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# Using a Practice-Orientated Approach to Inform the Design of Energy Efficiency Measures for Older Homes

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## Abstract

CALEBRE, a four year research project, is developing technologies to improve the energy efficiency of solid-walled housing, particularly in the owner occupied market. The engineering partners within the project require very specific information from user centred design practitioners in order to develop innovative glazing, heating, ventilation and insulation technologies. However the project recognises that it is the 'soft factors' that must be addressed in order to make these measures acceptable and appealing to householders. This requires a deeper understanding of users' motivations for improving their homes and the complex interplay of factors relating to aesthetics, lifestyle, life events, energy efficiency and finance.

Rather than solely focussing on specifying user requirements for each of the project's energy saving technologies, CALEBRE is taking a systemic approach, seeking to understand what householders value about their homes aesthetically and practically and the home improvement practices they currently adopt in order to maintain and improve their homes. The introduction of energy efficiency measures requires the homeowner to make major one-off (often irreversible) decisions relating to the structure and appearance of their homes. Understanding the factors shaping such significant acts of consumption is therefore essential if wide-scale adoption of such measures is going to be achieved.

This paper presents the challenges associated with using a practice-orientated user-centred design approach to inform the design of energy efficiency measures and the strategies for retrofitting these technologies into older homes. It will introduce two data collection methods developed within CALEBRE specifically to address these challenges.

## **Keywords**

*Sustainability, practice orientation, user-centred design, home improvement*

## **1 Introduction**

CALEBRE, a four year UK research project funded by EPSRC and E.ON, aims to establish a validated, comprehensive mechanism for reducing UK domestic carbon emissions within solid walled housing that is acceptable and appealing to users. The project takes the approach of identifying, from a user perspective, the barriers and key challenges to the deployment of retrofit carbon-reduction technologies, and then by using the knowledge gained through householder engagement and surveys to appropriately modify selected technologies for field-trialling and user evaluation including thermal comfort evaluation. The selected technologies include electric and gas-fired heat pumps, home ventilation heat recovery, energy-efficient vacuum glazing and innovative advanced surface treatments to control temperature and moisture via nano-technology. (Vadodaria, et al. 2010).

The CALEBRE project is focusing on older properties (pre-1930) in the UK which were constructed with solid (as opposed to cavity walls). These are often referred to as 'Hard-To-Treat' homes, as they offer significant challenges for energy saving. The growth in housing during the late 19th century has meant that the UK presents a unique challenge in addressing its solid walled properties. The project is also focusing on owner-occupied homes (homes that are lived in by their owners, who are therefore responsible for, and have to fund, any upkeep of their home). According to the English House Condition Survey 2007, 15.5 million homes in England are owner-occupied, with 29% of these homes (4.5 million) having non-cavity walls. The UK Energy Research Centre's scenarios for the UK energy system in 2050 anticipate that significant energy efficiency measures will need to be introduced to homes in combination with behavioural changes in order to meet the Government's carbon reduction targets (UK Energy Research Centre 2010). Given that up to 75% of the housing stock that will exist in 2050 is already constructed (Boardman, et al. 2005), understanding how to maximize the energy savings achieved through retrofitted measures is essential if carbon reduction targets are to be met. This requires an understanding of the process by which home owners undertake home improvements and their motivations to do so. It also requires an understanding of everyday practices, routines and lifestyle choices in order to

ensure that the energy efficiency methods developed are acceptable and appealing to consumers.

A practice orientated User Centred Design (UCD) approach has been developed in order to inform two particular research questions:

- How should the energy efficiency measures be designed to ensure they meet the needs of householders?
- How should the process of retrofitting energy efficient measures be implemented to ensure it engages homeowners and fits with their other home improvement activities?

This paper presents the particular challenges associated with using a practice-orientated approach in this context and introduces the data collection methods developed within CALEBRE to address these challenges.

## **2 Methodological challenges**

The long established premise for UCD is that an early focus on user requirements leads to the design of useful, useable and desirable products. The principles of UCD (Gould and Lewis 1985) are generally accepted to be an: early focus on users and tasks; empirical measurement; and iterative design. Preece, et al. (2002) suggests five further principles that expand and clarify the first principle. These are:

- Users' tasks and goals are the driving force behind the development.
- Users' behaviour and context of use are studied and the system is designed to support them.
- Users' characteristics are captured and designed for.
- Users are consulted throughout development from earliest phases to the latest and their input is seriously taken into account.
- All design decisions are taken within the context of the users, their work and their environment.

