

Smart Homes and Energy Efficiency

Constructive Technology Assessment of ICT Use in Sustainable Buildings

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ABSTRACT

The paper reflects on the process of developing user-centered scenarios for information and communication technology (ICT) use in sustainable buildings. ICT in buildings can arguably contribute to improving building energy efficiency by integrating and enhancing the control of building services, providing energy consumption feedback to users, or enabling new services of utilities (e.g. load management).

The aim of a recent project in Austria was to develop perspectives for the use of IT in sustainable buildings which better meet both the needs of users and energy efficiency criteria. A process of 'constructive technology assessment' was established to allow designer and user perspectives to engage with each other—by conducting a series of focus groups with dwellers in sustainable buildings, analyzing expectations of technology suppliers and the practical use of these technologies in existing buildings. Based on such a socio-technical analysis a series of workshops with the participation of different groups of stakeholders (utilities, technology producers, environmental experts, building companies and user representatives) was set up to interactively develop services and initiatives geared towards a user's point of view.

Understanding markets and demand from this perspective means to provide sufficient scope for a co-evolution of technology configurations, services and patterns of usage by allowing users and designers to interact at an early stage of product development.

Introduction

Discussions about 'buildings of tomorrow' mostly follow one of two separate routes. From the perspective of energy-efficient or sustainable buildings, issues such as resource efficiency and use of renewable energies are raised, whereas the perspective of 'building automation' makes extensive use of information and communication technologies (ICT) with a smart response to user requirements. These two pathways are usually followed in isolation without much effort being made to explore synergies between them.

From the perspective of sustainable buildings, more emphasis should be put on questions such as: How could the use of ICT further sustainable buildings? Do energy related functions of smart homes meet the demand of potential users and are they effectively used? How could public policy support usage of ICT in buildings to improve energy efficiency? This article will draw on a recently completed research project in Austria, which was dealing with such questions.

A remarkable potential of building automation in residential apartments and buildings to improve environmental performance does indeed exist, as will be pointed out in the next sections, but there are other plausible scenarios which could also result in higher energy consumption by increasing standby losses or triggering further electrification of the

household. The contribution of ICT applications to energy efficiency largely depends on the availability of particular functions but perhaps even more on the way such applications are used and accepted by users and on the availability of services building on these technologies. The energy performance of smart homes is not so much a question of developing appropriate technologies or of providing sufficient information to potential users but of evolving contexts of usage and associated learning processes of users and suppliers.

How technologies will be used is generally not clear at the time they are first introduced. The path from designing smart home technologies to certain kinds of usage should rather be understood as a process of social learning that has various degrees of freedom at different points of development and spans the whole process from the early design phase to diffusion and (active) appropriation of the technology by users.

User requirements and product characteristics can often be discovered only if the product is actually used (see Habermeier 1990). Product testing (laboratory testing, field testing) and market research are strategies to organize an effective user-producer communication but often cannot fully capture the context of use and mismatches between technology design and the practice of technology use. Moreover, understanding users' needs deeply and well is a very costly matter for firms, since "need information is very complex and market research techniques only skim the surface." (Von Hippel 2001) Under these conditions of uncertainty firms are likely to develop technological configurations that build on established patterns of user behavior and user expectations. In the case of smart homes this could mean that applications favored by designers and suppliers rather focus on entertainment or computer networks but not on energy efficiency.

The main question posed in this paper is how applications could be promoted that harness the potential of smart homes to improve energy efficiency. After sketching applications of smart-home-technologies that could reduce energy consumption we will discuss preconditions to establish new product uses and strategies to induce social learning processes between users and producers of smart homes. The third part of the paper will present results from an Austrian 'Constructive Technology Assessment' project on smart homes, where user acceptance, existing practices of use and the expectations of designers and suppliers were investigated and brought together in a series of stakeholder workshops and focus group discussions.

