User Evaluations of Energy Efficient Buildings – Literature Review and Further Research

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ABSTRACT

This paper is based on a review of research that describes user experiences with different types of energy efficient buildings, focusing on indoor climate, technical operation, user attitudes, and general satisfaction. Energy efficient buildings are often rated better than conventional buildings on indoor climate, but when investigating more thoroughly, the users have different concerns. The varying results from the user evaluations reflect that the quality of the buildings differs. However, user concerns may also be a result of inappropriate use. Perceived personal control and sufficient information on operation and use is crucial for an overall positive experience of the building. Three areas for further research could be identified: There is a shortage of research that takes into account the social context for evaluation. The social environment, the process of moving into an energy efficient building, and prior knowledge on environmental issues, influences the evaluation of the building. Energy efficient buildings may also require specific architectural solutions, and further research should consider architectural and aesthetic aspects in the evaluation. Research on use and operation of energy efficient buildings is increasing, but there is still a need to give more detailed attention to different ways of providing information and training in operation and use.

Keywords: User evaluations, POE, energy efficient buildings, passive houses

INTRODUCTION

In the end, the performance of buildings depends on the users. Therefore, it is important to focus on users' experiences with different types of energy efficient buildings. There exists a well-known gap between predicted and actual performance of energy efficient buildings. In some cases, actual performance is quite different from predicted performance, especially for the first years (Hinge *et al.* 2008). A study by the New Building Institute (2008) found that 30% of LEED[1]-rated buildings (Leadership in Energy and Environmental Design) perform better than expected, 25% perform worse than expected, and a handful of LEED buildings have serious energy consumption problems. These problems may be caused by technical failures, too high expectations, or by inappropriate operation and use.

Bordass *et al.* (2004) suggest that the gap between a building's expected and actual energy consumption *"not so much arise because predictive techniques are wrong, but because the assumptions often used are not well enough informed by what really happens in practice because so few people who design buildings go on monitor their performance"* (Bordass *et al.* 2004:1).

Hinge *et al.* (2008) do also point to the use of the buildings, and the meaning of the role and active involvement of building operators and facility management to explain this gap. In order to reach a building stock that has zero emission of greenhouse gases related to them, it is not only crucial that the building operation is comprehensible, and that people get the information they need to operate it, but also that they will want to live and work in zero emission buildings. Therefore, it is essential to take into consideration the use and implementation of these buildings.

Concerning usability, there are many aspects in common for all types of energy efficient buildings. The evaluation of energy efficient buildings from a user perspective includes research on the experience of indoor climate, heating, light, ventilation, local energy production and other technical installations, in relation to experienced housing quality in general. In this paper, "energy efficient buildings" is used as a collective term for different types of buildings made to reduce energy consumption to different degrees. The research presented includes studies on low-energy buildings, passive houses, LEED buildings and green buildings. The research is thematically categorized as "indoor climate", "technical operation", "user attitudes", and "general satisfaction".

1. INDOOR CLIMATE

1.1 Residential Buildings

Are the users satisfied with the indoor climate in energy efficient buildings? Isaksson & Karlsson (2006) has investigated the thermal environment and the space heating in 20 low-energy terraced houses in Lindås, south of Gothenburg, Sweden. They applied qualitative interviews with the occupants as well as measurements of physical parameters. The heating system in the terraced houses in Lindås is based on the emission of the household appliances, the occupants' body heat, and solar irradiation. Many agree that the heating system functions well. However, during wintertime when the heater is on, varying indoor temperature is experienced. The study shows that people experiment with warming up the house, as for instance by leaving doors open and lighting candles. When the houses are empty for some time, it takes half a day to warm it up. Therefore, some of the residents leave the heating on when they are away. Interestingly, when comparing the residents' opinions to the measured parameters, there were main differences between the measured indoor temperature and the occupants' experience of the thermal environment. The indoor temperature was often higher than experienced, indicating that the subjective experience differs from person to person (Isaksson & Karlsson 2006).

