User Knowledge in Housing Energy Innovations

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Abstract

Energy and energy conservation are traditionally fields in which technical expertise has an important role. Other recent research has emphasized the role of user involvement in energy innovations. Yet, little is known about the type of knowledge that users and producers have in different industries or what actually happens in attempts to transfer this knowledge from one party to another. Do users possess knowledge that is significant for the development of new energy systems that conserve energy and combat climate change? What is the nature of this knowledge and how can it be mobilized? What can be gained in energy innovation by involving users? Is enhanced knowledge exchange sufficient to align the interests of users and producers? We address these questions by applying the user innovation framework to a case study on the development and introduction of a low-energy housing procurement competition and labelling concept in Finland.

1. Introduction

According to the EU *Green Paper on Energy Efficiency*, the buildings sector accounts for 40% of the EU's energy requirements. Research shows that more than one-fifth of the present energy consumption could be saved by 2010 by applying more ambitious standards to new buildings and when refurbishing existing ones. Energy costs are also becoming increasingly significant for households as well, especially in cold climates, as the prices of electricity and oil are rising.

Energy and energy conservation are traditionally fields in which technical expertise has had an important role. Expert knowledge is needed to analyse energy flows, to select and install appliances, and to prioritize conservation measures. From this perspective, ordinary consumers are often seen to exhibit a 'knowledge deficit': many authors have been concerned that ordinary consumers are quite ignorant about energy issues (e.g. Kempton 1987; Melasniemi-Uutela 2000), and are thus unable to capably adopt their role in energy conservation efforts. On the other hand, other recent research has emphasized the role of 'user innovations' in alternative energy and energy conservation and has documented the role of user-innovators in housing energy innovations (e.g., Rohracher and Ornetzeder 2005). The above-mentioned lines of research represent two extremes: in the first, users are represented as ignorant and in need of training and education, whereas in the second they are represented as having important knowledge the innovation process.

Von Hippel and colleagues have highlighted the crucial role of users in innovation in many different industries and types of products (von Hippel 1986; 1998a; 2005; Lilien et al. 2002; Lüthje 2004). Von Hippel describes the innovation process in terms of the distinct domains of knowledge that producers and users possess. Producers have knowledge about technical solutions, production capabilities, etc. and users about their needs, the context of use, and their own capabilities as users. Both sets of knowledge are characterized by 'stickiness': they move relatively freely within their own domain, but are difficult to transfer outside it. Hence, close involvement and user participation is needed to 'unstick' the knowledge, allowing it to contribute to a common innovation process.

The notion of user involvement has also been highlighted in innovations with a sustainability or environmental aspect (Rohracher 2003; 2005). It has even been suggested that user involvement is particularly important for such innovations, which often attempt to find alternative and radically innovative ways to fulfill user needs in a more eco-efficient way (Heiskanen et al. 2005). Following this line of argument, a range of experiments in user involvement in sustainable innovation have been conducted in recent years, with more or less promising outcomes (e.g., Weaver et al. 1998; Heiskanen et al. 2005; Hoffman 2005). In spite of the evolving nature of this debate, there are also documented examples of cases in which users have made a distinct contribution to the development of sustainable technology.

The role of users has gained increasing momentum in innovation research, including sustainable innovation, during the past four decades. Yet not much of this research has focused on conceptualizing *the type of knowledge that users and producers have in different technological fields* and contexts of use, or on understanding *what actually happens in attempts to transfer this knowledge from one party to another.* The present article attempts to conceptualize the role of user knowledge in housing energy innovations. Do users possess knowledge that is significant for the development of new energy systems that conserve energy and combat climate change? What is the nature of this knowledge and how can it be mobilized? What can be gained in energy innovation by involving users?

We address these questions by reviewing recent research in user innovation and by applying this conceptual apparatus to a concrete case: the development and introduction of a low-energy housing labelling concept by Motiva, the Finnish Energy Agency. This project was not fully successful in reaching its aims, and one of the suggested reasons is that it lacked a "homebuilder's perspective" (Halme et al. 2005). After introducing the project, we examine how users were involved, and how knowledge was exchanged among experts and users. We then go on to consider other, alternative, ways in which users might have been involved or have been involved in other projects. On the basis of this analysis, we draw conclusions on the potential and limitations of user involvement from a knowledge management perspective in housing and energy innovations.

2. Perspectives on knowledge and expertise

Users and knowledge about household energy

Studies have found that people do not know a lot about household energy use (Eurobarometer 2002; 2006). For example, people do not know which sectors consume the most energy, and they do not understand the economics of energy conservation investments. In Finland, for example, a study commissioned by the MTI (2002) indicated that climate change mitigation is becoming one of the key motives for energy conservation. Yet people are not very aware of what the largest sources of carbon dioxide emissions are. Spontaneous responses (N=1002) to the question "how can you combat climate change personally?" mostly focused on reducing car use (36%). Conserving energy or using renewable energy in space heating was identified by only 10% of the respondents as one way to combat climate change.

While such findings suggest that more public education is necessary, they can also sometimes be criticized for exhibiting a 'deficit model' (Irwin and Wynne 1996) of lay knowledge concerning energy. It is assumed that because lay people do not have the same kind of knowledge that experts do, they know nothing. Other authors consider the problem of energy knowledge from the opposite perspective (Shove 1998; Chappels et al. 2000). Experts simply frame energy use in different terms – often ones that are very distant from ordinary households' concerns. They fail to understand why households behave irrationally because they fail to grasp the logic of energy use. The households' perspective is one in which an appropriate level of comfort is the dominant goal, not energy conservation. In-depth studies of energy-related behaviour reveal that households have an underlying logic to their behaviour, and energy-related actions ensue from that 'everyday' logic (Kempton 1987; Kempton et al. 1985).

