The interaction between building and users in passive and zero-energy housing and offices: The role of interfaces, knowledge and user commitment

Judith Thomsen, Thomas Berker, Åshild Lappegard Hauge, Karine Denizou, Solvår Wågø, S

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Abstract

Purpose – The article's aim is to present user experiences with passive houses and zero-energy buildings. The focus is on the interaction between the building and the users, specifically on how user interfaces, knowledge, and commitment influence the use of the building and the level of energy consumption awareness. Design/methodology/approach – The study follows an explorative grounded theory approach. This approach generates insights that will be consolidated in follow-up studies. Qualitative interviews with users of six buildings were conducted. Site inspections applying walk-through method and other available information complement the data. Findings – Users in general were satisfied with having a new energy efficient building. Several respondents were more concerned about the environment now than before. However, there were concerns about thermal comfort. Misuse or misunderstandings among users in some cases led to lower indoor comfort. New or dissatisfactory design solutions were also responsible for unsatisfactory indoor environmental quality. Practical implications – Specific topics that should be paid more attention to in the design and research on new energy efficient buildings: level of end-user control and adaptability of the building; level of complexity of systems; the need for adequate information. Originality/value – The open approach enabled occupants to influence the parameters of the evaluations. Most evaluations of zero-energy buildings are not yet publicly accessible.

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Introduction

Previous studies show that users are often satisfied with energy efficient buildings, but when digging deeper, there are different concerns, which are important to notice. Evaluations and measurements show that there are, in many cases, substantial gaps between predicted energy use and actual consumption (e.g. Bordass et al., 2004; Gram-Hanssen, 2010; Grini et al., 2009; Dokka et al., 2011). Also, the variability between households with more or less the same technical infrastructure is often surprisingly high. According to the literature, reasons for these discrepancies between prediction and result and between different households can be technical failures, but can also be found within the complex interplay between users' everyday practices and the built environment. More specifically, studying a site of 26 low-energy dwellings, Gill et al. (2010) found that occupants' behavior accounted for 51 and 37 percent of the variance in heat and electricity consumption, respectively.

A review of previous studies by Hauge et al. (2011) summarizes that general surveys often draw the conclusion that energy efficient buildings are experienced as being better than conventional buildings, however, there are also reported some concerns and frustrations among the users. Some buildings have operational systems that are difficult to understand, or users have not received sufficient information about how to operate them. The connection between energy efficiency, use, and occupants' satisfaction in buildings is more complex than is usually assumed (Hauge et al., 2011).

It is also interesting to ask which topics of the user evaluations that are related to new, energy efficient building concepts, and which were concerns in the evaluation of the interaction of buildings and users earlier. For instance, thermal comfort is a topic that has been addressed in user evaluation of buildings for many years and even standardized questionnaires are developed on the subject (e.g. Gossauer and Wagner, 2007; www.usablebuildings.co.uk). Krapmeier (2006) states that comfort and convenience in buildings throughout history have always been high priorities.

Expectations to comfort in passive houses and zero energy buildings tend to be higher than in conventional buildings due to high demands to air tightness, thicker insulation layers, resulting in higher surface temperature, and regulation of air exchange rate through balanced ventilation (Thomsen and Berge, 2012). It is, however, not so simple to predict and quantify individual comfort experience through measuring temperature since people experience thermal comfort in relation to their behavior, habits, and experiences (Nicol and Humphreys, 2002).

Studies have found a clear correlation between satisfaction and technology dissemination and good performance of the building. For instance, problems with the ventilation system in projects resulted in lower general satisfaction (Keul, 2010). Aspects that influenced overall satisfaction are the perception of high thermal comfort, good air quality, and low costs for heating (Thomsen and Berge, 2012). Leaman and Bordass (2007) add that aspects of maintenance of the building are important to pay more attention to, since energy efficient buildings in general are more complicated to operate and maintain than conventional buildings: "Green buildings are often more fragile in their performance, so it is more important that everything works well together" (Leaman and Bordass, 2007, p. 672). It should be remarked that each of the terms conventional, green, or energy efficient building room a wide range of building types with great differences in performance, control, and qualities. Comparison of these types of buildings has therefore to be conducted with caution.

