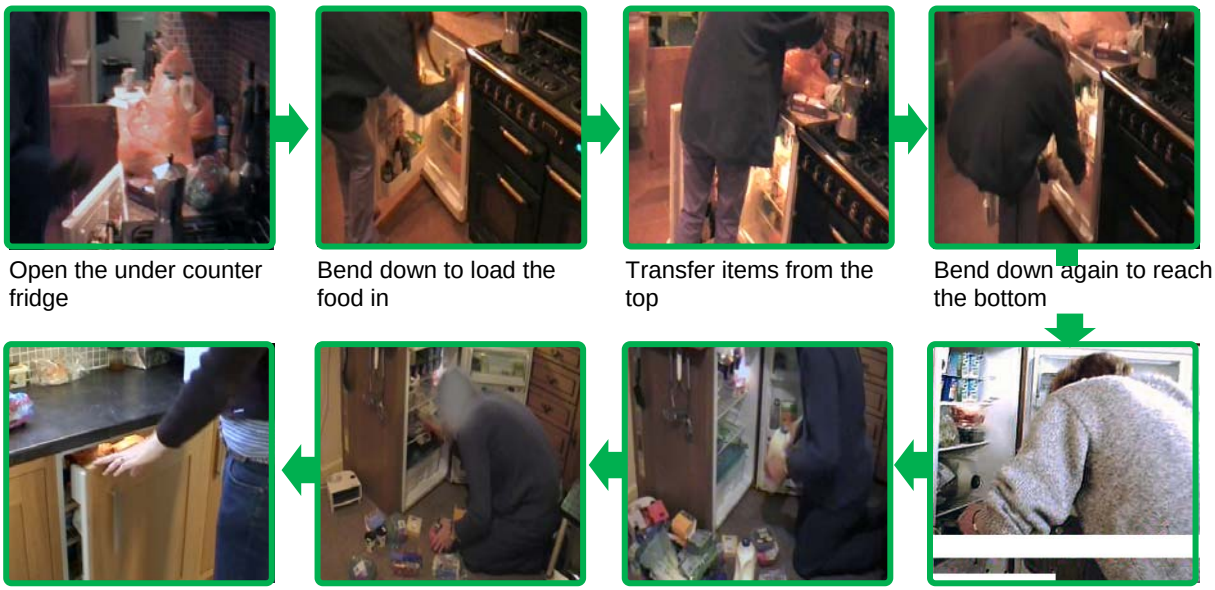


Figure 4: routines of movement when using the under counter fridge

- 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 the shelves, doors and drawers. The participants also exhibited how they designed and rearranged their fridge to meet their individualised needs as tasks could get achieved with a degree of effortlessness. Table 4 gives some examples of this.

Table 4: daily interaction with the shelves and drawers


The top shelf is too high to reach; "things on the top may be the things that you do not pull out very open. It is just storage" (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); "When I put the shopping away, if 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.

- Issues related to the accessories of the fridge and/or freezer:

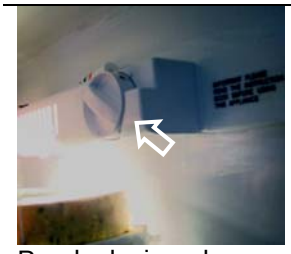
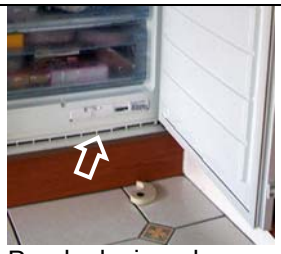
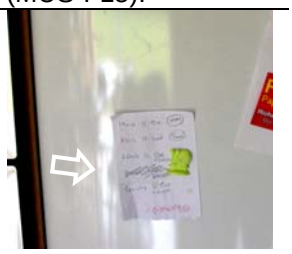
Product-in-use observation not only captured flaws in product performance and highlighted design limitations of the accessories and functioning parts in the fridge and/or freezer but also uncovered the latent customer needs and ways in which users adapt products to better suit their needs. Combined the findings of observation and the interview, the gaps between the consumers' "actual" versus "assumed" needs were identified, some examples are given in table 5 below.

Table 5: use condition of the accessories of the fridge and/or freezer


Poorly designed door vs. user's arrangement of the shelf–"the door compartments are difficult to arrange for cartons and bottles" "We took out egg tray out here (to make the space high enough for keep the big bottle)" (MUS-F03).

Poorly designed can holder-"This is space for cans but it just wastes space. We have hardly ever put cans" (MUS-F07).

Poorly designed temperature control panel-inside the door, users have to open the door to check or adjust the setting.