Smart Homes and Energy Efficiency

ICT in Residential Buildings

As we use it here, 'smart home' mainly refers to home automation, which is "the combining of appliances, information technology and services inside and outside homes into integrated concepts optimally adjusted to the specific needs and behavior of users." (Bos and van Leest 2001, 5) It is important to note that during the past two decades of smart home development, emphasis has shifted from traditional control technologies in home automation to services based on ICT infrastructure and integration of the building with external communication networks. As Clements-Croome (1997, 398) stresses, "it may be more useful to think of intelligent systems and intelligent networks rather than buildings." As a consequence such buildings can be regarded as nodes within wider organizational networks.

Although the idea of smart homes is not new at all and became a popular term in the U.S. as early as during the late 1970s, mass market development has so far failed. Between 1990 and 1995, home automation systems had only penetrated the market to a level of one-thirtieth of that projected in the 1980s (Gann, Barlow & Venables 1996). Nevertheless there are a number of reasons to believe in a growing importance of ICT use in buildings:

- Perhaps the main reason for an increase in its importance is the growing orientation of virtually every sector of industry towards the integration of ICT. Within homes the growing importance of the Internet, as well as small computer and multimedia networks may trigger the networking of building services and white goods too. Smart homes in general open up a potentially huge market for various branches of industry: household appliances, control equipment, services.
- Other socio-economic factors may also be important drivers for smart homes. One of these is the liberalization of electricity markets, which forces utilities to develop add-on services to stay competitive. Smart homes would provide an interesting basis for such services as security services, load management, etc. As an example, ENEL, the former national Italian electricity utility has started to equip all 27 million Italian homes with a residential gateway.
- Demographic and socio-economic shifts, such as a growing number of well-off elderly people or dual-career families, give rise to potential new target groups for smart home technologies and services (e.g. providing medical services and managed care).

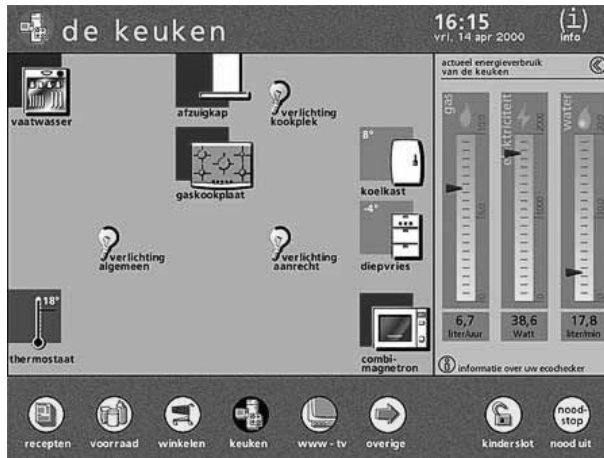
Energy Efficiency Applications in Smart Homes

Advertisements and brochures for suppliers of smart home equipment generally mention energy savings (along with comfort, safety and security) as one of the important advantages of smart homes. Without giving detailed evidence, they often talk about energy savings of up to 30% induced by smart home technologies. Whereas such figures are indeed often true for office buildings, where 'intelligent' building services (e.g. CO₂-based demand-controlled ventilation, occupancy sensors etc.) can significantly reduce energy consumption, there is less proven evidence for such claims in residential buildings. Nevertheless, there are a number of features that may contribute to better energy efficiency in smart homes.

Energy management, home automation. Applications that allow advanced control of heating, ventilation and lighting certainly provide the largest energy savings potential of smart home applications. 'Smart' control of the room heating system may include pre-programmed temperature settings in each room, automatic temperature reduction overnight and during vacations, joint management of heating and ventilation (e.g. turning radiators and ventilation off while windows are open), 'smart' use of blinds to optimize solar energy gains, and so on. Moreover, there are specific applications for lighting, such as adjustment to the level of natural light or occupancy sensors. Finally there are functions that may also have some effect on energy consumption, such as the possibility to centrally switch off all (pre-defined) appliances and lights before leaving the home, or warnings about open windows.