Another study on residential satisfaction with the indoor climate is a diploma work by Samuelsson & Lüddeckens (2009). They did a survey on three different passive houses in Sweden. Questions were asked about experienced temperature and temperature variations, draughts, and perceived indoor climate. They have also calculated the energy consumption and simulated the indoor climate for two of the projects. The results between the two models do not vary a lot, neither in terms of energy consumption, nor in terms of heating. The models indicate that in theory, the heating unit is enough to heat up the houses during the winter. The results from the survey show, however, experienced problems with the indoor temperature during the winter. Especially in one of the three projects, where more than 50 per cent of the residents report that it is too hot in the summer and too cold in the winter. They criticised that they cannot adjust the temperature, and that weather conditions influence the indoor temperature. They also report temperature differences of 3-4 C between rooms during wintertime and that the ventilation system did not function sufficiently. They had to use additional heating during winter, which influenced the use of electricity. Similar discrepancies between the findings of the different methodologies (evaluation and simulation) were found by Isaksson & Karlsson (2006). Samuelsson & Lüddeckens (2009) state that the problem with the simulation model is that it cannot simulate reality in a sufficient way, and that it might not capture the problems experienced by the residents. Samuelsson & Lüddeckens (2009) cannot give a clear answer to why the residential satisfaction with the indoor climate differs between the cases. Their discussion shows how difficult it is to comprehensively predict indoor climate through simulations. Another challenge is the fact that people experience temperature and draughts differently.

Buber *et al.* (2007) investigated the meaning of the terms comfort, well-being, cosiness, and housing comfort in relation to experienced housing quality in passive houses. The personal opinions of residents were investigated in focus group interviews. Results show that the type of heating had a crucial influence on housing comfort, and thus on the well-being of its residents. None of the residents interviewed would have agreed on moving to a house that is just heated by the ventilation system. They wanted to have an additional heating, such as wall heating or wood pellet ovens. The visual and sensible effects were of importance for perceived comfort. In regard to fresh air supply, the ventilation system with frequent air exchange was seen as imperative for a high level of comfort.

In conclusion, studies of thermal comfort show that the way indoor thermal environment is evaluated depends on the relationship between people, climate and building and can vary over time (Nicol & Roaf 2005). This can explain the difference between experienced comfort and simulated indoor climate found by Samuelsson & Lüddeckens (2009). When users living in passive houses declare that they miss a fire place or wish for an additional heating it reflects that the feeling of a comfortable indoor climate is influenced by visual or sensible signs of heat. Differences between perceived and measured temperatures show that user satisfaction in domestic spheres includes subjective factors. While this is true for most evaluations, homes may be considered to be special ‘territories’ (Morley 2009) where demands for comfort are particularly high (Aune 2007).

1.2 Occupational Buildings

Leaman & Bordass (2007) have studied if occupational buildings designed for lower environmental impact are better than conventional buildings from the occupants’ point of view. They compared user experiences through surveys in 177 conventional buildings, with mixed modes or air conditioning, and green buildings, with natural or advanced natural ventilation. They found that green buildings scored better on: ventilation/air, health, design, image, lighting, overall comfort, and perceived productivity. While the best green buildings ranked higher than the best conventional buildings, a few of the lowest scores were also attained by green buildings. Many of the green buildings were experienced as too hot in summer, and seemed to have more ambient noise. The experience of indoor climate may also be related to whether the occupants have single offices or open plan layout. In a single office an employee is more in control over the temperature, ventilation, lighting, and noise.

An article by Heerwagen & Zageus (2005) evaluates the Philip Merrill Environmental Center in Annapolis, Maryland, an educational institution. A survey on indoor environmental quality was distributed and a series of interviews and discussion groups were conducted. The findings show that occupants were highly satisfied with the building. Air quality, daylighting and artificial lighting, as well as the access to views, were rated positively by close to 90 per cent of the respondents. The evaluation also revealed critical aspects. Acoustic conditions, and also temperature conditions, noise distractions due to the open landscape, insufficient provision of meeting rooms, and glare from windows caused some concerns (Heerwagen & Zageus 2005).

Wagner *et al.* (2007) have also made a survey on workplace occupant satisfaction in 16 office buildings in Germany. This survey revealed that the occupants' control of the indoor climate, and moreover the perceived effect of their intervention, strongly influence their satisfaction with thermal indoor conditions. Another study by Barlow & Fiala (2007) also focuses on the occupants' ability to control the indoor climate, and how this increases their thermal comfort. They suggest that active adaptive opportunities should be made an important part of future refurbishment strategies for existing office buildings. In the study, opening windows was voted to be the most favourite adaptive opportunity followed by controlling solar glare, turning lights off locally and controlling solar gain. Occupants also expressed desires to intervene with heating and ventilation currently operated centrally.