- The interface between users and buildings: How do users adjust to the energy efficient building, how do they adjust the building to their needs and desires?
- How does the users' knowledge about the building influence the interplay between users and the energy efficient building?
- How does the meanings that users ascribe passive houses and zero energy buildings influence the interplay between users and the building?

Occupant behavior and satisfaction

A study by the New Building Institute (2008) found that 30 percent of Leadership in Energy and Environmental Design (LEED)-rated buildings perform better than expected, 25 percent perform worse than expected, and a handful of LEED buildings have serious energy consumption problems. These problems may be caused by technical or design failures, differing expectations of users, or by inappropriate operation and use. Besides the gap between predicted and actual performance of buildings, Brown and Cole (2009) focus on a second gap, which is found between "[y] assumed and actual comfort-related behavior within buildings" (Brown and Cole, 2009, p. 229). They add that we know little about how occupants "interpret and understand the environmental features and systems of the buildings in which they live and work, and the role knowledge plays in shaping comfort and energy use patterns." (Brown and Cole, 2009, p. 228).

Knowledge and understanding are identified as crucial factors for influencing comfort in other studies: users are much less satisfied when they cannot understand how things work or how to control temperature and ventilation (Leaman and Bordass, 2007; Nicol and Roaf, 2005; Brager and deDear, 1998). The investigations of Isaksson (2009) and Isaksson and Karlsson (2006) of user satisfaction with passive houses in Sweden showed that knowledge about the heating system was an important issue for residents. Some told the authors that they had not received sufficient information about the heating system when moving in. In order to achieve thermal comfort, they tested the system during the first winter, which resulted in varying indoor temperatures and high-energy consumption. Interestingly, people seem to tolerate more discomfort if they know how the building is supposed to operate (Leaman and Bordass, 2007).

Regarding the gap between predicted and actual comfort-related behavior within buildings Brown and Cole (2009) identify three potential impact factors: practical/ design related, behavioral/situational, and social/psychological. The practical/design- related causes of the gap have to do with the complexity or simplicity of the building, the usability of the systems, the accessibility of the systems, and lack of feedback on the operating of the building. The behavioral/situational causes of the gap regard the users' prior experience, time spent in the building, knowledge and information provided the users, satisfying ways of operating the building instead of optimizing the operation, and confusion with operational systems. The social/psychological causes of the gap address the individual sense of responsibility, awareness of the surrounding environment, expectations of building performance, and social/normative influence. Gram-Hanssen (2010), studying variation in energy consumption due to different usage patterns in DK, addresses similar factors as Brown & Cole. She states that technologies, embodied habits, knowledge, and meanings are the main components in the understanding of what influences occupants' practices. For instance, habits can be a continuation or reaction to learned habits and are influenced by prior experience and knowledge. Media can be one source to knowledge. The occupants' commitment and the meanings that they ascribe to the building can include whether the environment is important, whether saving money is important, or what meanings are attached to a building (Gram-Hanssen, 2010). She also adds that it is absolutely possible that occupants are interested in environmental issues without knowing technically how to influence the level of energy consumption and vice versa.

Another approach that focusses on users not using technologies or buildings in the way they were intended is known as script/anti-programs. "When the object is taken into use, the technologies are 'read' by their users. In the simplest case the designers' in-scription and the users' de-scription is coinciding. More often, however, negotiation with the original script will take place or users may even revolt. In these cases they develop their own anti-programs, which lead to unexpected uses" (Berker, 2011, p. 260). The contingent interplay of user, technology, and building is in focus. In the metaphor of technology or building being compared to a text that has to be understood and that will be interpreted, users are granted a limited possibility to thwart the original intentions, the perspective of script and anti-programs therefore can be relevant for examining what happens when assumed and actual (comfort-related) behavior of users does not correlate. It is plausible to expect that buildings with high-energy ambitions will impose more rigid or at least unfamiliar scripts on their occupants, which increases the likelihood of resistance in the form of anti-programs. The important role of natural ventilation for occupant satisfaction is well documented in the literature. As has been demonstrated by deDear et al. (1997), occupants tolerate a wider range of temperature in buildings when they are able to open the windows. Subjective factors such as expectations toward the type of ventilation (natural or mechanical) account a great deal for experiencing thermal comfort (Brager and deDear, 1998). Nicol and Roaf (2005) describe that people react if a change in the environment occurs which causes discomfort. They tend to restore their comfort by putting on cloth or opening windows, and they are active participants in the relationship with their environment. Thus, scripts inscribed in energy efficient buildings that aim at controlling air in- and outflow (either technologically or behaviorally) are likely to face challenges related to occupant dissatisfaction.