Feedback on energy consumption. Although being only indirectly linked to energy efficiency, immediate and easy-to-understand information about energy consumption may have an impact on energy-relevant behavior of users. In Scandinavia in particular, where European electricity markets were first liberalized, there are presently a number of field trials to provide immediate energy information via the Internet or direct displays, such as the 'Energy Guard' displaying current consumption and daily consumption compared to a selected average consumption. Energy feedback by the utility via the Internet can also be combined with offers for energy audit or advice.

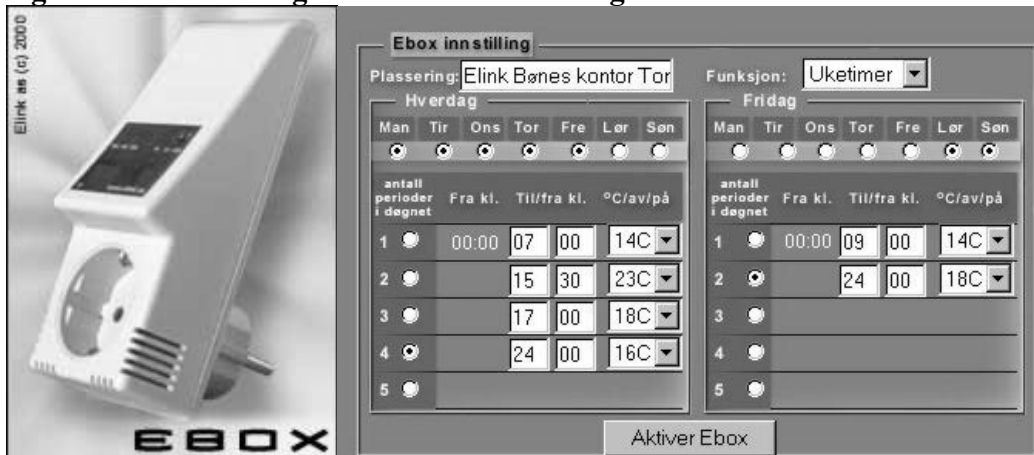
Figure 1. The 'Eco-Checker'— Energy Feedback in a Smart Kitchen



Source: <http://www.kijkopkeukens.nl>

Load management. A third possible contribution of smart homes to energy efficiency is load management—which does not directly affect household energy consumption but has effects on the overall efficiency of electricity generation. In Scandinavian electricity markets, where electric room heating and warm water provision is widespread, load management in households has already been tested in combination with smart devices.

Figure 2. Load Management with the Norwegian Ebox



Source: www.elink.no

An example for such applications is the Ebox (shown in Figure 2), a small device that can be connected to room heating or a water heater, and allows remote control by the utility and pre-setting of temperature parameters by users through the Internet.

Internet platforms. A way of using ICT for energy efficiency purposes that is not directly linked to smart home technologies and home automation is the creation of 'community platforms' for blocks of apartments or neighborhoods—as is presently done in Vienna. Such platforms may either provide building-specific energy-saving advice or may support initiatives such as car sharing, where dwellers in the building can check the availability of cars and make reservations via the platform.

Smart Homes as a Driver for Electricity Demand

Despite the number of possible energy saving applications of smart homes, increased use of ICT and home automation may have adverse effects as well. The Swiss Federal Office of Energy conducted an extensive study on the likely impact of networked households on electricity consumption (Aebischer and Huser 2000). Additional standby consumption may add up to 657 kWh of additional annual electricity consumption, or 16 percent of an average Swiss household's annual usage. Moreover, networking may induce a higher electrification level of the household; i.e. additional devices and increased use of household appliances and systems. Scenario calculations (including impacts on the level of household electrification) give an upper limit of around 30 percent of additional electricity use, one-fourth of which is attributable to standby consumption. It should be noted that this scenario does not include energy savings from smart home applications or improved standby controls.