 Poorly designed temperature adjuster - Hard to understand	 Poorly designed temperature setting - Hard to read	 Poorly designed ice-cube tray	 Use condition of egg trays - most of the participants do not use the egg tray
 User's way of storing eggs - "we put eggs into the fridge with box since there is date on the box" (MUS-F01).	 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 has eggs in, it wastes a lot of space on the top and second shelves (MUS-F15).
 Use condition of bottle racks (MUS-F08)	 Underlying needs – additional containers to keep cheese, fruit and vegetables.	 Poorly designed instruction	 Underlying needs "food calendar" - note of expired date of food on the fridge

Discussion

The results of the main user study clearly illustrated that the different usage patterns of household fridges and freezers resulted in unnecessary energy consumption. Analysis of the routine use of household electronic appliances proved that the three perceptive elements of the daily practice model [23] existed between which users swung. It explicitly suggested the behaviour in terms of the use of household cold appliance is complex and informed or restricted by a range of internal and external factors. There is a gap between environmental intention and real action as well as issues arising from the routine practice performed automatically with little deliberation ingrained in our use patterns of the fridge and freezer. It was also found that how the household appliance and kitchen infrastructure came together with the purpose of directing and influencing people to behave in a specific way. "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). However, due to the complexity of motivations for shifting behaviour, different levels of interventions need to be designed accordingly to ensure behavioural and habitual change.

The following sections presented a few examples of the how design-led interventions can facilitate user behaviour change to improve the energy efficiency of the fridge and freezer. Based the discussion, the suggestions were divided into four levels: product design, system design, service design and food packaging design.

Changing user behaviour through sustainable product design

Firstly, the results show there is a lack of consumer awareness of the link between their personal behaviour and the direct impact on the environment and energy use. Design-led interventions would need to build on energy conversation to guide a behavioural change. Designing an effective way of communicating makes sure consumers know how to use the product efficiently through a range of design interventions through providing information, choice, feedback or behaviour spur [23], 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). For example, some kind of scale is for users to see how efficient they are, advisedly; in term of cost because that is what people understand. Also as MUS-03 suggested, a counter was to 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 could limit behavioural energy waste of the fridge and/or freezer, such as, separate temperature drawers and shelves and “more doors” to reduce the cold air exploration when the door was open. Making good use of space inside the fridge was 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 back easily and to make much more useful room in fridge. Additional, 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 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 consumers with a clear view of the food inside the fridge and freezer decreasing food waste and the amount of time with the door open.

Influencing user behaviour through sustainable system design

The modern kitchen design restricted 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). It needs to be a 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. Taking the food storage, preparation, fridge and freezer design and kitchen design as a whole into consideration, designing a food system in the kitchen could encourage sustainable energy and food consumption behaviour, such as, to reduce the energy losses of transferring items and the food waste. Furthermore, kitchen infrastructures would be designed for the user to operate electronic appliances at ease and get tasks achieved with deftness and effortlessness. For accessing the items inside easily, the fridge might be placed at the suitable height and location for the practitioners to reduce the time waste for bodily movements.

Facilitating change in user behaviour through sustainable service design

As discussed the loads in the fridge and freezer had links with 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 consumers 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 harvested 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 a local community services may be set up to reduce the energy and food waste during the food life cycle from growing, storage, consume, give away leftover or needless purchase to the end of food disposal. Moreover, considering the life cycle of the fridge and freezer, more services should be provided by manufactures including supplying more choices of the accessories kit, such as the compartments, shelves and drawers, detailed DIY repairing tips and other measurements to encourage the user replace older machines with newer, more efficient ones. This would avoid unnecessary replacement, usage of a second cold appliance and unnecessary energy consumed by more than ten-year-old mode.

Assisting change in user behaviour through sustainable food packaging design

According to the type and shape of the food or food packaging, more behaviour constraints and affordances [23] can be designed to lock the location of the food quickly. And the label on the packaging needed to be read easily in order to transmit the information better and to reduce the time for user to check the expired date or look for the desired item with the fridge door open.

Conclusion

This paper concludes that usage patterns studies can offer rich resources to assist manufacturers and designers in minimising environmental impacts product use. The qualitative data uncovered the way in which the product is used and its unnecessary energy use, the gap between environmental awareness and real action, and the reasons for such a gap. It also identifies the critical role of product design plays in daily routines. By understanding the limitations with current designs and the affects they have on user behaviour, a real potential was identified to enable design to create “better” user behaviour. The suggestions presented are some examples of design ideas that could be drawn from the behaviour study. The next step will be to create some ‘behaviour changing’ product ideas from each suggestion and test them 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.

References

[1] Evans, S., Burns, A. and Barrett, R., *Empathic Design Tutor*, Cranfield University, UK, 2002

[2] Maguire, M. *Methods to support human-centred design*, International Journal of computer studies, 55, 2001,pp. 587-634.

