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Understanding Consumer Behaviour to Reduce Environmental Impacts through Sustainable Product Design

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Abstract

The use phase of the lifecycle of electrical products has a significant environmental impact, mainly determined by the consumer's behaviour. Many consumers do not make the link between their daily consumption behaviour in the household and environmental problems such as climate change. In the 21st century, the residential sector, together with transport and industry, is one of the largest man-made contributors in the UK to climate change. It is argued that technological innovations, current eco-efficient products and consumer education have been ineffective in creating the long term radical behavioural change needed to reduce the impact of product use. Products, as the interface between consumers and consumption activities, have the potential to influence the way in which consumption occurs. In the sustainable design field however, designer responsibility traditionally considers raw material selection and product disposal. There is limited work that addresses the environmental impacts relating directly to use behaviour of the product.

This paper illustrates that user behaviour studies can be the preliminary step for designers to improve energy efficiency of products. A single product type, household cold appliance, was chosen as a case to explore the capacity of designer-conducted user study to identify unsustainable aspects of product use. Adopting a user-centred approach, two pilot studies were used to gain an insight into domestic fridge and freezer use in the UK. Qualitative ethnographical research methods were employed to investigate the daily practices and "real" needs of user as well as the connection between the knowledge, attitudes, intention and actual action. The design suggestions drawn from the user behaviour analysis provide examples of how energy impact level of the interaction with the product can be reduced through design.

Keywords

User-Centred Research; Sustainable Product Design; Changing Consumer Behaviour; Design Research; Household Energy Consumption; Household Cold Appliance.

Between 1970 and 2006, the growth of total energy demand was almost 7% whilst domestic energy consumption increased by an astounding 24%. The residential sector makes up around 30% of total UK energy demand (BERR,

2007) and more than a quarter of end-user carbon dioxide emissions (Defra, 2007). 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, 2006), 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 in the appliances and manufacturing has hardly achieved the reduction in the domestic energy consumption. To date there has been little work specifically focussed on the user and this is an area of considerable potential given that consumption is the reason why things are produced and how the things are used.

Consumption is not only purchasing, but developing routines and rituals of use and modifying the product concretely or symbolically. According to Koskijoki (1997), consumption involves the selection, purchase, use, maintenance, repair, disposal and recycling of any product or service, as opposed to their design, production and marketing. It has been identified that efficiency gains achieved in the product and manufacturing have been overridden by consumer preferences for more appliances and unsustainable patterns of use. On one hand, in modern society with increasing levels of affluence, rapid technology development and specialised trends in product design provide people sufficient abilities and opportunities to own what they want to own, leading consumers' towards a more individualistic (Sanne, 2002; Jackson, 2005) and more hedonistic lifestyle (Vergragt, 1998; Buchholz, 1998). Multi sociological and psychological motivators behind the 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. On the other hand, the manner of consumer interaction with the product has large impacts on the environment (Environmental Change Unit, 1997; Sherwin & 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 resident's behaviour is responsible for 26–36% of in-home energy use. Governments have continued to seek consumers' active participation in the environmental debate by a range of information campaigns, however, literature suggests that these measures have largely been ineffectual in creating sustained long term change in the majority of consumer's behaviour (Jackson, 2005).

Products, as the interface between consumers and consumption activities, can give immediate and direct responses to users' operations: how it is perceived, learned, and used. Designing a product means designing a user experience with the product, which also determines the compound impacts of this experience. A better understanding of what users do with, and how they interact with products as well as the hidden factors behind the daily decision-making process should be gained in order to develop a valid critique of environmentally significant consumption.

This paper aims to show that in-depth user research can be the breakthrough point for developing new energy efficient products. A single product type, household cold appliances, was chosen as a case to explore the capacity of designer-conducted user study to identify unsustainable aspects of product use. The user-centred approach (Evans et al, 2002; Maguire, 2001) is adopted in two pilot studies to understand the user behaviour and activities around household fridge and freezer in the UK. Qualitative ethnographical research methods are employed to investigate the daily practices and “real” needs of user as well as the connection between the knowledge, attitudes, intention and actual action. Moreover, the case study presents an example of the way in which the design solutions can be drawn from the user behaviour study to reduce environmental impacts.

The Environmental Impacts of the Household Fridge and Freezer

There are very few pieces of equipment in the home 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 (Energy Saving Trust, 2006) and 25% of the average household bill (Ethical Consumer, 2001, cited in: CAT, 2007). The Energy Saving Trust (2006, 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 (MTP, 2007b).