The studies presented on user evaluations of indoor climate in energy efficient occupational buildings are *in general positive*, but when investigating more thoroughly, the users have complaints and frustrations that are important to notice. Different from residential buildings, control in occupational buildings is, at least in part, delegated to centralised control systems. Comfort experience varies greatly between individuals – what one person experiences as chilly may be too warm for another. This leads to many ways in which individuals manage comfort in their work environment, some of which may outright counteract the designers' intentions (Heerwagen & Diamond 1992, Hitchings 2009). Therefore, the users' perception about their ability to control the indoor climate is of great importance.

2. TECHNICAL OPERATION

2.1. Information and Knowledge

Leaman & Bordass' (2007) study of the difference between user satisfaction on green and conventional occupational buildings shows that users tend to have a higher tolerance for deficiencies in green buildings than in more conventional buildings. People seem to tolerate more discomfort in a green building *the more they know about how the building is supposed to operate*, and how they can use for example thermostats and window controls. Users are much less satisfied when they cannot understand how things work or how to control temperature and ventilation (Nicol & Roaf 2005, Leaman & Bordass 2007). Information on use and operation of technical facilities is therefore crucial.

The indoor climate in a residential building at Husby Amfi in Stjørdal was in general experienced as comfortable (Kleiven 2007). 70 per cent of the residents used the energy operating panel in these flats, and most residents experienced them as user friendly, intuitive, and simple. Most residents also put their flats into standby mode when they left, however, a few residents found the energy operating panel difficult to understand. They wondered if it didn't work, or said that they had not been well enough trained in operating it. The flats had a web-based follow-up system for energy use, but this system was barely used, as it was experienced as too advanced.

In Isaksson (2009) and Isaksson & Karlsson's (2006) investigation of the houses in Lindås, the interviews showed that knowledge about the heating system was an important issue for the residents. Some residents told the authors that they did not have sufficient information about the heating system when moving in. Consequently, they tested the system during the first winter, something that resulted in varying indoor temperature and higher energy costs. The process of operating the energy system was a dynamic learning process. Isaksson (2009) emphasises the importance of learning-by-doing in operating energy efficient technology and concludes that implementing energy efficient buildings is not just a question of developing new technologies, but the great challenge is that *"tools must be developed that support people to choose the sustainable ways to use the new technology"* (Isaksson 2009:195).

To summarize, the studies show that the operation of energy efficient buildings may be difficult for the users, and that if the technology is experienced as too advanced, they are not used or not entirely understood. This may lead to uncomfortable indoor climate. The research also shows, once more, that perceived personal control and sufficient information on operation and use is crucial for an overall positive experience of the houses.

2.2 Motivation to Operate Energy Efficient Housing

Schnieders & Hermelink (2006) evaluate residential satisfaction with passive houses in two CEPHEUS projects (Cost Efficient Passive Houses as EUropean Standards), Hannover-Kronsberg and Kassel. The development of the residents' opinions, attitudes, behaviour, and satisfaction over time were recorded. Several studies have shown a high level of satisfaction with living in the passive houses in Hannover-Kronsberg. The building in Kassel is the world's first multi-story passive house. The main difference between the projects in Hannover and Kassel is the type of occupancy. The houses in Hannover-Kronsberg are owner-occupied and therefore represent typical passive houses. This is in contrast with the multi-story passive house with 40 flats for low-income tenants. The project was built at low costs by a social housing company. A hypothesis was that the demand for heating energy might be much higher in the Kassel project than in other, owner-occupied cases because *"Tenants usually do not identify themselves as much with their dwelling and its characteristics as owners do. Therefore the motivation to deal with unfamiliar technologies and the willingness to change customs might be lower"* (Schnieders & Hermelink 2006:162).

The study investigated the tenants' ventilation behaviour. Keeping the windows shut is an important factor to keep the ventilation rate steady. The results showed that in general, the "forbidden" ventilation through windows stayed within a tolerable range that did not upset the energy balance as such. More interestingly, residents who showed a high level of window-ventilation expressed a low opinion of the controlled ventilation, probably because they interfered with the system which consequently did not work properly. The maximum ventilation switch is situated in the kitchen and the location leads to the misconception that it is dedicated only to kitchen odours, even though it affects the whole flat, including the toilet and bathroom. When an information letter was sent out, the use of maximum ventilation increased immediately. Prior to the first winter, many expressed worries that the ventilation system without additional radiators would not be enough to keep the flats warm. This scepticism was altered after the first winter. The average of satisfaction with the ventilation system heating the flats was 4.7 on a scale from 1- 6. It was also assessed whether the residents were of the opinion that living in a passive house increased or decreased comfort. The results indicate a perceived increase of comfort. Most of the tenants adapted to the new building quickly and *"very easy control of the ventilation, very high thermal comfort and air quality make the tenants feel very comfortable. In addition, they are realizing that costs for heating are extremely low"* (Schnieders & Hermelink 2006:162).