As a result of these considerations regarding the energy-saving potential of smart homes we are confronted with a mixed picture. There is the potential to raise efficiency, but at the same time smart homes may induce additional energy consumption. In the end not only the market penetration of smart homes is important, but also and even more so, the way smart home systems are configured, which applications are included and the way the system is used.

Design and Diffusion of Technology as a Process of Social Learning

Smart home systems have characteristics of 'configurational technologies'; i.e. technologies that are composed of mainly standard products but can be implemented and configured in a variety of ways according to particular user needs. In this section we will take a closer look at the implementation of technologies and the importance of learning processes between suppliers and users occurring at this stage.

Extending Networks, Defining Uses

From the perspective of technology suppliers, we can look at the transition from innovation to diffusion as a matter of extending and reconfiguring the actor networks these technologies are embedded in. Weyer (1997) analyzes the process of technological development as a succession of three characteristic phases with specific types of actor configurations – beginning with the early creation of loose networks and a 'socio-technical

core' to a phase of stabilization and creation of more stable networks and finally to a stage of the breakthrough of a technology. The interesting point is that Weyer treats this final phase – traditionally the diffusion of an innovation—as a distinct act of innovation, where contexts of use have to be created, where the number of actors involved has to be increased significantly and where a coupling of producers and users and a mutual adaptation of technology design and patterns of use has to take place.

Moving from innovation to diffusion means moving from what is an essentially small and specialized network of actors to a broader network of different and heterogeneous user groups and different groups of professionals. Finding allies and interesting users in this broader network means creating contexts of use in interaction with these new actors and adapting the technical system to these new requirements. As we will see later, at the present stage of smart home diffusion one of the big problems is that producers and electricians fail to provide cogent scenarios for uses of smart home applications and thus have difficulty enrolling new user groups into their actor-networks.

Appropriating Technologies

If we approach the process of early diffusion of a technology from the perspective of the users, we find that they are far more actively involved in this process than generally expected. As mentioned above, contexts and ways of usage of a technology are far from clear when an innovation leaves the limited social context of design and production. Designers need to have certain visions of use and certain representations of users in mind when constructing products and these visions and assumption to some extent materialize in the physical shape of the product as a script (Akrich 1992). Still the practices and ways of usage that eventually develop in the course of actually using products and integrating them into daily life, the values and symbols that are being attached to a product by users cannot be fully anticipated by designers. This process of actively integrating products into daily life, of finding out which way of using products is best suited to a person's own situation, intentions and habits, can be called the appropriation of products. Thus "one should be careful about accepting the common a priori distinction made between use and design, between user and designer. This distinction implicitly inscribes assumptions that the one is passive (user), the other is active (designer)," (Lie & Sørensen 1996, 8)

Facilitating Social Learning Processes

In the context of smart homes, this means that acceptable and working energy efficiency applications have to be negotiated in an extended process of learning that takes place among designers, intermediary actors and user groups. We can speak of a process of co-evolution of usage patterns, smart home applications and institutional and organizational structures (e.g. services provided). However, these interactions and learning processes are usually far from being complete or frictionless. A recent European study analyzing social learning in multimedia applications found that "designers do not possess clear representations of the user and the user's setting and instead work with rather implicit and poorly specified models based on incomplete and often unreliable sources of information." (Williams, Slack & Stewart 2000, 17)

This leads to the question of whether there is a possibility for public policy to intervene in the appropriation process of products: e.g. by providing arenas for the interaction of designers and users and fostering the involvement of users in product development. The challenge is to stimulate a process that favors technological configurations of smart homes that support energy efficiency applications and provides more space for developing patterns of energy-efficient usage of smart home technologies.