The latter does not necessarily mean that users are actively involved in design decisions but designers should remain aware of user requirements when making design decisions. Preece et al. conclude that providing "an easily accessible collection of gathered data" will help designers remain focused on user needs. Clear communication of requirements to designers in a way that is meaningful and relevant is therefore a crucial component of UCD.

Practice-orientated design approaches are becoming increasingly popular within many fields of design including Sustainable Design (Kuijter and de Jong 2009). Although essentially still user centred, such approaches prioritise understanding of routines, habits, conventions and conceptions of normality over efforts to make individual technologies or behaviours more efficient (Shove 2003). It is argued that practice theory provides a meaningful theoretical framework for considering issues relating to consumption (including purchase and use) and for dealing with less tangible issues relating to user acceptance and unpredicted changes in user behaviour that might result from design interventions (Scott, Quist and Bakker 2009). A focus on practice also provides insight into how new technologies and products are normalized into domestic life leading to new practices and social norms (Shove and Southerton 2000).

The needs of the research, led the researchers towards the development of a practice orientated methodology in order to:

- Understand existing home improvement practices.
- Consider not only the use but also purchase of energy efficiency measures by householders.
- Understand how the energy saving measures proposed may impact upon existing everyday practices.
- Ensure that knowledge of everyday practices informed product development.
- Ensure a systemic approach to considering user needs (as opposed to considering the design of each technology in isolation).

Additionally, focusing on practices within the home had other methodological benefits. Many of the technologies under development were likely to be considered novel or complex by householders. By concentrating on practices, householders would be able to narrate stories about their homes and way of life. They should, with the help of appropriate questioning, be able to comment on how a technology might fit into their everyday lives without knowing the detail of how the technology worked. It was anticipated that the researchers would then be able to interpret practice-orientated behaviour to identify implications for design of the retrofit process.

However the project faced particular methodological challenges that led to the development of a bespoke project methodology containing both practice-orientated and more traditional UCD activities. The challenges are outlined below:

*Significant one off acts of consumption:* Practice-orientated research usually focuses upon everyday practices such as bathing (Scott, Quist and Bakker 2009) or doing the laundry (Pink 2005). Such practices may not literally occur every day but are routine aspects of a household's day to day existence. The introduction of energy efficiency measures within the home requires the home owner to make one off, often expensive and often irreversible purchase decisions. The researchers therefore wished to investigate existing home improvement practices to understand how these are embedded in the everyday lives of householders and how they relate to life events and the lifecycle of the home.

Home improvements increase the value of a property as opposed to maintenance activities that are aimed at offsetting physical deterioration (Potepan 1987). Reschovsky (1992) reports that home improvement is one of the least studied aspects of housing economics. To date, little is known about home improvement practices or how they impact upon the retrofitting of energy efficiency measures. Studying these practices required the development of a method to support recollection of past actions and decision making processes. Previous research has shown that visual representations of context considerably help participants recall past events (Mitchell, Harker and Eason 2004). Storytelling has also been identified as a valuable medium for describing not only actions but also feelings and motivations (Erickson 1996). The timeline tool described later in this paper was developed to provide a rich pictorial and personal context for encouraging participants to tell the story of their homes and past home improvement practices.

*Uncovering motivations for making home improvements:* Although the householders were aware that the study was about making 'hard to treat' homes more energy efficient, the researchers wanting to uncover the householders' motivations for making any type of home improvement so that future policies developed to support retrofitting reflected the aspirations of householders regarding the upkeep and improvement of their property. The researchers were also interested in exploring whether saving energy was already a driver for making changes to the property or whether other factors were of greater importance to householders. The methodology was therefore designed so that attitudes to energy saving and climate change were not discussed until the second of two visits, allowing initial discussions to

centre upon home improvement practices, enabling motivations for making changes to the property to be explored freely without potentially biasing the findings through directly questioning participants about their energy saving practices.

*Technologists required specific user requirements:* Practice orientated research is often focussed upon supporting product innovation and the identification of unmet user needs. CALEBRE is developing advanced technology based interventions to increase the energy efficiency of older properties. Through dialogue with the technology developers, the researchers realised that the technologists had some very specific questions that they wanted answering in order to tailor technology development to meet user requirements. For example, heat pump based heating systems provide constant background heat to the home but radiators are likely to operate at a lower temperature than the householders are currently accustomed to. The technologists wanted to know whether the practice of drying clothes on radiators was common place in order to assess whether cooler radiators would be acceptable to householders. Therefore rather than enabling an understanding of everyday practices to drive design and present opportunities for innovation, the study was on the whole seeking to target particular practices in order to address specific technology related questions.