This study indicates that type of occupancy is not necessarily relevant for the motivation to operate energy efficient buildings, or to identify with them, if good information on operation is provided and personal advantages are understood. The study also shows that user evaluations have to take into account what the occupants know and that their knowledge may be subject to change. Brown & Cole (2009) compared occupants in a conventional and a green building in British Columbia. They found that users in the green building were more interested in learning how the building and its controls work. However, while those who knew more about their building's inner workings used the controls more extensively, they did not report higher degrees of perceived comfort. Thus, even though cognitive aspects like knowledge and learning are central for a well-functioning energy efficient building, and should be improved through easy to use controls and appropriate guidance and feedback, there are other factors at play. Furthermore, users have certain expectations towards energy efficient buildings.

3. USER ATTITUDES

3.1 Choosing an Energy Efficient House

Research shows that energy efficient houses are mainly bought or chosen for other reasons than the energy profile. Isaksson & Karlsson's (2006) findings in the user evaluation of housing in Lindås show that the low-energy profile of the houses was positively evaluated, but the inhabitants' main reason for moving there were the location and getting value for the money. Buber *et al.* (2007) state that passive houses are usually advertised as "houses without heating" and not as "comfortable houses", even though housing comfort aspect is a crucial argument for potential (passive) house buyers, while the environmental effect might just be a side-effect for many.

Schnieders & Hermelink's (2006) study of the Kassel project also focuses on the residents' reasons for moving in. The first advertising campaign for flats was aimed at passive house characteristics and low energy demand. The response to this campaign was weak and only after advertising other characteristics such as attractive location, balcony and new buildings there was a great response.

In the study of the flats in Husby Amfi, the low-energy concept of the flats was important for only 1/3 of the buyers. Interestingly, most of the residents answered that living in a low-energy building had made them more aware of energy use and environment friendly behaviour (Kleiven 2007)

As a conclusion, energy efficient buildings are seldom sold due to their energy profile, but due to other aspects such as preferred location or having a balcony. Nonetheless, most residents seem to appreciate the environmental benefits over time, and become more aware of environmental issues. By the time the positive aspects of energy efficient buildings become more generally acknowledged, the energy profile of buildings may become a more relevant marketing factor.

Regarding the findings that other aspects than the environmental profile are important for marketing energy efficient buildings, it is noteworthy that there are very few studies on aesthetic or architectural preference as perceived by the users. It can be assumed that architecture and aesthetics are important factors when choosing a house (Thomsen 2008). Architectural preferences in energy efficient buildings are not a main focus of any of the studies reviewed.

3.2 General Satisfaction

There are however, a few studies that evaluate more than indoor climate and operational aspects. They cover general satisfaction and the concept "comfort" in these studies is used in a wider sense than "thermal comfort". It may for example include comfort in relation to light, architecture and aesthetics.

This research is interested in if the improved thermal comfort and the architectural qualities affect the users' performance and well-being. Some of these studies indicate that energy efficient buildings have a positive impact on comfort, performance and well-being, other studies do not. Heerwagen and Zargeus' study on user evaluation of the Philip Merrill Environmental Center (Heerwagen & Zargeus 2005), focused on the impact of the different passive house features on the respondents' ability to work. Both temperature and acoustics were named as the conditions that can contribute positively, but that also can interfere with working abilities. Even though acoustics was a concern, the detailed assessment shows that most of the respondents seem to be able to concentrate and achieve privacy when needed. Lighting (74 per cent) and air quality (61 per cent) conditions in the centre were rated as enhancing the ability to work. For the Philip Merrill Environmental Center, also the building's overall aesthetics were named as a positive aspect. The educational institution had open plan offices that housed a staff of about 90. Social benefits such as improved communication and sense of belonging are linked to the buildings` design, as well as perceived psychosocial benefits. About 80 per cent experienced a high level of well being and sense of belonging at work, and 97 per cent felt proud when showing the office to visitors (Heerwagen & Zargeus 2005). Factors that influenced working ability negatively were distractions, interruptions, uncomfortable temperatures, and glare from windows. The authors also compare the results of the survey with results from evaluations of other LEED buildings that could be found in the database maintained by the Center for the Built Environment (CBE) in 2005 at the University of California, Berkeley and the results clearly show differences in user satisfaction with these LEED buildings. The Merrill Center is number 2 in the entire database (170 buildings) for overall satisfaction with the building. This is also a much higher score than any other of the LEED buildings achieve. The comparison of conventional buildings and LEED buildings also shows that LEED buildings in general are not equivalent with high user satisfaction.