One of such facilitating approaches discussed in technology and innovation studies is 'Constructive Technology Assessment' (CTA), a concept developed in the Netherlands. The key strategy of this approach is to create a nexus between designers and groups outside the design process, such as consumer associations, or other non-governmental organizations. Broadening the design process in such a way increases the chances of developing widely accepted products, which are better adapted to the needs of users. "CTA proposes bring together all interested parties early in the design process Thus, in CTA, technology is assessed from many points of view throughout the entire process of design and redesign, and the interests of all parties can be incorporated from the beginning." (Schot 2001, 40)

The next section will discuss some results from the already mentioned Austrian 'building of tomorrow' project, which set up a (limited) CTA process regarding the energy-efficient use of smart homes by interactively involving users, intermediaries (electricians, architects, energy experts) and producers of smart home technologies.

Understanding (and Shaping) Demand: An Example of CTA in Austria

The empirical part of our research into energy efficiency aspects of smart homes tries to accommodate to a process perspective of co-construction of demand and technology by focusing on the ongoing interactions between suppliers and users and by organizing an additional (although limited) arena to compare visions of designers, intermediaries and users. In providing space for further learning processes and interaction, the strategy is similar to Dutch CTA processes.

The elements of the Austrian CTA study on "intelligent and energy-efficient buildings" consisted of four main contributions:

- Twenty interviews with representatives of technology suppliers, building societies and service companies, as well as energy experts and architects, about their perspectives and ideas on the design of smart homes, possible services and relevant user groups.
- Analysis of user experiences and dominant patterns of use in existing smart homes through semi-structured interviews and participant observation. Due to the low market penetration of smart homes to date, only results from users of eight buildings were analyzed in detail.
- As a forum for interaction among different stakeholder groups, a series of three consecutive workshops was carried out with fifteen participants, including equipment producers (Siemens, Honeywell), electricians, architects, representatives of consumer associations and energy experts. At these sessions, participants discussed opportunities, barriers and product ideas to contribute to energy efficiency in smart homes.

- Finally, four focus groups were set up—each consisting of 6-10 ecologically interested people living in apartments in urban environments and single-family houses in less densely populated areas. These groups dealt with expectations and wishes of potential users and also assessed scenarios of smart and green homes developed in the stakeholder workshops.

Despite the limited number of participants, interviews, workshops and focus group discussions brought up a number of qualitative results, which provide clues for further strategies to promote energy efficiency in smart homes.

Communities and Visions

Most suppliers of smart home applications pointed to the possibilities to save energy—mainly referring to programmable control of room temperature. Nevertheless, it turned out that the communities related to smart homes and to sustainable buildings differed considerably from one another and had different visions of what tomorrow's buildings should be like.

Architects, homebuilders and energy experts with experience of sustainable buildings mainly focused on the building envelope and 'intelligent' architectural design of the building. Far from hailing low-tech solutions, they saw building services in a supportive role and expected rather limited use from ICT in sustainable residential buildings. Quite often the fact was stressed that with highly energy-efficient buildings, the additional efficiency gains from sophisticated controls of room temperature are very small.

Smart home experts, in turn, were not interested in architectural solutions. A dominant metaphor of smart home supporters describing the future of smart homes was the automobile, which is in the process of being completely transformed by ICT integration¹. Innovation studies often point out the importance of metaphors and visions, which serve as collective projections that integrate various forms of perception of actors, give them orientation and serve as boundary objects mediating between different expert and popular cultures. The car seems to be such an orientation benchmark in the discussion about smart homes. It demonstrates the possibility to better control the environment with ICT and even gives hope that users will uncritically accommodate to new features (which car owner still asks whether he/she really needs electric windows?—as one of the suppliers asked).

Suppliers still have a strong feeling, however, that convincing users, let alone housing developers, builders and architects, of the added use-value of smart homes remains a problem. Their vision of smart homes is not sufficiently matched by the vision of demand side actors. Moreover, they have failed to create a coherent network of builders, electricians, housing societies and service providers, which would not only provide technology but also stable institutional structures to set up and use smart homes. This is even more the case regarding the task of integrating smart and energy-efficient buildings, where developers stress that each of the two concepts alone already poses an extremely complex challenge, where various professions and actors have to learn to cooperate better, to create specific know-how and to better integrate the planning process.

