User involvement in technological innovations: the case of balanced ventilation systems[1]

Harald Rohracher, IFF/IFZ - Inter-University Research Centre for Technology, Work and Culture

1. SYNOPSIS

Successfully transferring balanced ventilation systems to low-energy residential buildings will need better integration of the socio-technical system of production and installation with active processes of consumption.

2. ABSTRACT

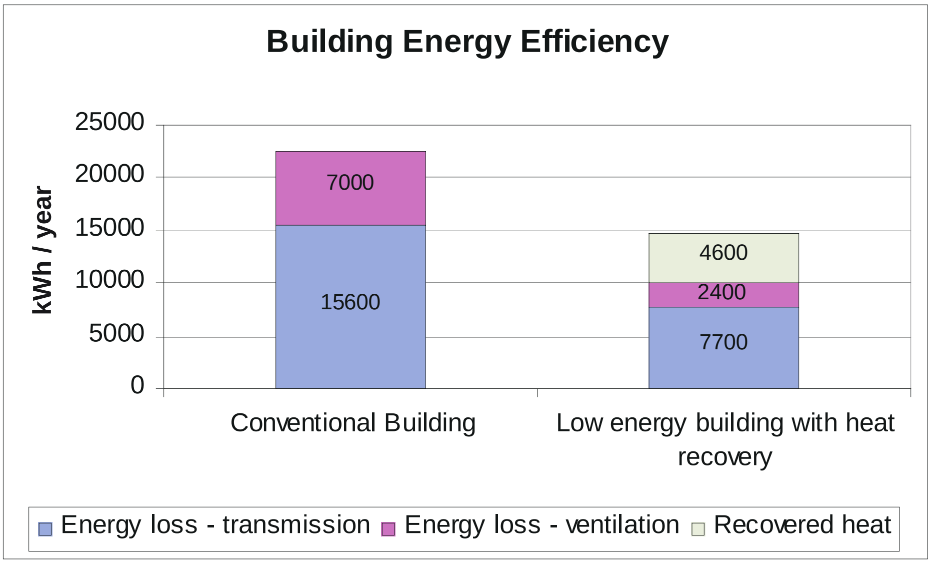
Balanced ventilation systems are technologies increasingly made use of in very low energy buildings. An analysis of the supply and demand side of this technology shows that the proper functioning and dissemination of ventilation systems not only depends on their 'technological hardware', but to a major part on the way they are integrated into the building system, on the co-operation and know-how of various actors such as planners, builders, or installers, and on the cultural embedding of the product in meaning and discourses – to put it short on shaping an appropriate socio-technical system.

We are not faced with a new technology but with transferring a product to a new cultural and technical context. The eventual improvement and social embedding of low energy house technologies can be analysed as a mutual learning process of component producers and users. An analysis of qualitative interviews and Austrian survey data suggests that the way these technologies are appropriated by users – i.e. integrated into everyday life in a meaningful way - affects the perceived functionality of these products. Acknowledging the active role of users/consumers in technology development could be a starting point for developing strategies to better integrate their perspectives and experiences into innovation processes.

3. THE FUTURE OF ENERGY-EFFICIENT BUILDINGS

Increasing energy-efficiency of buildings is one of the central goals of programmes to cut emissions of greenhouse gases and reduce energy consumption. Significant headway has been made during the past two decades, resulting in building envelopes and heating systems far more efficient than their counterparts up to the early eighties. This development has been reflected in iteratively improved building codes and regulations. However, energy consumption of new buildings still is far beyond state-of-the-art of building technologies leaving considerable space for improvements. When building insulation is improved beyond a certain level energy loss through ventilation and air leakage becomes dominant. To push energy consumption of buildings below a level of around 30 kWh/(m^2.a) the building must be equipped with a balanced ventilation system, which recovers waste heat from exhaust air and uses it to preheat incoming fresh air while maintaining a neutral pressure in the building.

Figure 1. Energy balance of buildings with and without mechanical ventilation with heat recovery

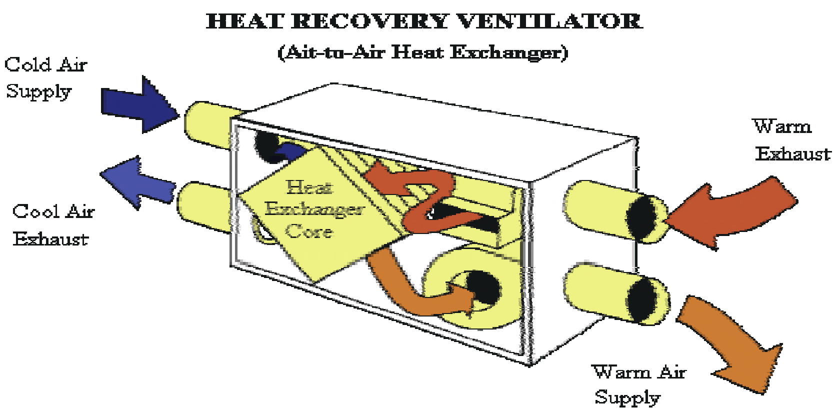


The regain efficiency of the heat recovery system may be as high as 90%. It is important to differentiate between balanced ventilation systems and air conditioning, as in balanced ventilation no active cooling of air is involved. Consequently the exchange rate of air is very low (ideally the so called hygienic rate of air changes per hour, which is a minimum level to sustain sufficient indoor air quality and which is much lower than the usual air exchange rate of air conditioning) and generally is not accompanied by the negative effects of air conditioning such as cold air or draft.