What is also important to keep in mind is that the energy profile of buildings is usually not the primary motivation for people to live or to work in these places. That is also a reason why they may not behave in the most energy efficient way. Users in new buildings may also be mostly interested in having a completely new building, whether it is energy efficient or not (Hauge et al., 2011). However, it can be supposed that in the long run, the energy profile may also have an influence on knowledge and awareness of these topics as indicated by Vale and Vale (2010). In a Norwegian study, the low-energy concept of housing was important for only one-third of the buyers. Interestingly, later most residents answered that living in a low-energy building had made them more aware of energy use and environmental friendly behavior (Kleiven, 2007).

Methodology

The present study was commissioned by the Norwegian Research Centre on Zero Emission Buildings (ZEB, see www.zeb.no) whose goal it is to contribute to the development of good technologies for environmental friendly buildings and to raise the level of Norwegian expertise in this area. The center's subject area covers the whole building stock including both newly built and existing and both residential and non-residential buildings. Research on use, operation, and implementation of energy efficient buildings is central within the ZEB center, in addition to definitions, new materials, high-performance envelopes, and installations. The number of buildings in Norway that fulfill passive house or zero-energy requirements is still very limited and in order to learn from user experiences of existing projects, we decided to extend the focus to different European projects. The results presented here were produced in the beginning of the ZEB Center's funding period (2009-2018) in order to identify user-related challenges connected to buildings with high-energy ambitions that then became the subject of more directed research.

Both office and residential buildings are included in the study (a more detailed description of the case buildings is given below), even though these types of buildings have different functions and meanings attached. Results should therefore be seen in the context of the building type, e.g. experienced comfort at home or comfort in an office may be difficult to compare directly mainly because of different usage patterns.

All in all, it was difficult to get access to the projects we wanted to investigate and we had to change country, building, and building type several times. Most organizations or users initially contacted were not willing to participate. The main reason given was that the buildings already had been evaluated, in some cases even several times. It is noteworthy that results of these evaluations were not publicly accessible. This forced us to resort to "convenience sampling" (as opposed to purposeful and theoretical sampling, see Marshall, 1996), i.e. to make accessibility a criterion of choice both regarding the cases and the informants. Limited time and funding constraints also defined the limitations of what was possible to achieve within the individual case studies and the results have to be seen as being exploratory, i.e. generating research questions instead of testing hypotheses. In this sense the present study is using an approach that follows Grounded Theory's iterative approach (Strauss and Corbin, 1998) – with subsequent studies of the same or other buildings that then focus on research issues found here. More specifically, in follow up studies the topics that were identified here as being central to the occupants of (near) zero energy buildings are supposed to inform the choice of both sampling method and research tools. These subsequent studies (of which first results are published in Thunshelle and Hauge, 2012) consolidate and deepen the insights gained here. Still, being forced to resort to convenience sampling thwarted our initial plan to select buildings according to their characteristics, like different technical solutions used or building type and size. The lack of possibilities to compare cases within our sample according to controlled parameters limits this study's ability to produce findings that discriminate between individual factors. The approach we chose led us to a more explorative evaluation than initially intended. When applying for funding for new evaluations, we chose a selection of fewer projects with easier access.