¹ New cars provide fully technologically controlled environments, where virtually every function - from electric windows to drive-by-wire systems or different climate zones inside the car - is controlled through an ICT infrastructure.

Usage and Expectations

Interestingly, the metaphor of the automobile did not show up in interviews with users of smart homes or focus group discussions and did not serve to integrate projections of designers and users. Discussants were generally rather reluctant to accept the perspective of a fully controlled environment and gave the impression that there is a mismatch between the visions of technology suppliers and potential users. Although certain features seem nice to have, people do not want to spend much money on them and voiced apprehension of losing autonomy or of intruders via Internet, who could collect data or cause harm within the house.

An important message was that people generally were not enthusiastic about technical possibilities or abstract visions, but mainly focused on concrete—and in comparison to possible smart home features often banal—uses. A large proportion of actual users of smart homes pointed out that reducing the growing number of switches for electric blinds was an important motivation to network these devices, switch them centrally or control them with daylight sensors. Central switches for light or the possibility to easily switch off appliances when leaving the house also ranked high, along with the possibility of smart temperature control. Apparently, there are currently not many features of smart homes that residents wish to integrate in their daily routines and practices.

To some extent this depends on the social framing of these features and applications. A lengthy discussion in one of the focus groups centered on the possibility and use of detecting defects, e.g. of the heating system, washing machine or fridge, and automatically alarming a fault-clearing service or the home owner, who might be on holiday, via mobile phone. Participants found this feature of smart homes quite attractive, but immediately turned to the question, what they should do when getting such an alarm during vacation? Should they allow service people to enter their home in their absence? How would they know what the cause of the fault was? Should they leave a key with their neighbor? These are entirely practical questions, but they point to the importance of embedding technical features in social practices that are acceptable to users. It is not enough to say: Here you have a nice fault detector, without having plausible social settings for these features. Suppliers interviewed in our project mainly focused on technical features and possibilities but usually did not consider appropriate social settings.

Based on our user interviews and the experience of suppliers, users with a broad range of implemented smart home features often were technicians themselves or at least technically interested. 'Playing around' (setting temperatures, etc.) with certain features and having the possibility to integrate additional functions in the future was quite important to them. In contrast to this rather knowledgeable group, the second group of less intense users, who just had some simple smart home installations, mainly relied on the advice and decisions of electricians. Both groups felt that their dependence on electricians was growing in smart homes and wished to have more autonomy in changing or re-programming certain features. As this example demonstrates, the diffusion of new technologies often results in a reconfiguration of actors and their mutual dependencies – in this case users have to rely on their electrician more than they did before, and electricians try to defend this situation against the possibility of self-installed and self-programmed applications. Successful diffusion in such a case may depend on successful re-negotiation of such shifts in power and autonomy—e.g. by developing tools that grant users more autonomy in changing systems settings.

Interest in Energy Efficiency

Let us finally turn back to the issue of energy efficiency. Most of the focus group participants appreciated the potential to save energy with smart home technologies. Their main focus was energy management, especially features like separate temperature control for each room or the possibility to pre-set lower room temperatures during the night or vacancy periods. Preference for such applications also turns out to be significant in quantitative surveys about attitudes towards smart homes, which have been conducted regularly during the past five years by the Berlin Institute for Social Research. The most recent survey (Meyer et al. 2001, n = 423) ranks room temperature control even higher than security and safety in the list of the most interesting applications. Nevertheless the time series of survey results points to a feature of smart home usage that has already been mentioned: interest in features such as security or remote control can be strongly influenced by the scenarios of use presented to interviewees. This too stresses the high sensitivity of the particular social setting of smart home uses (and to the caution with which we must treat survey results about prospective uses of new technologies).