However, energy efficiency is not the only reason for installing balanced ventilation systems. A major further advantage is improved indoor air quality and the increased level of comfort for people living in those buildings.

Highly efficient buildings with balanced ventilation moreover give way to new concepts of heating systems. So-called 'passive houses' have turned into a 'technological guidepost' (Sahal 1985) in the current discussion about sustainable buildings – at least in Austria and Germany, but increasingly in other European countries too. Such houses are highly insulated, optimise gains from solar radiation and reduce heat loss through air leakage and natural ventilation by controlled ventilation systems with heat recovery. The low amount of 'rest energy' needed for room heating (below 15 kWh/(m^2.a)) usually is also provided through the ventilation system, which means that no conventional (active) heating system is necessary any more and overall investments are reduced. This means that balanced ventilation systems even more become one of the core technologies in these houses, as not only air quality but the whole heating system depends on this product. Efforts to kick-start the market for such passive houses are currently made at the European level (e.g. within the project CEPHEUS – cost efficient passive houses in EU countries). In Austria several single and multi-family houses have already been set up with these standards and many more are under construction.

Figure 2. The central unit of energy-efficient balanced ventilation systems



Building experts and environmentalists are putting high hopes into the dissemination of ultra-low energy houses – many of them expect such buildings to be standard in several years. This means that balanced ventilation systems may become an almost obligatory feature of ecologically advanced houses.

However, although technical concepts of these houses appear to be convincing, current adoption is restricted to a small proportion of architects and dwellers. Not more than probably 500 to 1000 balanced ventilation units per year are presently installed in Austrian low-energy buildings, though this figure is growing. Compared to 60.000 new flats per year in Austria this is not more than one percent of all flats. Much of the scepticism regarding the dissemination of these buildings centres around the issue of balanced ventilation systems. Many architects and installers are doubting their usability, especially when used as heating systems too. While proponents of 'passive houses' claim ventilation systems to be simple and user friendly technologies, which have been widely in use in the USA or in Scandinavian countries, many architects, installers or planners have serious doubts about the future of this product – ventilation systems would not work properly, they strongly would restrict the behaviour of occupants, they would be noisy and would not qualify as a heating system.

4. THE PROBLEM - AN OLD PRODUCT IN A NEW CONTEXT

This leaves us with a product that is on the one hand politically highly desirable – as its wide use would result in a major improvement of building energy-efficiency – but which on the other hand is highly contested within the building community and is only slowly taken up by users. Moreover, as proponents rightly point out this product is not new at all[2], although certain features (such as the efficiency of heat recovery) have been significantly improved during the past few years, and is in wide use in some other countries or e.g. in office buildings.

Why has this product, which has apparently already proved its usability, so little acceptance in Austria? And how could public policy support a wider usage of this technology, which proves to be so environmentally favourable? - More research? Better marketing? Subsidies?

The research project this paper is based upon was designed to investigate some of the reasons of the supposedly low acceptance of balanced ventilation systems in Austria. The hypotheses and the line of argument which I would like to find evidence for with the empirical findings presented later are as follows:

- Putting technologies into a new context (from Scandinavia to Austria, from office buildings to residential buildings, from conventional houses to low energy houses) often requires far reaching changes in the socio-technical system these technologies are embedded in, i.e. the way technological features are matched and integrated with social features. Seen from this point of view we are faced with product innovation processes even if the artefact as such is not new. Mismatches in the socio-technical configuration of a product - i.e. in the way the technology is handled by suppliers (producers, building professionals) and how the technology is adapted to the preferences of specific user groups - may result in low rates of user acceptance and satisfaction.
- Users are of central importance if the reconfiguration and extension of such a socio-technical system is to be successful - the integration of new users into a socio-technical system is a dynamic process with users not being passive adopters of a new technology, but actively appropriating it and putting pressure on product modification.
- Such a reconfiguration process may be conceptualised as a mutual learning process of actors involved - building professionals, architects, building societies, producers and various types of users, a learning process which also involves understanding different rationalities, which guide the adoption perspectives of these groups.
- Technology policy may enhance this learning process by supporting and institutionalising interaction between these groups.