As well as encouraging the product technologists to provide specific questions to inform the user research, the researchers also spent considerable time developing a detailed understanding of each of the technologies under development in order to predict the likely impact of existing practices upon the efficiency of the proposed interventions. This again created the need for targeted investigation of particular practices rather than the creation of a practice driven innovation process.

*A range of technologies were being designed:* A range of energy efficiency measures are being developed within CALEBRE: efficient energy supply through retrofittable heat pumps (gas and electric), energy management and control (mechanical ventilation heat recovery (MVHR) systems) and advanced insulation (vacuum glazing and advanced surface treatments for moisture and temperature control). Generating user requirements to inform such a wide range of technologies placed a strain upon the user research as an equally wide range of daily practices needed to be considered. This made an ethnographic based approach impractical and also meant that the research would need to provide a broad

overview of relevant everyday practices rather than detailed exploration of one practice or daily routine.

The CALEBRE project recognises that although each technology is being developed separately, each house is likely to require a suite of energy efficiency measures. The most appropriate solution for each house will vary according to the physical characteristics of the house but may also be shaped by the practices and preferences of the household. The researchers, whilst recognising that they needed to provide user requirements for each technology, wanted an approach that also allowed them to take a more systemic view that took into account the potential interplay between the different technologies within a future retrofitting context. A practice-orientated approach facilitates this but again the wide range of practices of potential relevance was problematic given that the study needed to be kept to a length that was acceptable to householders and achievable within the timescales of the project.

*The findings must be meaningful and relevant to technologists:* Development of each of the energy efficient measures is being led by experts in their respective fields with their main focus on technical performance. The context for practice-orientated research is more usually a design team comprising of researchers, product or industrial designers and perhaps the users themselves (Scott, Quist and Bakker 2009), where there is a focus upon conceptualizing user needs in a way that enables designers to iteratively formulate design problems and begin to explore solutions (Dorst and Cross 2001). Engineering design is typically a much more structured process involving the creation of design specification documents. In keeping with the principles of UCD, it was essential that the outcomes of the user research could be conveyed to the project technologists in a meaningful and familiar form (Preece, Rogers and Sharp 2002). Requirement trees as described later in the paper were identified as an appropriate communication tool for this purpose.

The challenges described above led to the development of a hybrid methodology within which a practice-orientated approach was supplemented with more traditional user centred design activities. Two main components of the adopted approach are introduced in this paper: the development of *product requirement trees* for each technology and the *timeline tool* developed to explore home improvement practices. Before these are described an overview of the study is provided.



### **3 Study outline**

Given the range and type of data required, the data collection was conducted over two visits; the first visit was to establish a rapport with the householders and understand their home improvement practices since moving into their home. The second visit was to explore in more detail the energy efficient technologies being developed and to see how these might fit into people's homes, lifestyles and everyday practices. This information would inform the design of the technologies more directly. Data in visit 1 were collected through an in-depth semi-structured interview and the use of the timeline tool. Visit 2 similarly used an in-depth semi-structured interview approach, but also presented participants with factsheets about the technologies, and included a tour of the home in order to take photographs of relevant features mentioned in the two interviews. This home tour was scheduled for the second visit to allow trust to be established between the participants and the researchers during the first visit (Dray and Mrazek 1996).

Following agreement to take part in the study, householders were visited at their homes at pre-arranged times, often in the evening when all adults could participate. Two researchers attended each visit, for ethical reasons and to provide a lead interviewer who could focus on the discussion and a note taker who could ensure all details were recorded. Discussions were also recorded with a digital Dictaphone and later transcribed in full.

A total of twenty households from the East Midlands area of the UK were selected to take part in the research. These twenty households (which included a total of 66 permanent occupants) were recruited using a variety of methods: advertising, word of mouth and direct approach and were selected to represent a wide range of owner occupied, solid wall houses. This allowed for a range of house and household types to be included in the study, representing a range of family structures, incomes and social status to provide a spread of participants. Whilst this was never intended to be a statistically representative sample, it allowed for a snapshot of different domestic situations to be explored.