Some attempts have been made to find ways in which experts and ordinary households could communicate sensibly on energy, taking into account the breadth of the chasm separating their 'vocabularies' and conceptual frames. Mostly, this has involved qualitative, observational research or ordinary households' sensemaking processes, and analyses of how energy experts attempt to target their messages in a way that takes into account the experiential knowledge of ordinary consumers (e.g. Darby 2003). Yet the problem remains: energy efficiency is 'invisible', and thus very difficult to communicate in a way that integrates both experts' and ordinary citizens' perspectives (Chappels et al. 2000; Parnell and Popovic-Larsen 2005).

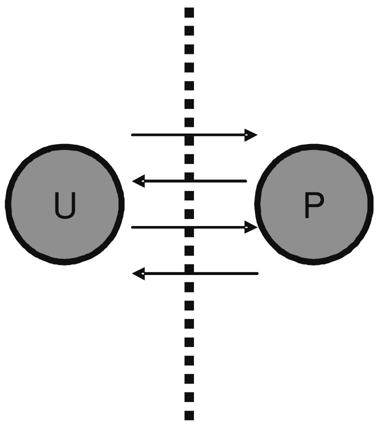
Perspectives on knowledge and expertise

The previous discussion on the exchange of energy efficiency knowledge among experts and lay people reflects a fundamental problem in product innovation and design. Von Hippel (1998) has termed this a problem of "sticky information": information about users' needs and manufacturers' capabilities is highly contextual, tacit and difficult to transfer from one site to another (von Hippel 1988b; von Hippel 2005). This problem slows down the product innovation process – a number of rounds of information exchange are needed in order to establish facts and clarify perspectives. Often, these rounds occur through experimental product introductions, which may sometimes entail costly failures (Figure 1a).

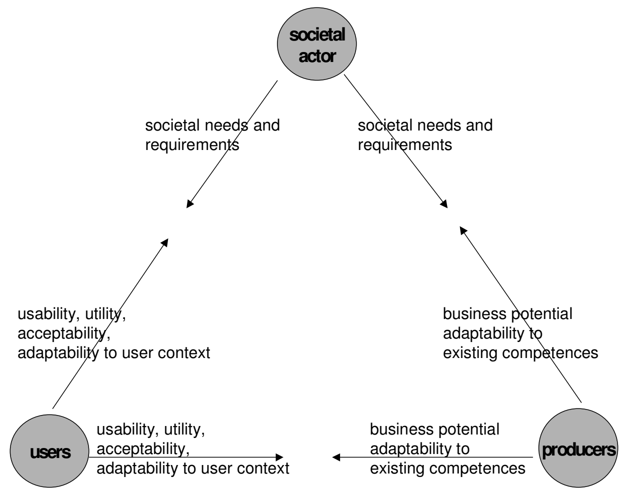
The problem of "sticky information" is further complicated in the case of societal innovations such as those concerning energy efficiency (Kivisaari et al. 2004). Here, societal actors like public energy agencies have their own perspective on the innovation, which differs from those of the users and producers. The societal actor may know more about the need to promote energy conservation innovations and about the new technologies available to do so. The societal actor will thus need to try to communicate with both producers and users in order to promote its own knowledge and understand the requirements and competencies of the market actors, i.e., the users and the producers (Figure 1b).

Figure 1. (a) Von Hippel's (1988b) view of the problem of 'sticky information' in product innovation and (b) the particular problems in societal innovations (based on Kivisaari et al. 2004)

a)



b)



The most frequently proposed solution to this problem is intensified interaction between the world of designers and the world of users. This can consist of *designer participation in the user context*, *user participation in design*, or *user innovation* (Table 1).

Designer participation in the user context: Designers may go to visit the users at home or at their workplace, and use ethnographic observation to understand the users' world (e.g., Koskinen, et al. 2003; Hyysalo 2004). A number of design tools have also been developed on the basis of ethnographic or field observations, such as contextual design (Beyer and Holzblatt 1998) and empathic design (Leonard and Rayport 1997). These design tools help designers to convert the results of ethnographic observations into design solutions. For example, the empathic design method draws on "user personas" or "user scenarios" as a background for designers to brainstorm solutions that are more user-responsive.

We are not aware of any direct applications of ethnography-based design tools in the field of sustainable innovation. But, for example, Chappels and Shove (2005; see also Shove 2003) have made extensive use of field research to investigate and problematize the concept of "thermal comfort". They argue that laboratory-based research on thermal comfort (which has formed the basis for design codes and standards) has adopted a 'naturalized' fixed conception of comfort that does not correspond to reality as reflected in field studies. Field studies have engendered 'adaptive' models of thermal comfort, which reveal the cultural variety of perceptions of comfortable temperatures, as well as the active role of building users in adapting to various kinds of indoor environments. Chappels and Shove also reveal the historically and socially constructed nature of thermal comfort and argue that designers should not unquestioningly adopt a fixed definition of comfort, but also take into account adaptive behaviour and offer designs that offer "sensory stimulation and extensive adaptive opportunity". Stated simply, this could mean offering natural ventilation and accepting some variability in indoor temperatures.

User participation: Participatory design, in particular in the worksplace, has a long tradition in Scandinavia (Kensing and Blomberg 1998). In recent years, user participation has also evolved to encompass a broader range of users. User participation means that users join designers “at the drawing board”, for example by participating in “user groups” (Tomes & Armstrong 1997). User groups can be used, for example, for idea generation, and have been found to develop highly original ideas for new products (Magnusson 2003). Other tools and methods in this category include “customer idealized design”, in which customer groups engage in redesigning a product or services to meet their ideal requirements (e.g., Cicianntelli and Magdison 1993; Kaulio 1998), and focus groups, which can be used in a variety of ways to critique and improve product and service concepts (Bruseberg and McDonagh-Philp 2002).