With respect to our product 'balanced ventilation system' this would mean that its transfer to Austrian low-energy buildings is difficult, because product design yet has to be aligned with a new social (e.g. dominant user groups) , historical (ventilation traditions, experiences with and reputation of air-conditioning, etc.) and cultural (values) environment. This reconfiguration of the product 'balanced ventilation system' and its social environment involves learning processes on the part of various actors with users being active participants in this process.

Public policy may support and enhance this reconfiguration process and thereby improve conditions for a wider dissemination of balanced ventilation systems and low energy houses.

Before moving on to an empirical investigation of the acceptance and adoption of ventilation systems in Austria, we will shortly turn to the theoretical concepts mentioned above - namely the socio-technical systems approach and product appropriation by users.

5. A SOCIO-TECHNICAL PERSPECTIVE

Social studies of technology in various conceptual variations – social constructivist approaches, actor network theory, but also evolutionary economics – are analysing the design of technologies as an inherently social process. The central claim is that of an inseparability of the technical and the social with respect to technologies and artefacts, which results in socio-technical ensembles (Bijker 1993) as the smallest unit of analysis or the notion of technology and society as a seamless web (Hughes). The design and dissemination of technologies not only depends on technical parameters but on institutional structures, legal regulations, interests and interactions of relevant social groups, on cultural patterns of use and symbols technologies are connotated with. During the past decade technology studies have also been extended ‘downstream’ to analyse the consumption, use and modification of products as part of the design process of technologies. Such a comprehensive approach to the design and adoption of technologies seems to be better suited to understand the consumption of products – especially if they are contested and still in a process of change.

Controlled ventilation as part of a socio-technical system

Looking at the product ‘balanced ventilation system’ the importance of its embedding in a social context of different groups of professionals, circulation of know-how and the social organisation of constructing a building appears to be striking indeed. Contrary to many other consumer products ventilation systems are not highly standardised end-products but have to be specifically integrated into other technical systems that finally constitute a building. This means that apart from the production of the main elements of ventilation systems – mainly the central unit with fans and heat recovery system, pipes and outlets to supply rooms with fresh air and remove exhaust air – substantial planning processes and adaptation to the specific building is involved. As it turns out the quality of these planning processes and the integration of ventilation systems into buildings is a crucial point for the quality and technical operativeness of this product. Moreover the fine-tuning of the system and the qualified usage is of importance.

However, optimised integration into the building is not a task which can be carried out by specialised ventilation planners alone. It is important to take care of the specific requirements of ventilation systems already during the architectural design and planning of the building. Furthermore a tight building envelope is a prerequisite of fully functional ventilation systems, which means that all the builders, professionals and manual workers involved in raising the building have to apply new quality standards to their work.

As a result, even the technical operativeness of the product ‘balanced ventilation system’ highly depends on the social organisation of constructing a sustainable building, i.e. on questions like – Is it possible to organise a coherent and integrative planning process (of so far separated elements)? How is the collaboration of various professions institutionalised? Who controls certain quality standards? How is the actual construction process supervised? Innovation of such products in this respect not only means improvement of the technical hardware but social innovation, or better: improvement of the socio-technical product ‘balanced ventilation system’. As it turns out in interviews with actors involved in the production and dissemination of balanced ventilation systems, innovations of the technical hardware take place in an incremental and foreseeable manner. This definitely leads to a gradual improvement of certain parameters of the product, such as energy efficiency or noise level. However, most of the experts concede that the highest potential for improvement lies in the social context of this technology, i.e. the planning processes, know-how of actors, etc.

Moreover, these innovation processes are highly dispersed over various actors – from internationally oriented component producers to highly regionally operating installers and planners. This dispersed know-how makes strategies to support product improvement an even more difficult task.

As Weyer (1997) analyses, it is an important step within the product innovation process to transfer a product from a narrow network which dominates the early development phase (few specialised planners, few lead users or early adopters) to the wider actor-network which characterises the dissemination or consolidation phase of a product. Weyer calls this process 'de-contextualisation' of a technology. One of the challenges for the dissemination of ventilation systems is to find ways to widen the above described social organisation around balanced ventilation and make it attractive to additional intermediary actors (architects, etc.) and users. Finding a better match between technology, its social and institutional framework and user interests is an active and iterative process, as will be pointed out in the following section.

Acceptance and appropriation of technologies by users

Having focused on the interwoveness of the social organisation of integrating ventilation systems into buildings with the technical and functional side of this product we now have to ask: In which respect are users important too for the working and technical functioning of balanced ventilation systems. Again we will first turn to some considerations of social studies of technology as a conceptual background for further analysis.

The social shaping of technology cannot be properly understood if it fails to take account of the appropriation of technology by users, as Mackay and Gillespie (1992) stress – appropriation not just being different ways of usage of products, but also the meaning technologies get for users. In this respect users play an active part in the processes of design and innovation and "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 and Sørensen 1996: 8). The 'domestication of technology' as Lie and Sørensen call the appropriation of technologies in everyday life directs the view to the broad variety of actions taken on by people when they acquire artefacts and is sensitive to the systemic qualities of the process through which technology is consumed (Lie and Sørensen 1996:13).