Heerwagen & Zagreus (2005) indicates that energy efficient buildings can have a positive impact on well-being and daily performance while other studies do not confirm this. Paul & Taylor (2008) for instance, conclude that their study revealed insufficient evidence to support the hypothesis that green buildings are perceived as more comfortable than conventional buildings. They measured occupants' perception of comfort and satisfaction in three university buildings in Australia, one green building and two conventional university buildings. The survey found no evidence that the green building is perceived more comfortable than the conventional buildings. The aspects of aesthetics, serenity, lighting, ventilation, acoustics, and humidity, were not perceived differently by the occupants of the two types of building, and the authors state that they were surprised by these findings (Paul & Taylor 2008).

In conclusion, these studies, which are based on more comprehensive accounts of comfort, show how the overall level of user satisfaction is influenced by a broad variety of factors. Floor plans, design, noise levels and many other parameters determine how occupants experience a building. The important finding of these studies, therefore, may be that there is not determinism in the relation between energy efficiency and user satisfaction: energy efficient buildings *can* be experienced very positively, but this depends on many other factors.

4. CONCLUSIONS AND FURTHER RESEARCH

Some buildings function very well and have a positive impact on well-being and performance, others do not. Some buildings have operational systems that are difficult to understand, or the users have not received good enough information on how to operate them. These in part contradictory results of the research presented above show that the connection between energy efficiency and user satisfaction in buildings is more complex than is usually assumed. Concluding, we propose three ways of improving the evaluation of energy efficient buildings:

4.1 The Meaning of Social Context in Evaluation of Energy Efficient Buildings

Heerwagen (2009) and Paul & Taylor (2008) state that in order to test the hypothesis that green buildings are perceived as more comfortable, and contribute to a healthier and better living and working environment, several case studies have to be conducted. The findings by Heerwagen (2005; 2009) are controversial to the findings by Paul & Taylor (2008). The articles of Heerwagen indicate that green buildings increase comfort, well-being and work performance, while Paul & Taylor (2008) could not find differences in perceived comfort between a green building and two conventional buildings. The differences in findings may be due to the features of the buildings, but as well to the attitudes and preferences of the users, e.g. whether they can identify with the concept of energy efficient building. When comparing energy efficient buildings with conventional buildings, it is important to consider the social context of the users, and process behind the building.

The research presented often lacks focus on the meaning of the social context, or it lacks focus on the attitudes and meaning the users associate with the building. Leaman & Bordass (2007) state that users tend to have a higher tolerance of deficiencies in “green buildings” than they do in more conventional buildings. This implies that image and process mean something for the evaluation of the building. According to Vischer (2008), it is important to conduct user evaluations of buildings on more than one level. Contextual variables cannot be ignored. Users in a new occupational building may be happy about receiving a completely new building, no matter if it is energy efficient or not. A new building signalizes that the employees are worth something, and it may contribute to a company’s positive image. It is then easier to evaluate a building as positive, and ignore frustrations with ventilation and comfort. In the same way, evaluations of occupational buildings may also be coloured by conflicts with leaders, colleagues, and a difficult organizational environment. Residential buildings are also evaluated on the background of the residents’ knowledge of the building they live in. If the building has received attention in the media and among researchers, this will affect the evaluations.