This approach has been applied, for example, by Spaargaren et al. (2006) to identify how well a variety of sustainable innovations fit into their everyday life and social practices. Consumers participated in focus groups, in which they discussed the way such innovations interacted with their social practices, and the types of technological and behavioural change involved. Through such participation, the organizers were able to identify misfits between the innovation and the everyday settings in which they were intended to be used. For example, early introductions of compact fluorescent light bulbs were found to give off a white, cold light that was considered uncomfortable. In a similar vein, Hoffman (2006) and colleagues have used user workshops to identify development needs in a sustainable product concept in the GELENA project. The product concept was an electrically amplified bicycle, which was expected to reduce private car use and thus carbon dioxide emissions. The user workshops identified features of the product concept that required improvement, such as concerns about theft.

User innovation: Users’ own inventions and innovations can be a direct source of commercial products. Von Hippel and colleagues (Lüthje, 2004; Franke & Shah, 2003; von Hippel, 2005) have found that at least in some product groups, a large proportion of users invent and customize their own products (von Hippel 2005). Such innovative users are called “lead users”. Companies can support and make use of users’ own inventions through “lead user workshops”, and for some products like computer games, “user toolkits”, i.e., open design platforms, allow designers to outsource part of the software design to innovative users (von Hippel, 2001; Jeppesen & Molin, 2003; Holmström 2004).

Alternative energy is a sustainable technology in which user innovation has traditionally had a significant role (Jamison 2001). As contemporary examples of sustainable user innovation, Ornezeder and Rohracher (2006) have analysed two Austrian cases of user innovation in solar thermal collectors and woodchip boilers. Here, enthusiastic users organized to build sustainable energy appliances in local self-help groups. Even though such approaches are not mainstream, the Austrian examples are not insignificant: self-build groups manufactured 40 000 solar collectors and about 100 wood chip boilers in the past decades. In the case of the woodchip boilers, users also made some significant design improvements (safety, comfort) to manufacturers’ existing designs. Ornetzeder and Rohracher (2006) stress the role of knowledge sharing in groups of users with different professional and educational backgrounds, as well as a good knowledge of their own requirements for such applications. They also highlight the role of self-organized groups in disseminating sustainable innovations – in particular, in the solar thermal case, self-organized groups contributed significantly to the diffusion of solar technologies in Austria.

Table 1. Types of user-producer-society interaction in sustainable innovation

Type of interaction	Examples of projects	Key contribution
Designer participation in the user context	Field studies of thermal comfort and building users' adaptive behaviour (e.g., Chappels and Shove 2004)	Field observations can identify alternative usage patterns, challenge technical definitions of user needs and problematize existing designs
User participation in design	Focus groups for testing and developing sustainable innovation concepts with citizen-consumers (e.g., Spaargaren et al. 2006) User workshops for testing sustainable product concepts (e.g., Hoffman 2006)	Users can identify problems in innovative concepts and suggest design improvements based on everyday experience
User innovation	User innovations (e.g., Rohracher and Ornetzeder 2006)	Self-organizing user groups can make design innovations and disseminate sustainable innovations

The examples show that user-producer interaction and user involvement in design can make a significant contribution to sustainable innovation, and can also facilitate the dissemination of knowledge on the need for and the available solutions for adopting more sustainable technologies. With this promise in mind, we now turn to consider a project aiming to promote an energy-efficient innovation, low-energy housing, with a view to considering user needs and involving users in the innovation process. We first simply describe the project and its context, and then turn to analyzing how users were involved, or represented, at different stages of the project.

3. The Motivoittaja project – introducing a user-friendly low-energy housing concept

As a case study on the role of user knowledge in the introduction of energy innovations, we consider a recent Finnish project aimed at promoting 'low-energy housing', i.e., a housing concept that consumes at least 50% less energy than standard models[1]. In 1999, Motiva, a state-owned company responsible for promoting energy efficiency and renewable energy, launched a project aiming to mainstream and 'normalize' the concept of low-energy housing through a technology procurement competition and labelling system (called 'MotiVoittaja') targeted at the producers and consumers of *prefabricated detached homes*. The project was a moderate success: it managed to attract a large number of entries, and contributed to more public interest and debate on energy conservation in space heating. Yet the product concept and label did not become popular, and the definition of low-energy housing remains ambiguous. In the following, we first consider the aims and design of the project

[1] The case study is based on earlier research (e.g., Mikkola and Riihimäki 2002; Savonen 2004; Halme et al. 2005). This research has been complemented by reviewing other documents, conducting an analysis of construction-oriented Internet discussion sites and an interview with a representative of Motiva, the project manager in this case (Aho 2006). More details about this case study are available in Heiskanen et al. (2007) as part of the *Create Acceptance* project funded by EU FP6.