The active participation of users in what finally comes out of technologies (though this may be an open ended process) can even be analysed as a dramatic process between the parties involved. Pfaffenberger (1992) calls this process 'technological drama', which is a specifically technological form of political discourse, as "technology is designed not only to perform a material function but also to express and coercively reinforce beliefs about the differential allocation of power, prestige, and wealth in society" (p. 283). Technological innovation in Pfaffenberger's view is not more than an "opening statement in a technological discourse", which is accompanied by other technological activities, such as user appropriation, user modifications, sabotage, etc.

Actor network theory stresses the active role of technologies ('non-human actants'), as moral statements are delegated to machines (see e.g. Latour 1992) and 'technical scripts' embodied in artefacts represent "a large set of technically delegated prescriptions addressed by the innovator to the user" (Akrich 1992). However, users often react to those technical scripts and may develop their own 'user scripts' that challenge established political and engineering scripts, as Gjøen and Hård (1998) analyse in a study on electric vehicles. Again this leads to a dramatic relation between design and use, to programs and antiprograms of action (Latour 1992:251), to a constant shift between the social and the technical.

In the following sections an empirical study of users and suppliers of ventilation systems will be presented. The study focuses on acceptance of this technology and challenges and barriers perceived by supply-side actors. As it turns out it is not appropriate to speak of a 'static' acceptance of a technology but we rather observe several issues, which are 'negotiated' between users and planners / producers and sometimes result in product improvements.

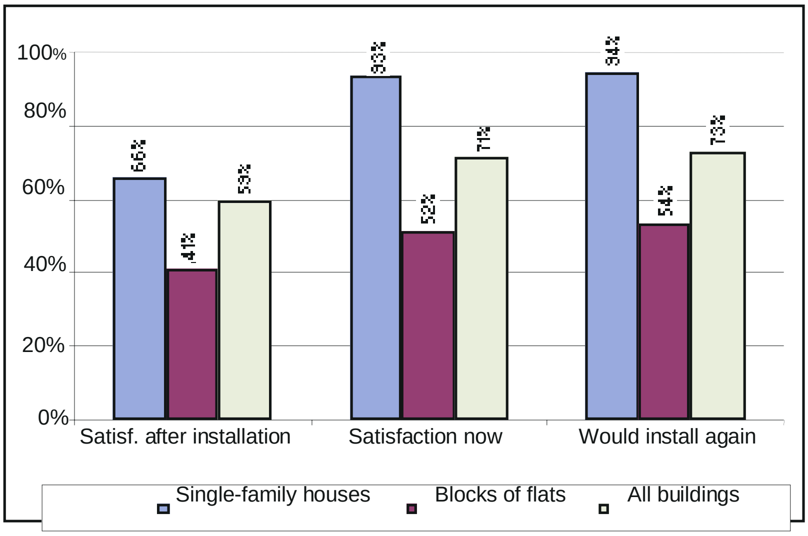
6. AN EMPIRICAL INVESTIGATION OF USERS OF BALANCED VENTILATION SYSTEMS

In an empirical study on users of balanced ventilation systems data from about 50 semi-structured interviews with users from all over Austria as well as 144 completed questionnaires have been gathered. One of the problems of the survey was that the total number of users and their demographic structure, etc., is unknown. The strategy thus was to gather user addresses from various sources – customer databases of producers and planners, people who have got advice from energy agencies, people having applied for subsidies, addresses from building societies and so on. Although the resulting database is not a statistically representative sample in a strict sense, it covers a wide range of user characteristics – geographical distribution, residents of single and multi-family houses – and types of ventilation systems.

Users were asked in a standardised questionnaire about their experience with ventilation systems, the reasons to install them, the information they based their decisions upon, their involvement in the planning process, the way they use those products, changes in their living habits and behaviour, problems encountered with ventilation systems, and strategies to modify and adapt these products, by e.g. altering certain features. With some of the users (about 30) and around 20 non-users (people who considered to install a ventilation system but decided against) open interviews were led. These interviews were transcribed and analysed as well.

Just to give some sketches of the results: The main reasons for installing a ventilation system were ecological and energy-efficiency considerations followed by fresh air supply and comfort. Usually this decision was accompanied by some fears about e.g. noise, draft, or maintenance, as only few of the adopters of this technology had already seen it in use in other buildings. Generally the adopters belonged to the segment of highly educated people (spread over different education levels was almost exactly inverse compared to average population), which is rather in line with findings about environmental consciousness (Diekmann and Preisendörfer 2001: 110). For many people the decision in favour of ventilation systems was part of the decision for certain buildings concepts (energy efficient buildings).