## **4 The research approach**

### **4.1 The timeline tool**

To encourage householders to share their stories and engage with the research process, a timeline tool was developed to prompt recollection of past home improvements and other life events that had taken place since the participants had purchased their house. Development of the tool built on previous work by Haines et al (2006) and Kanstrup and Christiansen (2006), where an engaging data collection approach was required that respected the privacy of the householders and encouraged individuals to take part in the study during their leisure orientated time at home. Interviews were conducted in a room of the participants' choice, often around a dining table.

The development of the timeline allowed participants a degree of control over the data collection process, a requirement raised by Crabtree and Rodden (2004). Participants were asked about their home from the point of purchase, exploring issues relating to why they chose the particular property, whether they moved in straight away and if they undertook any home improvements at this stage. This established a known starting point which was generally easily recalled by participants. Participants were then asked about other improvements they had made to their home, for example major renovation, replacement of heating systems, wiring, structural changes etc.

As participants volunteered information, the timeline was drawn up in front of them, using pen on magnetic boards, supported by a bespoke set of magnetic cards containing relevant images which could be added to the timeline to indicate particular aspects. These were in several categories: dates, to structure the timeline, life stages (birth of a child, wedding, etc) and home improvements (double glazing, new boiler etc). These were added when the participant mentioned a particular activity or event, and notes added along the timeline. Mateas et al. (1996) used a similar approach with felt pieces and a flannel board to assist householders to walk through their day. They comment that the visual and tactile engagement of the board facilitated recall and kept the conversation grounded.

Participants were also prompted for information about disruption relating to each event, and approximate time and cost of the activity. Where professional trades people had carried out the work, participants were asked about how and why they chose the particular supplier and

whether they had carried out any of the work themselves, in order to inform the researchers about the process of home improvement. Figure 1 shows a timeline in development and Figure 2 shows an example of the completed item.



Figure 1. Timeline in development

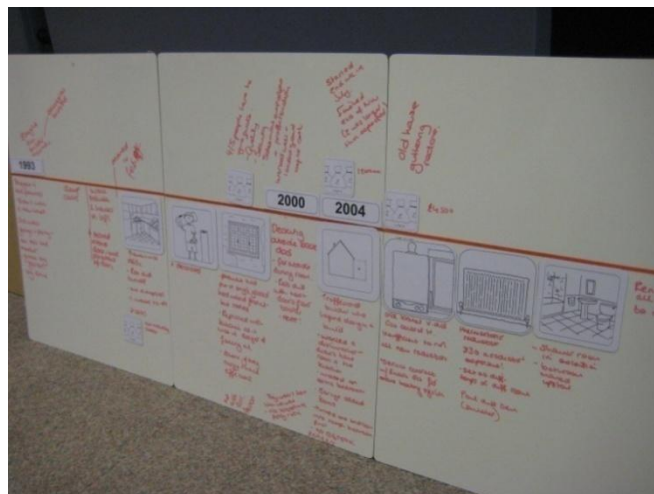


Figure 2. Completed timeline

As participants were able to see the development of the timeline, they were fully aware of the type of data being recorded. They were also free to volunteer information as they wished, in any order they chose, as a formalised set of questions were not presented. This built trust, and made the process an enjoyable one, as participants were able to recall their lives in their homes and reflect on the achievements (and sometimes failures!) of their home improvements.

## 4.2 Requirement trees

Requirement trees aim to convert non technical, non-quantified customer requirements into a set of product characteristics (Wright 1998), and so could be used to organise the range of requirements from householders into something that was useable by the technologists. These could then be developed into product design specifications, which form a conclusion to the first stage of a typical engineering design process. Roy's model of the design process (1996) identifies four key phases to the product development process: Task Clarification; Conceptual Design; Embodiment Design and Detail design. The requirement trees and design specification are generated as a result of the first phase, following the development of ideas, needs and an initial brief.

The requirement trees took a user perspective and were based on whole lifecycle of a technology from decision to purchase to end of life. This allowed for a very structured, systematic approach to considering how a product might be purchased, transported to the property (by a home owner or professional), installed, used, maintained, decommissioned and disposed of at the end of its life. For each of these aspects of the life cycle, issues that would affect the user were listed. These were then expanded further to ensure the full details of the requirements were considered. This was done using expert opinion (based on human factors knowledge and reviewed literature about each technology), which populated these requirement trees as far as possible. Quantifications were included wherever available, for example *no thicker than x cm, expected life span of y years*. Thus, the trees included issues relating to the design of the products as well as the process of installation. These trees, drawn using Microsoft Visio, developed into large documents, too large to be reproduced in this paper. An extract from a requirement tree is shown in Figure 3.