As part of the research a literature review was conducted to build understanding of current research, commentaries and solutions for reducing environmental impacts in three areas: directions of policy and legislation, solutions of manufacturers and technology, and knowledge of institutes and public bodies.

To reduce environmental impacts 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 (MTP, 2007b). However, about half the efficiency gains have been offset (Energy Saving Trust, 2006) by the “rebound effect” (Velden, 2003; 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 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 (Lockwood and Murray, 2005). On the demand side, it is reported that every household at least own one cold appliance often with two or more (Environmental Change Institute, 2005). A survey by Mintel (2007) 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. Furthermore, using small drink chillers and coolers in the bedroom, living room

and car is becoming popular. The Energy Saving Trust report (2006, p. 27) states that "a small drinks chiller can use half more electricity than an under-the-counter A-rated fridge". 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. 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 and so on (VHK, 2005; MTP, 2007b). In research of the real-life usage, the consumer surveys on actual energy consumption have given the following results (see Table 1 below).

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, 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. There is limited work within design concerned with the environmental impacts of operation and energy consumption of real-life usage of the product.

Table 1, difference in electricity consumption of fridge and/or freezer between actual and the label provided by research from different countries (Mennink et al. 1998; VHK, 2005; Tsurusaki et al, 2006; MTP, 2007a, 2007b)

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 & Berchowit z (1994) 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 (Tsurusaki et al 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)

Methodology

User-centred research techniques were used to capture opportunities for design to solve environmental problems of use behaviour and activities around the fridge and freezer relevant to energy and food consumption. Product-in-Use observation was carried out with aid of audio-visual equipment. The visual recordings enable researchers to “capture peoples’ behaviour in real-life contexts” (Evan et al, 2002, p. 18), offering more detailed and more accurate source of daily practices and routines (Knoblauch et al. 2006). It is an “interactive, naturalistic” (Evan et al, 2002, p. 18) method to record “behaviours which people may not report or be able to articulate when asked, such as habitual behaviour” (Loffthouse & Lilley, 2006, p. 3). It is also a good method to identify true opinions and actions as people often say one thing but think or do another (Kelley, 2001). Schmid (2006) suggests that a comparison between interview statements and everyday observations for the same person often reveals the difference between their thoughts and own actions. Video analysis of the practices and everyday routines can be used to generate new product ideas, redesign existing products and evaluation of those new concepts or prototypes.

As illustrated in Figure 2, a series of user studies were developed to test the effectiveness of the strategies identified in the literature review. These aimed 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. A questionnaire and semi-structured interview were developed to investigate what consumers think about their fridge and freezer and the environmental impacts of their use. The interaction between the user and the product assesses 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. Then, 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.