Figure 3. General satisfaction with ventilation systems



As it turns out satisfaction with the living situation in sustainable buildings in general is rather high but the perception of the balanced ventilation system in particular is rather mixed. More than 70% of interviewees expressed at least some satisfaction with respect to balanced ventilation systems as it works now and would install such a system again. However, there are striking differences between single and multi-family houses which is more or less equivalent to owners and tenants. 94% of single-family house owners would install a ventilation system again compared to only half of the tenants, who would chose to live again in a flat with mechanical ventilation.

However, even for many users in single-family houses the product was problematic in certain aspects. The most common ones stressed by dwellers, producers and planners alike were as follows:

1. Noise problems: Though properly planned ventilation systems could run extremely silently, many users complained about noise disturbances - over 40% of house owners were disturbed by noise in the sleeping room. Noise may originate from fans in the central unit or from air outlets in rooms. Moreover ventilation pipes may acoustically connect different rooms. Though the noise level is very low, the effect is enhanced by the high quality of the building envelope and windows, keeping noise off from outside. Interestingly the problem of noise was often denied by planners, but still ranked high in the perception of most users. Planners and architects tended to take technically ideal products as their reference products, even if the average case of building practice was far away from this mark.

2. Opening windows: Though it is possible to open windows it should not be necessary to do so with ventilation systems and it is even advisable to keep windows shut. It is often proposed that this restriction of otherwise habitual behaviour poses a problem for users. However, our interviews give no such indication - many people are glad not to be bothered by opening windows and do so only when they like to, e.g. during the warm seasons. However, especially non-users and tenants in flats with badly working ventilation complained about the (supposed) requirement to keep windows shut and used it as a main argument against ventilation systems. Still, this only marks the final step of a debate about being able to open windows or not, which is an interesting example of a struggle between users and designers, as pointed out in the literature on appropriation processes. When ventilation systems were introduced, they often came along with windows which could not be opened. Those restrictions of user autonomy (balanced ventilation systems were even called 'forced ventilation' in consequence – and still many people use this term) generally were rejected by occupants. Meanwhile designers stress that it is completely up to the users to open windows or keep them closed, as the function of the ventilation system will not be seriously impeded.
   The only situation that still leads to complaints is the necessity to shut windows over night as many people used to have windows open when sleeping in their previous flat and claim to sleep better at low temperatures. With passive houses this is problematic as in this case temperature drops all over the house and only slowly rises the next day. Contrary to this complaint ventilation experts contend that such habits are almost irrational and the effect that makes people sleep well is the low CO_2 concentration and not the cold air, so ventilation systems should do as well.
3. Control system: The types of control systems for balanced ventilation range from systems, which do not allow any user intervention, to fully programmable control systems, which allow to regulate the strength of ventilation (e.g. in case people are smoking) or to regulate and pre-programme temperature. The challenge for such systems is to cope with the often contradictory requirement of securing maximum autonomy of users and at the same time being easy to handle even for very inexperienced users. The control system is the main interface between users and the ventilation system and often is a source of discontent. Only a minority of users is content with the control interface.
4. Air heating: Special problems may arise if the ventilation system is also used as a heating system in 'passive houses'. Common problems are low humidity levels (resulting from high air exchange rates of badly planned systems), long reaction times of the heating system (especially at the beginning of the cold season, if people wait too long to turn on their heating), lack of possibility to regulate different rooms separately, constant temperature in all rooms – no warm spots, or low temperature in certain rooms. Using the ventilation system for heating purposes definitely requires changes in user behaviour and is very sensitive to planning mistakes. Many users insist on at least installing parts of conventional heating systems (e.g. radiators in the bathroom) – and many planners start doing so, while still stressing that they regard it as completely unnecessary.

To sum up this point: there are certain expectations of users diverging from those of designers and architects, there are controversies between users and designers, controversies which are about the autonomy of users (what is the user allowed to control by himself/herself), which are about the relation with nature (feeling cut off nature by highly insulated windows), which are about building automation and 'mechanisation' of housing, and which are about different definitions of comfort.

However, these perceptions of users were far from being homogeneously distributed. As with overall satisfaction, the perception of negative effects differed significantly between tenants and owners of buildings or flats, i.e. between users in different social and institutional contexts. Tenants appeared to be much more affected (and worse off regarding their power to initiate improvements) and more often voiced dissatisfaction with the ventilation system installed than house owners.

Still, usually the above mentioned negative experiences did not dominate user impressions of ventilation systems. A large proportion of users (again rather owners than tenants) strongly appreciated a persistence of fresh air, good indoor climate, and higher level of living comfort.