Background, aim and design of the project

Key technologies to reduce heating energy consumption were first introduced during the oil crises, and a number of experimental zero-energy and minimum-energy houses have been built over the decades. Yet the cutting-edge designs have not been widely adopted due to a lack knowledge, awareness and financial motives among homebuilders (i.e., users) and construction companies. Following some early unsuccessful experiments, low-energy technologies have also suffered from an ambiguous public image. Lay people still often associate high levels of insulation with the concept of "bottle houses" – i.e., houses that are too well sealed from their environment resulting in mould pollution and respiratory problems (e.g., Hakala and Hottinen 1998). The MotiVoittaja project aimed to overcome this stalemate by commercializing a new "moderate" and "user-friendly" concept of *low-energy housing.*

Low-energy housing as conceptualized in the project refers to a set of different technologies. The technologies employed include increased thermal insulation, low-energy windows, reduced air leakages, recovering heat from exhaust air, extracting energy with heat pumps, passive solar energy and building orientation. A key aspect of low-energy housing is a *systems view* of designing a house. Design is based on a thorough understanding, control and utilization of the energy flows within a building. Through this design approach, low energy solutions could be reached without large additional investments, and without compromising indoor air quality or comfort.

The Motivoittaja project sought to promote the diffusion of the low-energy concept through a technology procurement competition. Technology procurement is a policy instrument for stimulating innovation through a targeted acquisition process. An influential buyer or group of buyers formulate the requirements and evaluate the products, and market transformation is further influenced by support activities (e.g., rebates, labelling or awards) (Westling 2000). In the MotiVoittaja project, the award was designed to function as a label of endorsement, allowing prospective customers to identify 'certified low-energy houses'. Moreover, Motiva undertook to assemble an 'initial buyer group' of prospective homebuilders willing to make a commitment to purchase a 'MotiVoittaja' house.

The aim of the project was to transform the prefabricated housing market by creating a new product concept – the low-energy prefabricated house. This concept would signal a new, more positive image of energy-conserving construction solutions, such as convenience, indoor air quality and affordability. The project managers hoped that such houses would attract a broad range of customers, and would thus help to mainstream low-energy housing. A more general aim was to raise awareness of energy efficiency and its importance as an environmental aspect of housing.

Two organizations were closely involved in the development of the vision. The competition was launched and administered by Motiva Ltd. This fully state-owned company focuses on the promotion of energy efficiency and the adoption of renewable energy sources. The other key partner was the Finnish national technical research institute, VTT, which had been intensively involved in developing low-energy housing technology and design concepts with an emphasis on user benefits: comfort, healthy indoor climate, simplified heating solutions and reduced lifetime costs. One of the underlying ideas in this concept is that energy-efficiency and indoor air quality are not contradictory goals, but can be simultaneously improved through better management of air and energy flows (Halme et al. 2005).

Motiva and VTT also tried to take into account the consumers' expectations on the basis of previous experiences of problems in adopting low-energy housing (Savonen 2004; Halme et al. 2005). One was to reduce the financial risk involved. The construction process is stressful for consumers– for many, a once-in-a-life investment requiring significant time and financial resources. Few consumers are interested in experimenting with new technologies in this situation – hence, an external 'label of endorsement' by a reliable, unbiased party might increase consumers' confidence. Lack of branding and marketing was also perceived as an obstacle to low-energy housing (Halme et al. 2005). The underlying belief was that homebuilders are increasingly consumers of ready-made products. The product should be easy to identify and purchase, and it should convey other than energy- and environment-related benefits, such as comfort and healthy living (Halme et al. 2005)

A jury of external experts was invited to determine the winners. The jury included a representative from the VTT (the National Technical Research Centre), Tekes (the National Technology Agency), the Ministry of Environment (in the role of regulator of the built environment), and a regional co-operative bank (Länsi-Uudenmaan Osuuspankki), representing the interest of mortgage-lenders to reduce the financial risk of homeowners. Two organizations represented the user perspective in the jury. One was the National Association for Detached Housing Construction (PRKK ry). The 5000 members of this organization are mainly individual homebuilders and people renovating their houses, and the association serves them by providing training events and advice. The other user representative was the Technical Director of the University of Helsinki, representing an end-user of energy-efficient construction solutions. The jury members participated mainly as experts, but also partly as representatives of the respective interest groups (e.g., users).

Manufacturers of prefabricated houses were selected as the target group because of their growing market share[2]. The winners of the competition were promised the right to use the MotiVoittaja label in their marketing. The winners would also be entered into a product record allowing homebuilders to identify the best solutions from an unbiased source. In addition, Motiva made a commitment to assemble a purchaser group and facilitate the winning manufacturers' negotiations with them.

The competition was published at the beginning of April 2000 and the winners were announced in May 2001. The initial response, i.e., the number of entries into the competition, was positive. There were 20 entries into the competition – i.e., almost half of all manufacturers entered a design, including three of the ten largest manufacturers. Eight of the entries were considered by the jury to merit being awarded with the MotiVoittaja label. The total energy consumption of the awarded designs ranged from 60 to 130 kWh/m^2, but was at least 35% less than average (Aho et al. 2001). In spite of the differences, all eight designs were promoted equally. Furthermore, the right to use the MotiVoittaja label was awarded retroactively to two other designs that met the criteria. The winning designs were very similar in appearance and overall design to the standard type of prefabricated house offered in the market. Motiva and the jury were quite happy with the cost level achieved: the construction costs varied from 1300 to 2000 euros per m^2 of living area.

Four of the 10 companies awarded the label actually offered their winning design for sale, and three were still offering a "MotiVoittaja" house in 2006. The housing manufacturers were somewhat disappointed with the sales performance: they had expected a more enthusiastic market response to their new models, and more deals with the initial buyer group (Mikkola and Riihimäki 2002; Aho 2006). They believed that consumers were cautious about low-energy models for fear that they involve complex technologies that are difficult to operate. Their impression was also that consumers only focus on initial investment costs, and fail to grasp the importance of total lifetime costs. They

[2] According to the current estimate, their share of the detached house market was about 68 per cent in 2005 (PTT 2006). There are about 40 producers on the market, producing about 10 000 houses annually (Nordic Ecolabel 2005). The most popular form of setting up a prefabricated house is for consumers to do part of the work themselves or have it done by contractors, but turnkey constructions are also gaining popularity (Halme et al. 2005).

were also aware of the fact that consumers are not very trustful of manufacturers' promotional materials: they thus called for third-party calculations of consumption figures and costs (Mikkola and Riihimäki 2002; Savonen 2004).