The wish for an environmental friendly image or the wish to be ordinary may also colour the building evaluations. The intentions of the different stakeholders at Lindås Park was not to build housing that appealed only to environmental conscious people, but to ordinary people (Isaksson & Karlsson 2006). Indeed, there are only a few residents who see themselves as environmentally engaged persons, who found the environmental aspects important when choosing the house. They expected to use less energy than in a conventional house, and wanted to reduce their impact on the environment, which they perceived as an important contribution to their family and to nature (Isaksson & Karlsson 2006). Most of the other residents characterise themselves as being average people when it comes to environmental friendly living. This also corresponds with the image that the stakeholders wanted to promote when marketing the houses. However, Isaksson (2009) emphasises that both constructing and buying a passive house is something beyond the prevalent norm. It is most likely that people buying passive houses are aware of that. Going beyond the norm can also be viewed upon as "extreme" by outside observers. This might be appreciated by some of the residents, but not by others, who rather choose to characterise themselves as the "norm". Even thought the majority of the residents' names other reasons than the low energy profile as reasons for choosing a house at Lindås Park, they were aware of the concept in advance, and they have to handle it in their everyday life. That implies that the people who look upon themselves as "average" have to develop an attitude towards it as well. Maybe they even feel that they have to "justify" their choice to outsiders. This may be one reason why people seem more likely to tolerate deficiencies in low energy buildings than in conventional buildings. It is therefore crucial to map the context of the building evaluation, the users' attitudes, and their knowledge of the building.

- Future user evaluation should include focus on social context, process and image for a better understanding of why a building is evaluated the way it is. This also implies the significance of being aware of the gap between the outcome of simulations and experienced reality in indoor climate energy efficient buildings.
- Evaluations should focus on the users' reasons for choosing to live in energy efficient buildings, to be able to give input to how to market energy efficient buildings.

4.2 The Meaning of Architecture and Aesthetic in Energy Efficient Buildings

It has been mentioned previously that the architecture and aesthetics of energy efficient buildings may have a meaning for the users. There is a lack of research on this topic and very few of the studies presented have focused on the architectural and aesthetic aspects of the energy efficient buildings evaluated.

An energy efficient approach influences the design and layout of a building through for instance orientation or limited window area, material use, and construction. It is commonly acknowledged that a building's appearance mediates information about its purpose and use, and that architectural aspects can have a significant influence on user satisfaction (Thomsen 2008). Therefore it should be of interest whether the premises of energy efficient building results in specific architectural expressions, and how the aesthetics of energy efficient buildings are perceived and influence user satisfaction. Do the users find energy efficient architecture as aesthetically appealing, can they identify with it, and what role does the aspect of aesthetics play when choosing to live in an energy efficient house? Further research should investigate these questions as they are main aspects of successful and comprehensive architectural concepts.

- Future evaluations should include more than indoor climate, temperature, air quality and operational aspects. Important aspects are perceived architectural quality and aesthetics, as well as light conditions.

4.3 The Meaning of Information and Training in Operation of Energy Efficient Buildings

Difficult energy operation systems are a common theme in the research presented, and is central to focus on in future building. It is of importance to make the operation of buildings understandable to the users to increase control over work or home environment, as well as to ensure the buildings optimum performance.

The lack of instructions on the adequate use of the building is a typical reason that people mention when having problems with the operation of their house or at their workplace (Kleiven 2007). In the study by Schnieders & Hermelink (2006) the handling of the ventilation system is not entirely understood. The maximum ventilation switch is situated in the kitchen and the location leads to the misconception that it is dedicated only to kitchen odours. Other problems they observed could be solved by better informing the residents about requirements, e.g. changing filters more often to avoid noise from the ventilation system. Schnieders & Hermelink (2006) also state that the results of informing people often are better if a qualified person explains and demonstrate the handling of the system as soon as a tenant moves in, rather than to provide written information. Also Isaksson (2009) points out that complicated technical descriptions are seldom read by users, especially if they are not interested in technical innovations. Only if the users can operate the building, the performance of the building will be close to calculations in the planning phase.

There is a lack of research on detailed evaluations of operation systems, and how information and training on use and operation should be given. How should energy operating panels be designed? Should there be differences according to resident groups and system operators? In what ways should information on use and operation be provided? How much information is needed, and should there be feedback on operation of energy efficient buildings over time?

Buildings and their users change over time (Brand 1995). Longitudinal studies focusing on operation and maintenance over years are significant for planning better and more usable energy efficient buildings.

- Future evaluations should be longitudinal, and focus on operation and maintenance over time.
- User evaluation must include a detailed focus on different types of user friendly operating systems. They should include a detailed focus on different ways of providing information and training for the users and system operators in energy efficient buildings.

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Endnote:
[1]LEED, Leadership in Energy and Environmental Design, is an ecology-oriented building certification program run under the auspices of the U.S. Green Building Council (USGBC). LEED concentrates its efforts on improving performance across five key areas of environmental and human health: energy efficiency, indoor environmental quality, materials selection, sustainable site development, and water savings.