Figure 4. Positive experiences of users of balanced ventilation systems

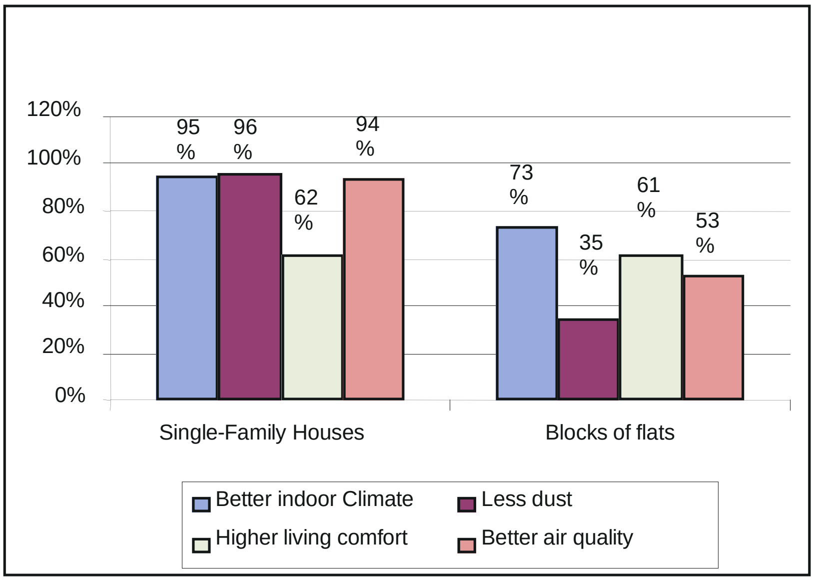
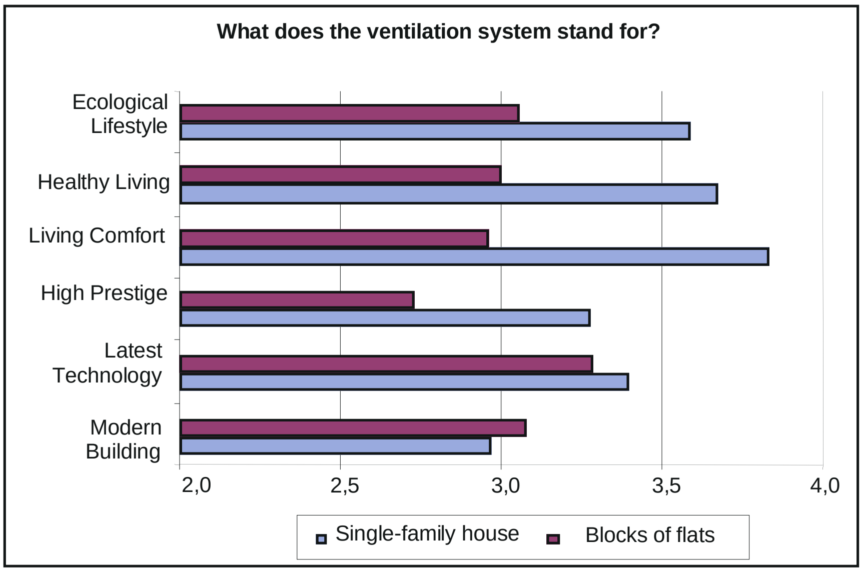


Figure 5 contrasts the connotations of balanced ventilation systems juxtaposing owners and tenants. As it turns out ventilation systems mean rather different things to these two categories of interviewees. Whereas owners connote this product with ecology, health and comfort, tenants rather stress ventilation systems being a modern technology. The view of architects and planners best corresponded with the connotations of house-owners.

Figure 5. Connotations of ventilation systems



Apart from attributing different meanings to balanced ventilation systems occupants were not just passively affected by these products. Quite often users were looking for ways to influence the performance of the ventilation system. As already mentioned, there were people who tried to block the system in sleeping rooms, or dwellers who tinkered with possibilities to regulate temperature and ventilation levels separately in different rooms. Building societies sometimes had to give way to the pressure of tenants and install additional radiators for room heating or shut down the whole ventilation system. Again owners of houses or flats were much more active in engaging with alternative technological solutions and often showed high technical competence.

It is possible to separate certain 'ideal types' of users of ventilation systems, who differ quite remarkably along dimensions such as connotations, satisfaction with product, level of know-how and engagement in adapting the technology:

- Owners of single family houses are generally rather knowledgeable as they have taken a conscious decision to install a ventilation system. On average theses users show a high level of engagement and identification with this technology and rather connote it with ecology or health.
- Tenants of flats show a rather low level of knowledge about the product, they are rather sceptical about its performance and contribution to environment or health. Contrary to house owners the ventilation system was usually initiated by the building society. Most tenants complained about not having got appropriate information on balanced ventilation.
- Finally there is a category of 'lead users', often energy experts, architects, or planners, who live in such houses themselves. These users often play the role of change agents, they consciously initiate learning processes with local builders or installers, when they build their own house and often try to tinker with better solutions.

As it turns out, it is problematic to talk about the acceptance of a technology or product in a rather static way. There are significantly different levels of engagement with products such as ventilation systems, which (in this case) to a large extent depend on issues like ownership of a flat or the possibility to participate in the planning process and not on demographic factors like age or education. Engagement with the product also influences its perception – not only in terms of connotation with health, ecology or comfort, but also in terms of satisfaction with functionality and handling. The relation between this product and its users apparently is far more active than initially expected.