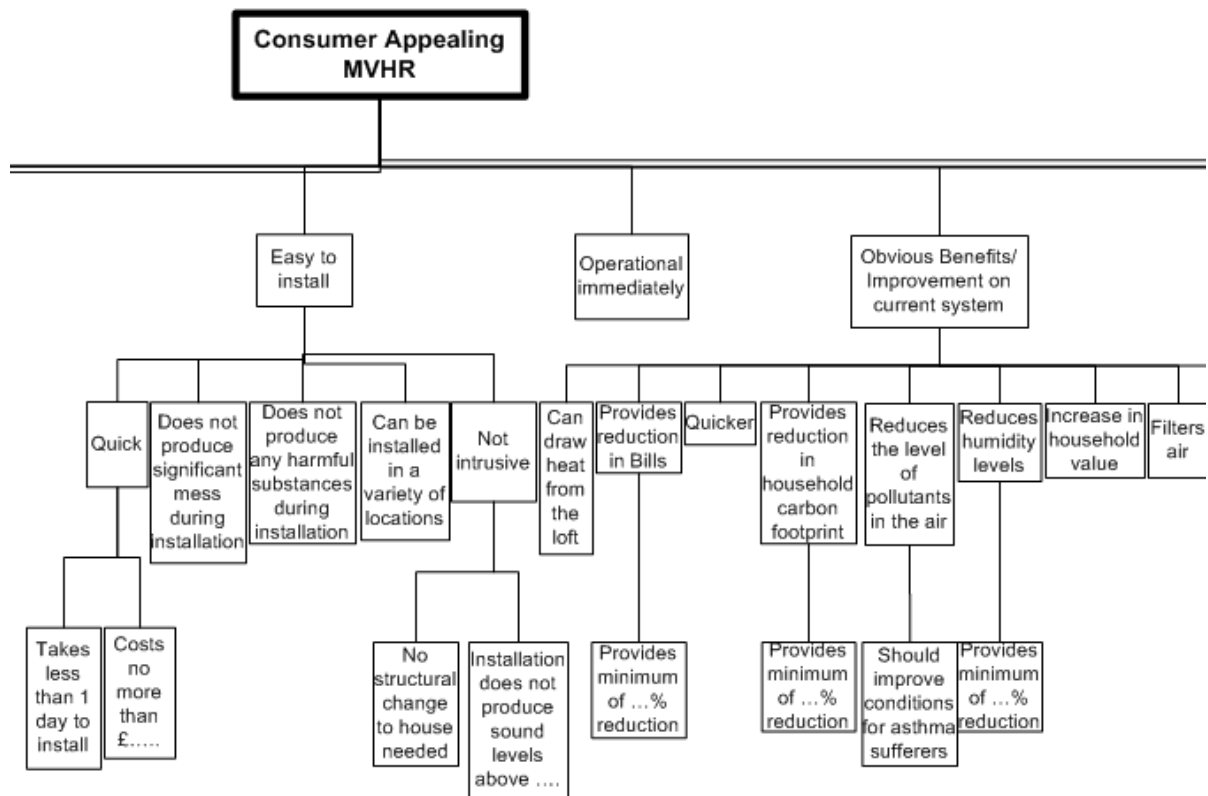


Figure 3: Detailed extract from the initial “Consumer Appealing MVHR” Requirement Tree

There were a number of areas where it was not possible to determine or quantify requirements from expert knowledge or the literature and these needed first hand evidence to inform the design process. This additional data was collected across the two home visits but particularly in the second visit within which more detailed exploration of the energy efficiency measures was undertaken. The requirement trees and their need for particular information defined the interview areas for the second visit and, in some cases, the specific questions that needed to be asked. An interview structure and detailed questions were designed around understanding practices within the home that would inform the technology design. For example, door closing practices will influence the effectiveness of a retrofitted centralised mechanical ventilation system. If it was found that people habitually closed all internal doors, then a single duct ventilation system is unlikely to be successful as there would be insufficient airflow around the house, and so the design of the ventilation technology would have to include multiple entry / exit points or some other workaround.