The interviews

Qualitative interviews with users of six case study buildings were conducted to capture the variety of opinions on living or working in passive houses and zero energy buildings. In each of the case study buildings, interviews with five to seven users were made. Interviews and site inspections were done by five different researchers, four architects, and one social scientist. A semi-structured interview guide was used to ensure comparability of results.

Leaman and Bordass (2007) state that users tend to have a higher tolerance of deficiencies in "green non-residential buildings" than they do in buildings without an energy efficient profile. This implies that image and process mean something in the evaluation of the building. According to Vischer (2008), it is important to conduct user evaluations of buildings on more than one level and not to ignore contextual variables. This paper is based on qualitative methods that include contextual variables, with a special focus on social aspects and personal experience. The interview guide included topics on image, identity, knowledge, and environmental friendly behavior in general.

The architects of the projects or a representative for the employees were contacted to get in touch with informants and propose the interviews. In the housing projects, the residents were interviewed in their homes, and in the office buildings, the interviews were done in the work place.

In addition to the individual interviews, site inspections were conducted. Site inspections included walk-through method, where pictures were taken and users showed the building, pointing out what was important to them. This gave us the possibility to talk in a more informal manner about the building. Moreover, all published information such as newspaper articles available about the cases was studied. More detailed information on technical aspects and building process are referred to in a main report (XXX, removed for peer review).

An important limitation of this study is that we have not conducted measurements to compare the occupant's subjective experiences to. Measurements of energy consumption and indoor air temperature are being done in the Norwegian cases of Marienlyst and Løvåshagen at the moment. Results from measurements are, however, not yet ready to be presented here. Due to limited access and financial resources we could not conduct measurements in the other European projects. The next step for the Norwegian cases was to extend the data collection to measurements and to see them in connection to the qualitative data from interviews. Moreover, in accordance with the methodological approach based on Grounded Theory that was used here, the present study has to be continued with repeated rounds of interviews. This has been done in the Norwegian research projects ZEB and EBLE (2012-2015). Results of a replication and consolidation of the present study in the Marienlyst case were published in 2012 (Thunshelle and Hauge, 2012).

The case study buildings – a short overview(Figure 1)

Important for this study is that all case study buildings have been operating for a short period (maximum three years) and most of them are still in an adjustment phase. If occupants are more tolerant toward experiencing discomfort in energy efficient buildings than in conventional buildings (Leaman and Bordass, 2007), this may be especially relevant when the building is still new or when the environmental profile implies that this building is something "good."

Discussion and results

Adjusting indoor environmental comfort

Despite a high level of general satisfaction, there are different complaints related to thermal comfort in all the case studies. Occupants report indoor air temperature too high during the summer and/or temperatures too low during the winter. The interviews show that occupants tend to adjust their environment, most often when they want to improve thermal comfort. Once the given solution is not perceived as comfortable and/or does not work in practice, other ways are found to improve the situation.

Adjustments that the users could do varied with the type of building. At Marienlyst school temperature, ventilation, and also sun shading are automatized and not individual controllable by the users. At Marche´ headquarters, sun shading is controlled automatically but office users have the possibility to override automatic functions and to adjust shades individually. When it comes to heating and ventilation, individual control is restricted. Only the floor heating has a simple low-high panel for regulating temperatures in different areas. Humidity and CO2 content are measured but there is only one person responsible for controlling and adjusting it.

The intention at Dragen Children's house was that ventilation, heating, and lighting should be controlled automatically. There is no sun shading, except for balconies and roof overhangs. The users of the building could, however, adjust the temperature to a certain degree by turning a dial. The dial had, however, no exact scale, except for turn right¼ warmer, turn left ¼ colder.

At Saint-Priest the employees cannot control temperature or ventilation. They control the artificial lighting above their working station and they can control the blinds during daytime.

Housing offers commonly a greater level of control over the living environment than office buildings and kindergarten. In the cases of Løvåshagen and Feuilly, the residents are responsible for adjusting temperature, ventilation, and exposure to sun. The ventilation system with heat recovery at Løvåshagen can be regulated by a switch (levels 1-3). The apartments also have a simple "on-and-off" button that can put the electric system of the apartment into a stand-by mode when nobody is at home. Sunscreens were not included into the sales package of the apartments at Løvåshagen and it is up to the residents to install sunscreens if they feel for it. Most of the residents had not installed any by the time of the interviews.