MotiVoittaja did not turn out to be a branding success. The project largely failed to promote commercial models marketed specifically as low-energy housing and to establish a widely acknowledged set of criteria for this type of housing. Yet in general, one can conclude that the targets of raising awareness of low-energy housing and mainstreaming the concept were actually fairly successful – even though it is difficult to isolate the contribution of the project to the overall development in this area. The idea of houses with about 50% less energy consumption has been adopted quite widely, but there is still a lot of debate about the effectiveness of different solutions to meet this aim.

User representation and participation in the project

User were present – directly or indirectly – at various stages of the project (Table 2): in setting up the criteria, in selecting the winning models, in assembling the initial purchaser group, and in communicating about the project in the media and in direct communications (e.g., fairs). Moreover, potential users can self-organize on the Internet, and the MotiVoittaja project and low-energy housing has provoked some interesting discussion threads on Internet discussion forums.

Table 2. Forms of user involvement in the MotiVoittaja project

Type	Organizers	Involvement	Purpose
Planning, criteria-setting and selecting the winning entries	Motiva	Representatives of expert and stakeholder groups: VTT, Tekes, Ministry of Environment, detached housing association, housing finance, expert end-user	Represent expertise and interests from different positions (technology development, finance and regulation, market players and end-users)
Assembling the initial purchaser group	Motiva	40 homebuilders (some of whom dropped out later)	Create market Spread knowledge through peer experience
Formal communications	Motiva	Media representatives > media users Housing Fairs > exhibitors and visitors	Create awareness of energy efficiency Disseminate information about new construction technologies and designs
Informal communications	Self-organized, facilitated by Internet discussion sites	Homebuilders Professionals	Exchange views and experiences about construction issues
Market	Manufacturers Motiva	Prospective homebuilders	Build a house (low-energy or not)

Planning, criteria-setting and selecting the winning entries was conducted by experts: the project managers, the expert evaluators and the jury involved in the competition. There were, however, two user representatives in the jury. In particular, the representative of National Association for Detached Housing Construction (PRKK ry) represented the homebuilder's perspective in the project. Moreover, the project managers and the jury made an effort to address some of the homebuilders' (perceived) concerns related to low-energy housing, namely costs, convenience and indoor air quality (for more details, see Tekes 2006):

Formal communications. Most of the communication on the project followed a top-down model. Communications were directed at the trade and daily press and other media. The project received relatively extensive media coverage, and most of the press was extremely favourable. Low-energy housing was introduced as a modern and future-oriented approach. Moreover, there is extensive information available on the project on the Motiva website, which has been complemented after the project with a calculation tool for energy costs. However, the project managers themselves were of the opinion that more efforts should have been placed in communications after the competition, but this was not possible due to budget limitations (Savonen 2004; Aho 2006).

Nonetheless, one important communication success was achieved through participation in the Finnish nation-wide Housing Fair events. These are annual events that create a new model housing development each year in a different location, and illustrate novel technologies through demonstration constructions. These events are visited by approximately 150 000 visitors each year, including both experts and ordinary people. After the event, the houses are sold to 'normal' families, and the fairgrounds are turned into a residential area. Motivoittaja was presented as a concept in the 2001 event, and demonstration houses were built for the 2002 event.

Assembling the initial purchaser group. Gaining market commitment from initial purchasers is an important part of technology procurement projects. In this case, purchasers were mainly private consumers, so assembling the group was a complex task. Prospective buyers were contacted through the National Association for Detached Housing Construction at training seminars and by advertising in the association's newsletter. Finally, a buyer group of 40 families was gathered. Yet the buyers turned out to be quite reluctant to make binding contracts with the manufacturers – they merely agreed to give priority to the awarded models. In the end, some were not satisfied with the standard awarded models, and requested so many modifications that the houses no longer met the energy efficiency criteria. Others 'dropped out' for various reasons, such as financial problems or other changes of plans.

The most important initial buyers were also purchasers of Housing Fair houses. Three different awarded models were constructed for the Housing Fair in Kotka (in Southeast Finland), and were actually sold before the fair. The families who moved into these houses became the most important showcases for the MotiVoittaja concept – so much so, actually, that they became quite annoyed with all the publicity, and decided to stop giving interviews. Their houses, the energy efficiency solutions, their construction costs and annual energy bills, as well as interviews about their family life were displayed on the Motiva website, offering at least some personal peer experiences for other prospective homebuilders.

Informal communications: In the formal communications, the media coverage was quite favourable. The 'unofficial' communication ongoing on Internet discussion forums reveals a more mixed reception[3]. Such sites are an important source of knowledge for a growing number of homebuilders. The 'experts' on these sites are often professionals or seasoned self-builders. The discussion sites showed that homebuilders are also faced with a confusing array of heating and insulation options

[3] 139 discussion threads in the Suomi 24.fi forum and 53 discussion threads in the Rakentaja.fi forum were examined, identified by using the search terms "low-energy housing" and "MotiVoittaja". The review also includes newspaper articles linked by discussants (e.g., HS 2004; HS 2005).

and combinations, but they also revealed that there was a lot of discussion on low-energy housing, and more and more discussants were telling about their own personal experiences.