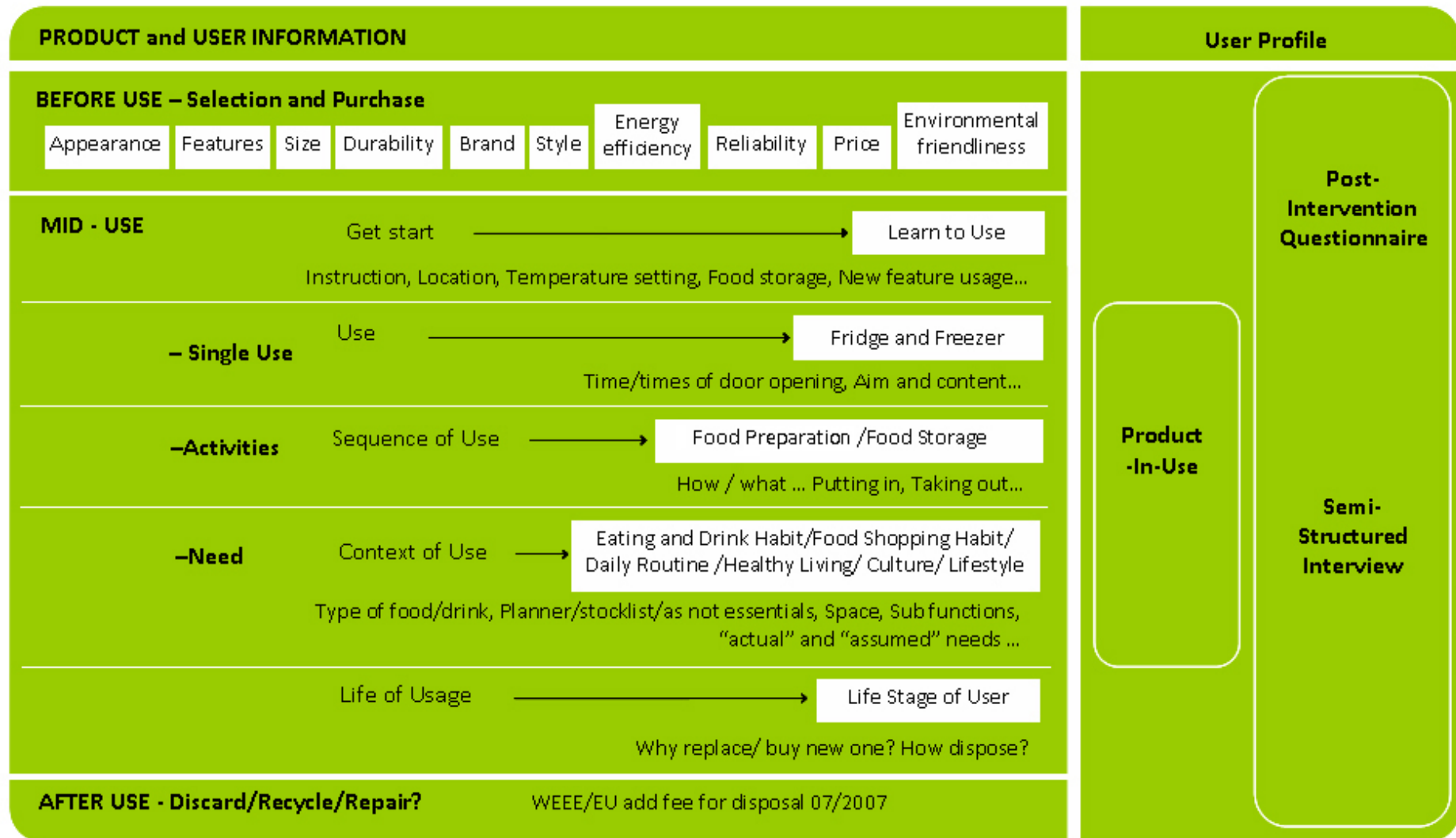


Fig. 2 Interaction with the fridge and freezer and user centred research approach

Pilot Study

In the first pilot study, the subjects were asked to fill out a kitchen user profile questionnaire and told that the study aimed to understand the relationship between the user and their kitchen. This cover story was used to avoid the unnatural desirable response tendencies (Verplanken & Faes, 1999). Two observations were then carried out to record food shopping unpacking and food preparation. Finally, a semi-structured interview and post intervention questionnaire provided a chance for participants to explain their behaviour in the observation sections. 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.

Pilot Study 2 added a 24-hour recording to the observation section and a range of questions about the factors influencing decision making and behavioural change to the post-intervention questionnaire. Three families 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 35-50 and had owned their fridge or freezer for between 1 year and 9 years. Figure 3 demonstrates the methods employed to understand consumer behaviours in the two pilot studies.