At Feuilly, the ventilation control was limited to a "low" and "high" switch. Temperature can be regulated individually for the bedrooms. The control panels were in the living room. Blinds are installed and individual controllable. The residents were still waiting for a control box that would enable them to check their energy consumption.

At Saint-Priest, the lavatories are not supplied with hot water in order to save energy. The informants state that they can manage without hot water in the lavatories during the summer, but it is difficult during the winter, especially when the indoor air temperature is perceived as too cold. The interviewees say that some employees, rather than using the cold water, walk to the kitchen to wash their hands with hot water. Three of the teachers at Marienlyst intervened with the heating of the building during the first winter to increase thermal comfort. They brought their own heaters to their office because they thought it was too cold. There is no individual control of heating and ventilation at Marienlyst. The Løvåshagen interviewees describe their houses as generally comfortable, always maintaining a satisfactory indoor temperature during wintertime. However, some report too warm indoor air temperature in summer. One woman who was interviewed twice had no sunscreens installed in first place and reported problems with too warm temperatures during summer. A follow-up interview conducted about two years later, showed that she had installed sunscreens and since she experienced indoor air temperatures in summer as satisfactory (Klinski et al., 2012).

Air quality at Løvåshagen is perceived as very good (Klinski et al., 2012). Airing though opening windows is, however, used to adjust temperatures and because of habits. If windows were opened frequently during winter it would lead to an increase in energy use since the heat recovery ventilation system is still running. One respondent tells that when moving in they were told not to open the windows too often by representatives of to instructions: "the house is a closed system, and we would then ruin the balance if we opened the windows [y] God knows which balance [y] After a while, around spring, we started opening the windows [y]." Personal comfort and the freedom to open a window are more important than keeping an energy balance that is not fully understood. This quote shows that an image of the building as a closed system is not only difficult to communicate. Having control over the environment, including opening window is essential for user satisfaction (e.g. Nicol and Roaf, 2005; deDear et al., 1997). It is not realistic to expect that users act according to a script that prescribes no or only limited natural ventilation. Thus, the expectation based on the literature that solutions for energy efficiency would be countered by the occupants with anti-programs has been confirmed.

The employees at Dragen kindergarden were also instructed to not open the windows, but according to the informants they do so anyway to adjust the temperature and to get rid of unpleasant odors. When occupants want to open the windows during winter because of odors or heavy air this can be an indicator of an insufficient air-exchange rate from the ventilation system. In Norway minimum air exchange rate/hour of 0.5 h (or 1.2 m3/h m2 for housing and 2.5 m3/h m2 for offices and public buildings) is defined in the technical building prescription (TEK 10). This rate varies in the different countries, e.g. in Germany the minimum air exchange rate/hour for housing is lower (0.3 h1) (www.passiv.de).

In some of our cases it has been given as an instruction that windows should not be opened in passive houses in order to keep the calculated energy and air exchange balance. It has not been made a difference between summer- and winter-time and the fact that deliberate opening the windows is not harmful to the concept. At Marche´ the employees are even encouraged to open the windows in the morning during summertime to let in fresh air. It is, however, important to be conscious of when to open the window. Once the summer heat comes in they are not able to get rid of it again. One employee explained, however, that restrictions with regard to airing by opening windows would be an obstacle for getting the idea of the passive house concept accepted as a common type of building. A literature review of studies on indoor environmental quality shows that people living in passive houses often experience good air quality and feel less need for airing through windows due to high air exchange rates from balanced ventilation (Kah et al., 2010; Ebel et al., 2003). Kah et al. (2010) and Ebel et al. (2003) have compared air exchange rates in passive houses with balanced ventilation and houses with conventional window ventilation. They show that balanced ventilation systems ensured constant and high air exchange rates in passive houses (around 0.5 h1) when compared to houses without balanced ventilation. The constant air exchange rate had also a positive effect on the measured level of CO2 concentration in passive houses, which was much more stable and lower in the cases with balanced ventilation than in the houses with conventional window ventilation (Ebel et al., 2003).