The remarkable differences with respect to balanced ventilation systems between these user groups indicate the extent to which the effectiveness of environmental technologies depends on the context of their appropriation. Users who get involved with planning processes and decisions about the way technologies are implemented are far more prone to integrate those technologies in their daily life, to adapt those technologies to their needs or to 'forgive' problematic features, such as slow reaction times of heating systems.

7. PRODUCT INNOVATION AS A MUTUAL LEARNING PROCESS OF USERS AND PRODUCERS

Moreover, our interviews turned out that substantial learning processes between suppliers of ventilation systems (producers, planners) and users have been taking place indeed, though the actors involved were not always aware of that. Table 1 demonstrates the improvement in satisfaction with different features of balanced ventilation towards newer products. Negative features are improving along the same trend, too.

Table 1. Experiences with ventilation system in relation to age of product

Positive experience with ventilation system				
Age of system	**Good indoor climate**	**Less dust**	**Higher living comfort**	**Better air Quality**
Less than 1 year (n=35)	97%	70%	97%	97%
1 to 3 years (n=22)	100%	63%	85%	94%
3 years and older (n=20)	78%	57%	83%	81%

Many of the improvements were based on changes such as:

- Integrative planning strategies bringing various professionals involved in the building process together at an early stage;
- Higher priority given to technical features such as noise reduction;
- Keeping air exchange rates low, even if heating is involved;
- More over-capacity of the heating system to cope with unexpected user behaviour;
- Installation of parallel heating systems with electric radiators or hydraulic systems;
- Earlier and better involvement of dwellers in blocks of flats; enhanced information strategies; stronger engagement of building societies;
- Higher emphasis on continuing support of users and maintenance measures;
- More autonomy given to users by e.g. switching from central systems to decentral systems for each flat.

However, this process is taking place in a rather uneven way, as it is often restricted to a few advanced planners or building societies with only slow diffusion to other building professionals. Most of the building professionals involved still lack much of the know-how needed to set up systems which have a good match with user requirements.

Moreover, supply side actors often are reluctant to take consumer experiences seriously and developed certain patterns of reaction to criticism. One of the often heard reactions of planners or producers was that there would always be 10% users who are always complaining – as a psychological law (compare this to the 40% complaints about noise). All the complaints they received or heard about, they put into this 10% category without having any evidence how many users really were affected. Even if planners and other professionals gave in to user demands, they often still deem these demands as irrational. As one of the more advanced planners told us in his interview, he for example gradually had learnt to install separate radiators or extra noise reductions, although he still was convinced this being completely unnecessary.

8. CONCLUSIONS

This leads us back to our hypotheses. Apparently, it is not straightforward indeed to transfer an existing technology like balanced ventilation systems into a new context - in our case low energy residential buildings in a country with little tradition of mechanical ventilation. On the one hand the example of ventilation systems shows us that there is still significant latitude to implement technologies in different ways and adapt it to the requirements of the new situation - noise limits, low air exchange rate as a new boundary condition to the planning of the ventilation system, extra heating provisions because users do not completely trust air heating systems, different cost requirements compared to office buildings, etc. These new requirements cannot be fully assessed in advance but have to be learnt in a 'negotiation process' with users.

In the end a new socio-technical system or actor network has to be set up again or has to be reconfigured from an existing one. Firms and professionals have to develop know-how on residential low-energy-house ventilation systems and specialise in this area, energy advice centres have to take this technology into account and have to develop certain opinions about it, planning procedures have to be adapted and co-operations between building professionals have to be developed, public authorities may introduce subsidies or have to adapt norms (e.g. noise level). Not least, a growing number of users have to be aligned to the system - by providing demonstration projects, by finding appropriate price levels, by adapting the design of ventilation systems to their needs and worries.

So far this process is restricted to a small group of specialised professionals and highly motivated users (either end users in the case of single family houses, or intermediaries such as building societies in the case of blocks of flats). As a next step the existing actor network will have to be widened significantly - a higher number of users, but also many more architects, installers and others have to integrated. Reacting to the problems of tenants in blocks of flats - who rather represent the average user than motivated home builders - and finding appropriate technical and planning solutions - is an important part of this integration process.

As our empirical investigation showed these changes and socio-technical reconfigurations are long-term learning processes between the different parties involved. What could this mean for a policy trying to promote sustainable housing? In the first place, the importance of the 'user-designer' should be taken more seriously. It may not be sufficient to focus on 'greening' the design of products and provide product information for consumers. The question is whether product policy should not intervene in the appropriation process of products by providing a platform for the interaction of designers and users and fostering the involvement of users into product development. This also means to develop strategies to shift more power to consumers, to support them in voicing their needs and actively using their experience with certain products.