## 5 Discussion and conclusion

The approach outlined above illustrates the adaptation of a practice-orientated approach to include more traditional UCD activities developed in response to the particular needs of the CALEBRE project. It was developed to address methodological challenges that arose from the need to provide user requirements to technologists in a meaningful and relevant form whilst still seeking to explore how everyday practices may influence the performance of the energy efficiency measures being developed within the project. As a successful retrofit process is dependent on consumers choosing to purchase and install available energy efficiency measures, the researchers also sought to understand existing home improvement practices so that the impact of future retrofitting policies can be maximized by understanding the triggers that lead to home owners undergoing home improvements and the motivations that lead them to make significant often expensive one off changes to their homes.

The timeline tool was an effective and engaging tool for exploring existing home improvement practices. Participants readily provided information and the timeline context helped recall of events that happened sometimes over a decade ago. Although participants struggled to remember exactly when improvements were made (and in such circumstances were reassured by the researcher that exact dates were not needed), they did usually recall the sequence in which home improvements took place and the motivations and triggers for making the improvements (for example, receiving a small inheritance or making an insurance claim). They were able to easily relate activities to life events, often using these as a starting point for the discussion: *“it was just after our son was born...”*. Householders appeared to enjoy the process, and were happy to spend time discussing their homes and their lives.

Participants rarely mentioned energy as a motivator for making home improvements (despite knowing the data collection was for an energy related project), instead issues relating to improved living conditions, reduced cost and more pleasant surroundings were cited as motivating factors.

Development of the requirement trees required particular questions to be asked about daily practices for each of the energy saving measures under development within the project. Each technology was introduced separately to the homeowners and then a series of practice-orientated questions were asked relating to the potential implementation of the

particular technology. However in contrast to the discussions centred around the timeline, the resulting discussion of everyday practices was somewhat disjointed and less rich in contextual detail. However a good deal of useful information that was needed to inform the requirement trees was elicited through this process.

The resulting requirement trees have been well received by the technologists developing the energy efficiency measures and have enabled large quantities of qualitative information to be structured and represented in a way that is meaningful within the context of an engineering driven product development process.

The researchers were acutely aware of the tension caused by needing to gather specific user requirements for a diverse range of technologies whilst still seeking to understand how the design of these technologies could be refined through understanding of everyday practices and routines. Data collection focussed more than the researchers had hoped upon the impact of individual technologies, whereas they had intended to develop a more holistic approach that reflected the likely implementation scenario where each 'hard to treat' property is treated with a range of customised suite of energy efficiency measures. The sheer volume of issues to be considered led to a more piecemeal approach being adopted. Further research will seek to focus upon daily routines (for example coming home from work or putting the children to bed) which will allow the interplay between daily practices and systemic implementation of energy saving measures to be more fully explored.

The development of this bespoke methodology to meet specific project needs has led the researchers to reflect on their role within design and how it may evolve in the future. Current trends in design research show changing roles for both researchers and designers particularly when addressing 'wicked' open ended problems (Rittel and Webber 1984) such as those arising from the urgent need to halt climate change and reduce the production of CO<sub>2</sub> emissions. Sanders and Stappers (2008) describe what they term as a 'caricature' of the classical UCD process where the user is the passive object of study and the researcher contributes theoretical knowledge and further knowledge developed through observation and interviews. The designer then passively receives this knowledge in the form of a report and interprets it in relation to his understanding of technological and other constraints into design concepts, ideas etc. The role of the researcher in this process is one of 'translator' between users and designers. They contrast this with the role of researchers within a Co-design process, where users are more actively engaged in the design process as 'experts of their

own experience' and designers explore the design space collaboratively with users. In this context the role of the researcher is that of 'facilitator', providing tools and methods to enhance the contribution that users can directly make to design. Within practice-orientated research, the trend is also towards more direct contact between designers and users as designers seek to embrace the concept that interventions can lead to innovations in practice that then foster further opportunity for product innovation (Scott, Quist and Bakker 2009).

However this study illustrates that there is still a valid role within more technology driven design processes for the researcher to act as 'translator' between technologists and users providing a much needed bridge between the two. In order to address the design challenges introduced in this paper the researchers have needed to invest considerable effort in firstly understanding the technologies under development, assessing how these may impact upon everyday practices and presenting these to users in an understandable and engaging form. The results of the user research then needed to be translated into a meaningful form suitable for informing the technology development process. Direct contact between technologists (designers) and users in this context is hard to envisage. However, the success of the timeline tool as a method for engaging householders in a discussion centred upon home improvement practices suggests that householders could in the future play a more direct role in the development of retrofitting policies and incentive schemes.

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