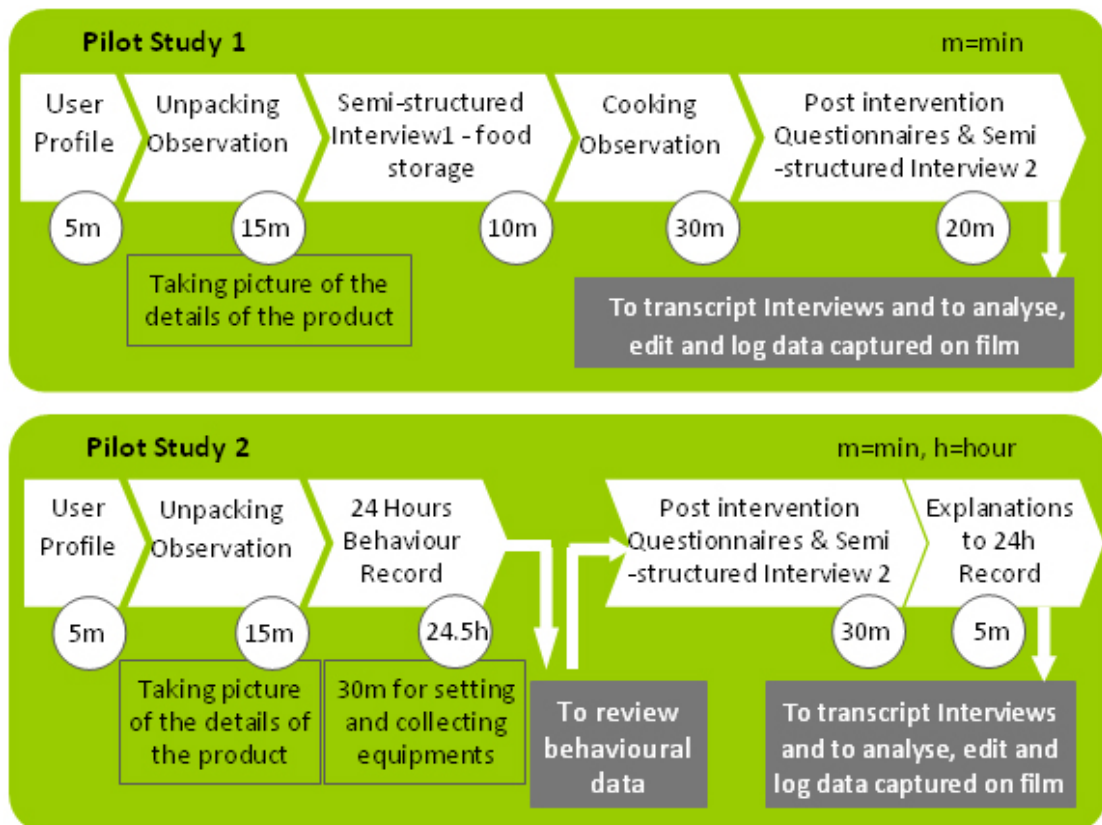


Figure 3 user centred research methods used in the two pilot studies.

Two pilot studies were designed to test the effectiveness of the approaches which aimed to gain an insight into their actual use behaviours and habits,

their problems and difficulties in operating the product, "actual" and "assumed" needs as well as look for opportunities for product design solution to bridging the gap between the intentioned use of a product and actual use patterns in order to reduce the environmental consequences.

Findings and Discussion

Studying user behaviour through user-centred research methods

The cover story 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. Combining Product – in – Use with post-intervention interview and questionnaire was particularly useful in exposing the environmental intention-actual behaviour gap in energy and food consumption. The post-intervention questionnaire and semi-structured interview provided the explanation of motives and reasoning for such behaviour, revealed the information about the decision-making process and the emotional and social context of product use. The user centred methods adopted in Pilot Study 2 were more effective in representing the real situation of the product use than in Pilot Study 1.

Changing user behaviour through sustainable product design

The data collected from the pilot studies provides interesting evidence to support the theory that an understanding of real use behaviour is 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. 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. This previous experience and knowledge saved time when returning things back to the fridge. Understanding what is an operational principle of the consumer, helps to reduce door opening time. The results of observations showed that consumers located items according to the following principles:

Expired date of food: all subjects put new 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 shelf at eye-height level or in the top door bin;

Types of food: packing the same type of things together helped to find food that they wanted, for example, User-02 put all pizzas in the chest freezer vertically side by side and they can be read on the spine easily;

Food packaging: sealed and packed foods and drinks such as strawberries, ready meals, beers, are stuffed on the shelves and one overlapped another; meat often went to the bottom glass shelf because the packaging may be broken and "it will not drip on everything" (User-03);

Weight of the items: "heavy" things, such as potatoes and carrots often were kept in the bottom of the drawer underneath the soft vegetables and fruit such as tomatoes and grapes, since "the heavy items squash everything";

User of food and drinks: for example, foods often sorted for the children, i.e. children's foods are located at User-01's eye height level and their mini cheese in the top door bin.

Temperature distribution in the fridge: consumers used the different temperatures inside the fridge to decide where to locate mince meat, ham and cheese, this was usually at the back of the fridge, however this lower temperature often froze vegetables;

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

Habitual place for certain food and drinks.

These points in routine fridge and freezer use patterns can be used to develop more acceptable product-led solution to improving the loading efficiency. A more adaptable interior, for example, would enable consumers to create the optimum arrangement of their food and drinks in the fridge and freezer. Additionally, according to the type and shape of the food or food packaging, more behaviour constraints and affordances (Tang & Bhamra, 2008) can be designed to lock the location of the food to save the thinking time of where they belong. 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.