There are two approaches discussed in technology and innovation studies such strategies could be based upon. The one is 'Constructive Technology Assessment', a concept developed in the Netherlands (see e.g. Schot and Rip 1996). One of the key issues of this approach is to institutionalise a nexus between designers and groups outside the design process, such as consumer associations, or NGOs. 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. A second strategy originates from management and innovation studies, where the importance of intense user-producer interaction for the success of innovations was recognised. Lundvall (1988) coined the phrase 'learning by interacting' to stress this issue. Von Hippel (1988) (for a more recent example see Herstatt and von Hippel 1992) drew further consequences from the importance of user experience for product innovations. His 'lead user'-method aims at identifying a small sample of lead users, who should face needs that are generalisable in the marketplace, but at the same time should benefit significantly by obtaining a solution to those needs. Those lead users are then recruited for 'problem-solving sessions' with designers and innovators to contribute to product innovations.

So far the construction industry has mostly been unaware of the innovative potential of the user (Pries and Janszen 1995: 45), although field-studies of certain residential building innovations clearly revealed the importance of user-builder innovations (Slaughter 1993). The vision of sustainable buildings will thus need both, new processes of planning and design, and new forms of integrating users and other actors.

9. REFERENCES

Akrich, M., "The De-Scription of Technical Objects". In: *Shaping Technology/Building Society. Studies in Sociotechnical Change*. Edited by Wiebe E. Bijker and John Law. Cambridge/London: The MIT Press, 1992.

Bijker, W.E. (1993), ‘Do not despair: there is life after constructivism’, *Science, Technology, & Human Values* 18(1), pp. 113-138

Cooper, G., *Air-Conditioning America. Engineers and the Controlled Environment*, 1900-1960. Baltimore: Johns Hopkins University Press, 1998.

Diekmann, A., Preisendörfer, P., *Umweltsoziologie*. Reinbeck bei Hamburg: Rowohlt, 2001.

Gjøen, H. and Hård, M., "Cultural Politics in Action: Developing User Scripts in Relation to the Electric Vehicle". Workshop: Cultural Politics of Technology; Centre for Technology and Society, NTNU, Trondheim, 1998.

Herstatt, C. and E. von Hippel, "From experience: Developing new product concepts via the lead user method: A case study in a 'low-tech' field", *Journal of Product Innovation Management* 9, 1992, pp. 213-221.

Hippel, E. von, *The Sources of Innovation*. Oxford/New York: Oxford University Press, 1988.

Latour, B., "Where Are the Missing Masses? The Sociology of a Few Mundane Artifacts". In: *Shaping Technology/Building Society*. Studies in Sociotechnical Change. Edited by Wiebe E. Bijker and John Law. Cambridge/London: The MIT Press, 1992.

Lie, M. and Sørensen, K.H., "Making technology our own? Domesticating technology into everyday life". In: Lie, M. & Sørensen, K.H. (eds.): *'Making technology our own? Domesticating technology into everyday life'*, Scandinavian University Press: Oslo, 1996, pp. 1-30.

Lundvall, B.A., “Innovation as an interactive process: from user-producer interaction to the national system of innovation”. In: Dosi, G. et al., *Technical change and economic theory*, London: Pinter, 1988.

Mackay, H. and G. Gillespie, "Extending the Social Shaping of Technology Approach: Ideology and Appropriation", *Social Studies of Science* 22, 1992, pp. 685-716.

Pfaffenberger, B., "Technological Dramas", *Science, Technology, & Human Values* 17 (3), 1992, pp. 282-312.

Pries, F. & F. Janszen, 'Innovation in the construction industry: the dominant role of the environment', *Construction Management and Economics* 13, 1995, pp. 43-51.

Weyer, J. et al., *Technik, die Gesellschaft schafft. Soziale Netzwerke als Ort der Technikgenese*. Berlin: edition sigma, 1997.

Sahal, D. ‘Technological guideposts and innovation avenues’, *Research Policy* 14, 1985, pp. 61-82.

Schot, J. and A. Rip, "The Past and Future of Constructive Technology Assessment", *Technological Forecasting and Social Change* 54, 1996, pp. 251-268.

Slaughter, S. 'Innovation and learning during implementation: a comparison of user and manufacturer innovations', *Research Policy* 22, 1993, pp. 81-95.

10. END NOTES

[1] I am grateful to the Austrian Federal Ministry of Transport, Innovation and Technology for funding the research project this paper is based upon. I am also indebted to my colleagues in this research project, Michael Ornetzeder (ZSI) and Brigitte Kukovetz (IFZ), who have substantially contributed to the empirical and conceptual basis of this paper. An earlier version of this paper has been presented at the EASST/4S conference 2000.

[2] Cooper (1997) provides an excellent introduction to the development of ventilation and air conditioning in America from the beginning of this century to the late sixties. The major technical components and challenges for dissemination have already been in place at that time.