Both positive and negative discussions could be found about low-energy housing. The sites revealed very divergent opinions on what "low-energy housing" means, and much debate about real-life heating costs (as opposed to calculations based on technical performance). One recurring topic seemed to be whether to invest in geothermal heat pumps or increased insulation. This line of discussion implies that the 'systemic design' idea represented by researchers at the VTT was not adopted by ordinary homebuilders – people considered different technologies as separate issues. There was also some competition between contrasting concepts of ecological housing: one being based on traditional, vernacular construction methods and natural materials, and other 'modern' one involving well-sealed structures and highly controlled air and energy flows. Some of the proponents of 'traditional' ecological housing oppose tightly-sealed and 'smart' low-energy homes.

Market: By stimulating a market for 'mainstream' low-energy housing, the project attempted to align itself with the (perceived) interests of ordinary homebuilders, and especially the growing group of middle-class people who rely extensively on ready-made market offerings. This group would also include people concerned about the environment and about future energy costs, and the project tried to serve up low-energy housing as a solution to both concerns. Yet homebuilders are, in fact, a quite variegated group of consumers. They typically consider a number of different heating and construction options (Mikkola and Riihimäki 2004) and balance a range of different requirements. Prefabricated houses are also not an ordinary industrial product. They are sold in small quantities, and even 'standard' models are often modified and tailored extensively. This is somewhat problematic when considering energy efficiency from a 'systemic design' perspective: modifications should not interfere with the planned and controlled energy flows.

The consumer segment that the design competition attempted to target does clearly exist, but is perhaps not as easy to enrol as believed. A survey conducted half a year after the competition was resolved (Mikkola and Riihimäki 2002) showed that homebuilders do value energy efficiency – 40% of the respondents (N=229) reported it being an important criterion when selecting a prefabricated house. Some of the respondents (8%) had never heard of low-energy housing, and about half had heard of it, but stated that they knew very little about it. A relatively large share (14%) had considered low-energy housing, but decided otherwise. Nine percent of the respondents stated that they planned on building a low-energy home – which does show a clear growth pattern.

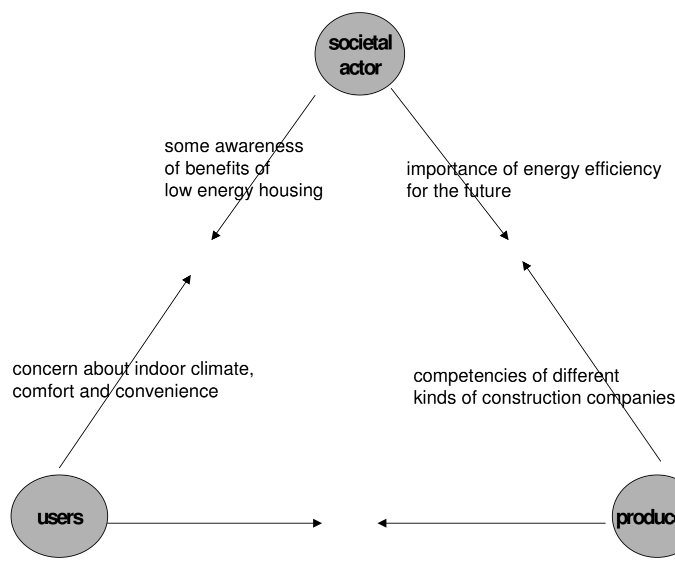
The consumer survey also revealed that interest in energy conservation and ecological solutions is growing among homebuilders. Homebuilders felt, however, that there is not much reliable information on the topic, and they were confused by the different concepts. The attempt to equate low-energy housing with ecological housing has not been too successful: only 39% of the respondents believed that an ecological house consumes less energy than a normal detached house. Less than half believed that one can halve a building's energy demand with small additional construction investments (Mikkola and Riihimäki 2002). The consumer surveys and Internet discussions thus show that there is still a lot of confusion about the concept of low-energy housing, and that energy-efficiency is not automatically equated with ecological housing.

User involvement and knowledge exchange in the MotiVoittaja project

In the following, we consider the interaction between users and producers and users and the societal actor involved, i.e., Motiva, in the MotiVoittaja project. We identify knowledge exchange challenges that were successfully met, and ones that were not equally successful.

In terms of successes, the Motivoittaja project surmounted some communication challenges vis-à-vis users and producers (Figure 2). It did manage to raise user awareness of the benefits of low energy housing, to some extent. It also managed to address some user issues, such as comfort, convenience, and good indoor air quality. But the project seems to have been more successful in communicating with the producers, i.e., the prefabricated housing manufacturers. A large number of these companies became convinced of the future importance of energy conservation in housing, which is reflected in the large number of entries in the competition. The competition design, which was fairly open to a variety of solutions, also managed to address the variety of competencies existing in these small companies.

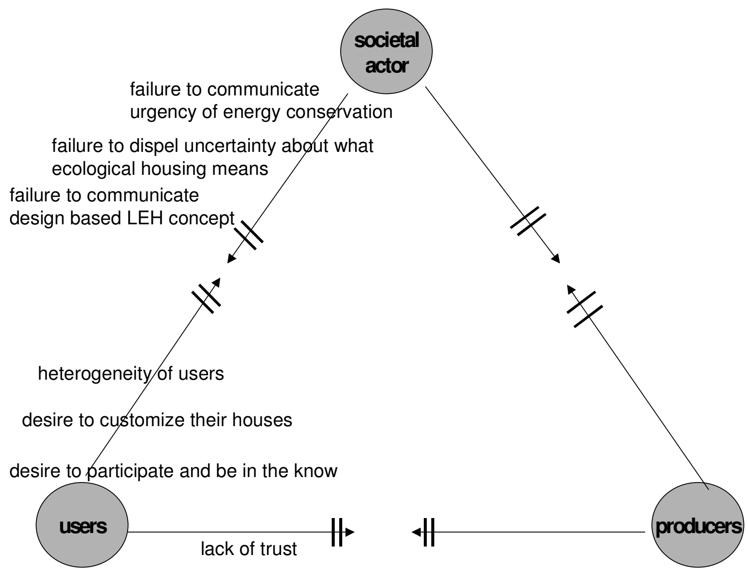
Figure 2. Successful aspects of the communication between societal actor, users and producers in the Motivoittaja project.