Need for individual control

The following examples indicate that variations in user behavior and perceived, personal comfort and satisfaction are reasons why adaptable controls are needed. As described in the previous section, the level of individual control varied according to the type of buildings.

At Løvåshagen the interviewees would like the possibility to control their own energy consumption more: "All we have is a big on-and-off-button meant to be switched off when leaving the apartment, and on when coming home [y] and then there is a bill every other month." Four of five respondents do not even use the "on" and "off" button and some have even demounted it. They claim that it is too close to the lighting button, and is therefore often switched off by mistake. Others complain that they cannot control the electric circuit to switch off. If the system would be more differentiated they would use it more.

People appreciate control on different levels and the inhabitants of Løvåshagen have started to use the possibilities given. They regulate ventilation, heating, and all other devices manually (three levels of ventilation) rather than using the "on" and "off" switch. Most of them say that the ventilation level normally stays on level 2. Some say that when leaving the apartment and during the night, they put it on level 1. When there are a lot of people in the apartment, they use level 3. None of them found this operation too complicated. They appreciate the freedom of being able to control the system and to adjust it for their needs.

A comparable example from Dragen also shows that systems are not always used in the way they are intended. At Dragen the employees report thermal discomfort and all year round there are notable temperature differences between the rooms. Interestingly, they could actually regulate the temperature in the building by turning a rather unspecified dial (turn left¼ colder, right¼ warmer), but they do not use it very often. They report other solutions to the temperature challenges than turning the button: bringing extra electrical heating, and putting clothes on/off. Instead of investigating the possibilities within the system, they find their own solutions. The interviewees find common and known ways of improving their comfort in the buildings without considering how to optimize it by using the new system.

Brown and Cole (2009) explain actual behavior (in contrast to assumed behavior) as satisfying (vs optimizing) actions. This implies that people behave in such a way as to meet their perceived needs, operating according to what is the most convenient for them, rather than logically appropriate. The case studies illustrate that putting on clothing or operating a familiar type of heating that shows immediate effect are perceived as convenient solutions. Controls are also often only used when a crisis of discomfort is reached, rather than continually optimizing conditions, systems are continuously left in their switched on state. Too simple systems may not give enough variation, such as on-and-off buttons. Loftness et al. (2009) states that automated control systems are not flexible enough to address the range of environmental conditions and the variation in occupants' individual expectations. Another factor why control systems are not used is that they are simply not understood and therefore by-passed (Brown and Cole, 2009).

Even with the best technological development and provided information, ideally, a building and its systems should be calculated for different types of uses and users, including some unintended uses. Therefore, more consideration should be given to the robust, flexibility of a building and its systems to deal with differences in uses and users.

From lack of previous knowledge to creating commitment

Many of the informants in our study did not know what to expect from their new environment and were unfamiliar with the concept. The knowledge about passive houses or zero energy buildings among the users was low in the beginning, but commitment, pride, and expectations were high and the findings show a success story in creating commitment to the new building and its energy efficient particularities.

Very few of the users in the six case studies had previous knowledge of passive houses and/or zero energy buildings. In the townhouses in Feuilly there was one informant who consciously decided to live in a passive house. The other interviewees at Feuilly stated that they were interested in discussions on climate change.

All the employees at Saint-Priest were informed about the design of their new office building and visited the houses at Feuilly before moving in. The teachers at Marienlyst School reported that their knowledge on the school has come mostly after they moved in, from the media and an information day. The pupils say that they had never heard about the passive house concept before they got a passive house school building. The pupils have also been enlightened through the media and teachers, and now have positive associations with the concept.