Temperature setting and control definitely is an application people already know and have certain experiences with. In focus group discussions with people who had no experience with smart homes, heating control was one of the preferred features too – especially of people living in apartments that lacked such control possibilities. However, when it came to the perspective of installing a smart home system, many people argued that there would be easier ways to install room temperature control and this would be no convincing reason to network their home. 'Low intensity' smart home users² argued similarly as to why they had not integrated the heating system. As an electrician put it: Many people at first are very interested in energy saving applications, but when it comes to installing smart home technology, these are not the features they want to spend money on.

Nevertheless, among intensive smart home users, a majority of respondents placed considerable emphasis on energy issues. Some of them had figured out sophisticated control algorithms on their own – e.g. a warm water circulation pump (to immediately get warm water even if the central water heater is at some distance) connected to an occupancy sensor in the bathroom. The pump then only worked for two minutes and the sensor did not react again for the next fifty minutes since the user had discovered that the water stayed warm in the pipes for this time. It seemed that much of the added value for these persons with technical interests was the possibility of playing with technology themselves.

So, energy efficiency applications were interesting to people because they had a positive attitude toward them and because they represent a familiar kind of use, which does not require new practices. Not least because of this fact, however, it was difficult to see the added value of temperature regulation with smart home technology. Moreover, applications where new kinds of usage within new settings would be required, such as energy-consumption-feedback or add-on services of utilities (e.g. load management), were evaluated more skeptically. They may only eventually become attractive in time as they are accompanied by institutional changes (e.g. rate structures) and new practices (e.g., overcoming the sentiment that, "I do not want to run my dishwasher overnight!").

² The users interviewed split up in a group having installed only some isolated applications based on a field bus (e.g. control of blinds and light) and a user group with fully networked homes (including heating, security, diverse sensors, gateway to communication networks)

Conclusions and Perspectives

To conclude with an ironic twist: the intelligence required for smart homes lies not in the technology but rather in the socio-technical network and in the negotiation of the social context.

As outlined in this paper, there is indeed scope for additional energy efficiency in smart homes, although controls of heating and ventilation lose much of their efficiency potential if buildings are already constructed in an energy-efficient way. However, there are additional possibilities of reducing electricity consumption from non-heating applications, functions aiming at the behavior of residents, such as energy use feedback, and add-on services, such as load management, where both the utility and the consumer may profit.

However, in the present situation only a small proportion of potential users seem to see much added value in such energy efficiency applications—although the appreciation of energy saving possibilities is high. The general problem with applications and services such as load management or energy feedback is that they are sometimes rather abstract ideas that do not sufficiently take into account the concrete and daily practice they have to be embedded in and the improvements they need to provide for current practice and routines. More effort has to be invested in understanding the point of view of potential users, to provide enough space to experiment with new kinds of uses and to reflect about these experiences.

Smart homes may well develop along routes that are not at all linked to energy efficiency: ICT penetration of buildings may, for example, focus on computer networks, communication or entertainment, and may in the end increase energy consumption instead of contributing to reducing it. Specific efforts are needed to shape smart home development in a way that gives energy-related applications a more prominent position.

To date, not many efforts have been made to look in depth at the patterns of use of particular smart home applications promoting sustainable energy use. One of the few examples is the ethnographic investigation of the use of the Ebox in Norway (Aune 2001). The research presented in this paper is but one small step in monitoring and understanding the present situation of smart and energy-efficient homes. However, the results of interviews, workshops and focus groups point to important issues of appropriately embedding smart home applications and to the value of organizing further interaction of actors involved in the process of mutually adapting technology and use.

It is important to see that demand is something that is created along with the evolution of institutional settings, practices of use and technology. Constructive technology assessment facilitates interactions between users and suppliers and may enhance such social learning processes. It could be a valuable element of environmental and technology policy to provide opportunities to make this learning process more effective and to provide conditions that may help to open up new pathways of evolving technologies and usages towards a sustainable construction and use of buildings.

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