Yet the Motivoittaja project also failed to address a number of communication issues (Figure 3), in particular vis-à-vis users. In communicating its own agenda and concerns, it was not capable of convincing the users (homebuilders) of the urgency of energy conservation. At the time of the competition, signs of this urgency were not commonly visible. After the competition, the price of energy has steadily risen[4]. More stringent requirements on energy efficiency in buildings have been placed (Ministry of Environment 2006a) and there was even a committee was set up in 2006 to investigate the possibility of setting a particular environmental tax on detached houses using electrical heating (Ministry of Environment 2006b). These developments were on the horizon at the time of the competition, but the project was not able to communicate them convincingly. Moreover, the project failed to dispel the confusion surrounding low energy housing. Even though awareness was raised, the Internet discussions and the survey (Mikkola and Riihimäki 2002) show that people are still confused about which solutions are energy efficient and environmentally sound.

[4] For example, the real price of electricity has risen by about 15 % since 2001 (Energiamarkkinavirasto 2007) and the price of heating oil has risen even more (Öjyalan keskusliitto 2007).

Figure 3. *Un*successful aspects of the communication between societal actor, users and producers in the Motivoittaja project.



The project also failed to discover some key features of the user context that would have been important for the project design. These include the diversity of the user base, the desire to participate and "be in the know", and their desire to 'tailor' solutions and to customize their house, which interfered with the design-based concept of low-energy housing introduced.

There is also a communication issue between the users and the producers, which neither the Motivoittaja project nor the producers have managed to resolve. This is the lack of trust of homebuilders (i.e., users) in the information provided by prefabricated housing manufacturers. Such trust is very important when investing in new, untried solutions such as the novel low energy housing concepts.

4. Discussion: alternative approaches to intensify knowledge exchange among users and experts

The previous section identified some of the communication failures of the Motivoittaja project, and next we consider whether more intensive interaction between users, producers and societal actors might have helped to surmount some of those failures. We revisit the three categories of user involvement presented in Table 1, and consider the kind of contribution that they could have made to the Motivoittaja project.

In the Motivoittaja project, users were mainly involved in an indirect manner. In the jury of the competition, users were involved through two representatives, and assumptions were made about users on the basis of previous experiences by the designers of the project. An attempt was also made to engage users in the pre-specified role of initial buyer. Users were not, however, eager to adopt this role, nor did they behave according to expectations. They were not willing to make a commitment to purchase a winning design, and moreover, some of the users wanted to make modifications to the prefabricated design, which interfered with the energy conserving features. In the survey conducted after the competition, homebuilders turned out to be a more heterogeneous group than was acknowledge by the user representation that informed the competition design.

Designer participation in the user context refers to close ethnographic or interpretive research of the user context by those involved in project design. As indicated in Table 1, this can contribute to more detailed knowledge of how users actually use technologies, and to a more sophisticated understanding of the origins of user requirements. In the Motivoittaja project, it seems that a better knowledge of the *user context* would mostly likely helped the project to address usability, utility, acceptance and user context issues to a greater extent. It is likely that the designers of the project were, in fact, to some extent aware of the diversity of the user base and the complexity of the homebuilding process. More systematic field observations might, however, reinforced the role of this knowledge in the design of the project. This is a problem that Akrich (1995) has identified: even when there is useful experiential knowledge or marketing research available, designers' user representations tend to converge around pre-defined project targets, and user knowledge that does not fit into the picture is easily discarded.

User participation in design refers to the direct involvement of users in the design of the development and promotion of the innovation. As indicated in Table 1, the reported examples of *user participation* in design have helped to identify problems in sustainable innovations which hinder their uptake by users. Such approaches (e.g., user groups, focus groups) might have revealed, in particular, the reservations that users have vis-à-vis their role in the Motivoittaja project. Issues that might have come to the surface include the lack of trust in prefabricated housing manufacturers claims and the users' desire to customize their homes. Moreover, a closer understanding of how homebuilders understand energy use and the concept of ecological housing could have helped the project managers to find ways to communicate the urgency of energy conservation.

User innovation implies a deeper and more fundamental participation by users. Here, users actually come up with solutions that are later adopted on a commercial scale or integrated into commercial-scale designs. As indicated in Table 1, this can contribute to low-cost solutions for disseminating sustainable technologies, and can also lead to design improvements, in particular in early stages of technological development. User innovations are not uncommon in low energy housing; in fact, many of the early 'zero-energy' houses were built by individual users for themselves. Individual users with a particular interest in energy do innovate in developing low energy housing concepts. Often, such concepts are quite variegated, ranging from extremely high-tech solutions with a high input by contractors to quite low-tech solutions with a large user input in construction. They are usually closely tailored to individual users needs (Daniels 2007).

The notion of user innovation is partly contradictory to the vision of the Motivoittaja project, which aimed to go beyond individual custom-tailored solutions and to move low-energy housing into the mainstream market. We agree that it is not obvious that even the best and most inventive users' self-designs are readily transferable to the mainstream market. There is a great variability in users' requirements and in their knowledge levels and desires to participate in designing, building and operating their homes. Most homebuilders are first-timers, with little experience and a relatively low knowledge level on construction issues in general and energy efficiency in particular (Mikkola and Riihimäki 2002). They accumulate a lot of useful experience during their homebuilding project, and the Internet discussion sites show that homebuilders are extremely willing to exchange experiences and reveal their knowledge and ideas to others.