The findings indicated that the condition of real use of fridges and freezers varied during the product life. It is not only related to the householders' shopping and cooking habits, but also the life stage of the consumers. The reasons for placing different amounts of consumables in fridges and freezers and the reasons given for purchasing of 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, since they had been leading a healthy lifestyle for couple of years;

One of the households' fridges became over full after they had children;

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 a third of the subjects had a second fridge or freezer running for keeping party food occasionally.

Providing consumers 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-out items in a "normal" day. 40% of door opening times were for milk to drink with meals or make tea, 10% for margarine and 4% for both. 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. What is more, in the user study, hiding food at the back of the shelf was one of the contributors of needless food purchase and food wastage. 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 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.

Guiding and maintaining changes in intention and habits through sustainable product design

By analysing the interviews, the barriers that may prevent energy-conscious practices taking place are summarized below;

Invisible energy: consumers were not aware of the amount of individual electronic equipment use.

Unawareness of the link: in ordinary people's opinions, the way of using fridge had small effects on electricity use;

Lack of Information: consumers felt that the cold appliance is a part of modern life and compared to the running cost it was more important to set lower temperature to ensure the quality and taste of the food and drinks, although, none of participants had ever measured the actual temperature inside the appliances and on average, fridges are operating at 5°C higher than recommended temperature;

Lack of concern: Product-in-Use observation, all young family members left the door open while transferring items for quick food and lunch box preparation;

Lock in lifestyle: participants assume that product is efficient enough by itself and there is no need for a conscious behaviour to improve the overall energy performance.

To address these, design-led interventions would need to build on the 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 such as providing information, choice, feedback or behaviour spur (Tang & Bhamra, 2008).

Changing user behaviour through sustainable system design

Modern kitchens were identified by participants to be the main restriction of consumption behaviour with regard to fridges and freezers. It not only required a second, often empty counter fridge and freezer to fit in but also it was responsible for half of cold appliances in the study were built-in style fridges and freezers and one third were located next to the oven. What is more, limited storage space in the kitchen is another reason for refrigerating some items that do not need to be. Therefore, designing a food storage system in the kitchen could provide design-led solutions to facilitate sustainable energy and food consumption behaviour.

Conclusion and Further Research

This paper presents how user-centred research methods can be used to illustrate product use behaviour and habits and their environmental effects.

The findings from the fridge and freezer use behaviour study highlight that understanding consumer behaviour can be the preliminary step for seeking solutions to minimizing environmental impacts of the household consumption through improving product design. The pilot studies not only uncover the different ways of using the product and its unnecessary energy and food consumption, but also identify the gap between environmental awareness and real action, and the reasons for such a gap. Firstly, the results show there is a shortage of consumer awareness of the link between personal behaviour and the direct impact of such on the environment and energy use. In addition, the routine practice and habitual activities ingrained in our use patterns of energy-consuming products are performed automatically with little deliberation. Also, the findings indicate that younger users tend to behave in a less sustainable way related to energy consumption (i.e. preparing food and filling vegetable box with fridge door open). What is more, the interaction of the consumer with the fridge and freezer exposes cultural and social values that conduct the ordinary consumption behaviour. The fridge and freezer can be considered as an epitome of the consumer's personal lifestyle. Food that is stored in the fridge and freezer, connected with the activities around the product, reflects the quality of life - consumers' approach to healthy eating and drinking, shopping habits, daily routines and arrangement of the leisure time.

These pilot studies pave the way for the future research. A series of main user studies is underway to detect what influences people's behaviour to reduce the impact of consumption. Furthermore, future work will investigate further how to design to shape the way of interacting with the product, as well as to bridge the considerable intention - behaviour gap between environmental values and consumer everyday action and locked-in occurrence. The findings will be applied in design to illustrate how consumer behaviour can be improved through sustainable product design.

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Tang Tang has a BSc and an MSc in Industrial Design and is currently undertaking a PhD in the Department of Design and Technology at Loughborough University. The aim of the research is to investigate how designers can influence user behaviour through sustainable products design. Her core research interests lie in identifying behavioural and psychological drivers for consumption and the environmental impacts of household appliance use and exploring sustainable design for behavioural change.

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Dr Tracy Bhamra is a Reader in Sustainable Design and Leader of the Sustainable Design Research Group in the Department of Design and Technology at Loughborough University. She is a Chartered Engineer, a Member of the Institution of Engineering and Technology (IET) and a Fellow of the RSA. Dr Bhamra has over fifteen years of research experience in Sustainable Design and has been active in developing this new research field within the UK and is the founder of the Sustainable Design Network. She holds a number of UK Government funded research projects investigating Sustainable Design and its implementation in industry.