[3] Wood, G. and Newborough, M., *Dynamic energy-consumption indicators for domestic appliances: environment, behaviour and design,* School of Engineering and Physical Sciences, Heriot-Watt University, Edinburgh, Scotland, UK. 2003

[4] Energy Saving Trust, *The rise of the machines. A review of energy using products in the home from the 1970s to today*. June2006. Can be downloaded at: www.est.org.uk/uploads/documents/aboutest/Riseofthemachines.pdf .

[5] CAT. *Cool It!* Tipsheet, Centre for Alternative Technology. Retrieved March 25, 2007, from http://www.cat.org.uk/catpubs/pubs_content.tmpl?sku=PUBS_20/08&key=ts_cool

[6] BERR, *Energy White Paper, Section Two. The Low Carbon Economy, Chapter 3: Energy Efficiency*, 2003, from http://www.berr.gov.uk/files/file21192.pdf.

[7] MTP., *Domestic: Cold Appliances, Market Transformation Programme, Supporting UK Government policy on sustainable products*, 2007, from http://www.mtprog.com/SelectProductStrategy.afspx?intSelection=1&intSector=1

[8] Environmental Change Institute. *40%house*, Oxford University, Oxford, UK, 2005

[9] Lockwood, M. and Murray, R. *RED Future Currents: Designing for a changing climate*. 2005

[10] Mintel, *Fridges and Freezers - UK - March 2007 Market Intelligence Essentials, Marke Intelligence: UK*, 2007

[11] Mennink B.D. and Berchowitz D.M.,*Development of an Improved Stirling Vacuum Super Insulated Fridges with Thermal Store and Photovoltaic Power Industrialized and Developing Countries*, IIR Conference - New Applications of Working Fluids in Refrigeration and Air Conditioning, Hanover, Germany. 1994

[12] VHK. *Refrigerators and Freezers, product case 5*, Methodology Study Eco-design of Energy-using Products (MEEUP) for European Commission,final report, Delft, 2005, from http://www.vhknet.com/download/MEEUP_Methodology_fin.pdf.

[13] Takahiro Tsurusaki, Yumiko Iwafune, Yoshiaki Shibata, Chiharu Murakoshi, Hidetoshi Nakagami *Actual Energy Consumption of Top-Runner Refrigerators in Japan*, Jyukankyo Research Institute, Inc., Japan, 2006

[14] MTP., BNC11: Domestic refrigerator test standard vs. real-use energy consumption, 2007 http://www.mtprog.com/ApprovedBriefingNotes/PDF/MTP_BNC11_2007May2.pdf

[15] Strauss, A., and Corbin, J., *Basics of Qualitative Research: Grounded Theory Procedures and Techniques*. Sage Publications Ltd, USA, 1990

[16] Miles, M. B., and Huberman, A. M. *Qualitative data analysis: an expanded sourcebook* (2 Ed.). Thousand Oaks: Sage Publications. 1994

[17] Sanoff, H. I*ntergrating programming, evaluation and particiation in design: A theory Z approach*. Hants Ashgate.1992

[18] Knoblauch, H., Schnettler, B., and Raab, J. *Video Analysis. Methodological Aspect of Interpretive Audiovisual Video-Analysis in Social Research*. In Knoblauch, H., Schnettler, B., Raab, J. and Soeffner, H. (Eds.), Video Analysis: Methodology and Methods, Oxford: Peter Lang. 2006

[19] Lofthouse, V. A. and Lilley , D. *What they really, really want: user centered research methods for design*, International design conference–design 2006, Croatia, May 15-18, 2006

[20] Kelley, T. *Innovation Begins with an Eye, the Art of Innovation* ,IDEO.Doubleday Publishing, 2001

[21] Daut, T. *Recording the "Habitus"*. In Pole, C.(Eds.) Seeing in Believing? Oxford: Elsevier. 2004

[22] Berger, A. A. *Media Research Techniques* (2 Ed.). London: SAGE, 1998

[23] Tang, T. and Bhamra, T. *Changing Energy Consumption Behaviour through Sustainable Product Design*, international design conference-design2008, Croatia, May 19-22, 2008.

[24] Jackson, T. *Motivating Sustainable Consumption; A review of evidence on consumer behaviour and behavioural change* In: A report to the Sustainable Development Research Network as part of the ESRC Sustainable Technologies Programme Centre for Environmental Strategy, University of Surrey, Guildford. 2005

[25] Siegle, L. *Your home may be hurting the planet Guardian Unlimited*, June 8, 2006, Can be downloaded at: http://observer.guardian.co.uk/shellenergy/story/0,,1793286,00.html