As in the case reported by Ornetzeder and Rohracher (2006), user innovation in housing energy is more likely a collective than an individual endeavour. A large group of users, with some existing experience in homebuilding, could likely come up with a range of ideas for better low energy concepts. Ornetzeder and Rohracher describe a traditional way of sharing knowledge through collective work among villagers. In less tightly knit communities, the Internet could offer a solution for systematic knowledge sharing and open innovation. For example Halme et al. (2005) suggested that the Motivoittaja project might have considered an "open design platform" rather than encouraging each manufacturer to come up with its own competition entry. Perhaps users could also contribute to such an open innovation platform. It might also be possible to create a design tool that allows users to customize their own low energy homes while maintaining the low-energy design features through selective customization affordances.

Nonetheless, we can argue that engaging *user innovation,* along with more *user context knowledge* and *user participation* would most likely have also helped the project to communicate the rationale (societal needs and requirements) underlying low energy housing. There are two reasons for this: a closer contact with users helps to understand their communication needs, but can also help to access peer-to-peer communication networks, which are most effective kind of communication. Projects aiming to promote energy efficiency (or other societal goals) can greatly benefit from the use of such existing networks by finding grass-roots promoters and "multipliers", i.e., people who carry the message forward on their own initiative (e.g., Brohmann et al. 2006). Peer-to-peer communication is usually more effective and is also perceived of as being more reliable than top-down communications.

In addition to the commonly mentioned problems of communication between users and producers, our case also highlighted the issue of *trust*, which has gained less attention in the user involvement literature. The users' lack of trust in the producers' communications was one of the problems not fully solved in the Motivoittaja case. Perhaps users would be more willing to engage in experimentation with low-energy housing if they could be directly served by a neutral, impartial third party (i.e., an intermediary organization) when contracting construction solutions. Motiva is an intermediary organization, but one operating on the national level and providing general information. In addition, it might be helpful if municipalities had specific service centres for consumers providing individual service and contracting low-energy solutions with the primary aim to serve the homebuilders' interests.

5. Conclusions

Motivoittaja is an example of a project that was quite ambitious and user-friendly when compared to many other energy-efficiency projects (see e.g., Vreuls 2006). Yet we have seen that even this state-of-the art project could most likely have been improved had users been involved more intensively, and had the project also made use of user participation in communication about the project. However, the case also shows that existing methods for user involvement require tailoring to different contexts.

Our case illustrates the fact that *users', producers' and societal actors' knowledge is differently distributed in different industries*. Methods for user participation need to be adapted to the needs of specific user-producer (and societal actor) constellations. The example of homebuilding is a special case: users have a strong involvement in their homebuilding projects, and they have a lot of ideas about their needs and expectations toward their new homes. Nonetheless, most users are first-time users, with little knowledge of the homebuilding process. Once having been through the process, the users are much wiser. Even today, users share much of their accumulated knowledge with each other, and promoting such peer-to-peer knowledge sharing may be one of the elements in successfully promoting low-energy housing. Thus, the notion of user-inclusive innovation communities (von Hippel 2005; Heiskanen et al. *forthcoming*) could provide some useful insights for energy efficient housing design.

Detached houses are also products in which local knowledge plays an important role. Unlike many other industrial products, users have a relatively large role in specifying the product, and thus those promoting low-energy housing cannot merely focus their efforts on producers. Prefabricated houses are not conventional mass-produced products, but rather mass-customized products. Design solutions need to consider this characteristic, and there is a need to find solutions that can accommodate a lot of customization without compromising energy efficiency features.

There are also indications that *more interaction between users, producers and societal actors could promote the flow of knowledge about the need for sustainability innovations* and the available solutions. In the Motivoittaja case, the project designers were aware of the impending urgency of improving the energy efficiency of detached houses, but were not fully capable of communicating this urgency to the users. Effective communication requires intensive interaction, which is not possible directly between an individual project manager and thousands of users. Closer user involvement can help both to target communications at issues of user concern, and to make use of peer-to-peer communication networks.

While the literature on the role of users in sustainable innovations provides promising examples, *the role of users, producers and societal actors in sustainable innovation is still poorly conceptualized.* This is the case in the user involvement literature more broadly (Heiskanen et al., *forthcoming*). For example, there is still a need to conceptualize better the different forms of lay and expert knowledge involved in the development of new knowledge and new solution (e.g., Collins and Evans 2002; 2004). Moreover, the user involvement literature has not paid much attention to issues of power, interests and trust (Hyysalo & Lehenkari 2002; Ivory 2004); it is often implicitly assumed that information asymmetries and conflicts of interest are solved by improved communications. The fact that different parties may not want to reveal all the information they have, or may not be willing to take the information received at face value, is usually not explicitly addressed. Thus, more attention should be devoted to finding ways of organizing user-producer interactions that serve to align the long-term interests of different parties.

We can thus conclude that the development and promotion of sustainable innovations can benefit from applying ideas and methods in the field of user-producer interaction and user-oriented design. It is, however, important to add that such methods cannot be transferred from one sector to another unquestioningly, but practitioners need to take into account the specificities of each sector, product and local context. Moreover, there is a need for more in-depth studies of the mobilization of different types of knowledge in the innovation process, and more systematic conceptualization of factors facilitating and obstructing knowledge flows and the alignment of different parties' interests.

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