Even if the users had little knowledge of the concept prior to moving in the passive houses or zero energy buildings some users have become more engaged in environmental behavior. The headmaster of Dragen children's house was involved in the planning process, as were two of the interviewees at Marche´. In both cases the employees learned a lot about energy efficient buildings during the process. However, they also say that they did not have clear expectations toward the building, because they had never experienced a passive house before. The headmaster at Dragen gradually became more interested in the concept, however, she also points out that the educational topics incorporated in the children's house are still of greater interest to her than the energy efficiency concept. At Marche´, the enthusiasm of the people involved in the planning process spread to the other employees. One respondent told us that: "Suddenly all employees were all in for it and becoming the first zero energy building in Switzerland was something that everybody was feeling proud of." The interest in energy efficient solutions increased during the building process also influenced choices in the domestic life of the respondents. One Marche´ respondent says that she has moved houses privately and that they were concerned with moving to a house that at least fulfilled Minergie Standard (Swiss standard). She thinks that because of Marche´, she now knows more about the possibilities of how one can live smarter and in a more sustainable way. Another respondent states that the project has raised his awareness on energy consumption in general. He also tells that he had to change the heating system in his own private house. He invested into a geothermal heat pump instead of repairing the existing gas heating, despite of higher costs. He states that he would not have taken this step without the positive experiences from his work place.

At Feuilly, one respondent says that they have changed some of their habits after they moved in and that she now attempts to reduce her consumption. However, the data also indicates that the respondents sometimes are aware of what they should do, but that they do not necessarily apply this knowledge in practice. Knowing and doing are two different things and changing habits may be extremely difficult for the users that lack engagement.

Two of the three employees at Dragen believe that their passive house experience has not changed their views or behavior – but the third individual has been slightly more interested (from not interested at all), and she also states that she would stand up for the concept now if anyone would criticize it. The employees of the Saint-Priest office also stated that they are changing some of their habits. For instance, they are much more aware of the use of artificial light and they have changed their practices, switching off the lights when leaving a room. All the teachers interviewed at Marienlyst School point to the fact that as teachers, they have to be role models, and therefore have to promote environmental friendly behavior among the pupils. The pupils of Marienlyst School state that they are concerned about the environment. They are proud of having a school building that is environmental friendly. Two of the pupils say that they are now more aware of how their behavior can contribute to energy efficiency at home after they started at Marienlyst, while the last student says that she has always done what she can for the environment. All informants at Marienlyst School also say that it would be very difficult to work in an ordinary building after having moved to a passive house. Interestingly, the school itself has become a pedagogic means to influence environmental consciousness.

The data also indicates that people beyond the occupants of the energy efficient buildings are affected. When asking the interviewees at Marché about other people's reactions, one employee mentioned that within the corporation group of Marché, Mövenpick, they were considered as exotic and that their goals were not taken seriously in the beginning. This perspective changed, however, when the building was finished. Since that time, they have heard a number of envious comments. Skepticism toward passive houses was also expressed by friends of a resident at Feuilly when they were buying the new house. After these friends paid them a visit experiencing the house themselves, they stated that they were positively surprised, especially by the good air quality. Creating awareness and learning about energy efficient buildings is thus not only limited to its users, but may also have a multiplying effect on outsiders experiencing the buildings. Skepticism toward new technologies can change through personal experiences. An energy efficient building does, of course, not influence the behavior of all people. One of the teachers at Marienlyst says that he had expected the pupils to treat the building better than they do, even if there are many positive examples among the pupils. There are differences in individuals' sense of responsibility, and people with less sense of responsibility are also more likely to engage less in environmentally responsible behavior (Brown and Cole, 2009).

As the case studies showed, none of the respondents had much prior knowledge of passive houses and zero energy buildings, however, the interviews indicated that using an energy efficient building has created a greater awareness of personal energy consumption and of environmental questions in general. Some users of occupational buildings reported that this newly gained knowledge even influenced decisions made in their private life. Energy efficiency was also often regarded as a bonus or side effect that was gladly accepted but not the main criteria for satisfaction or choosing a house. Nonetheless, most residents seemed to appreciate the environmental benefits over time, and became more aware of environmental issues.

Proud of the image

Both, the pupils and the teachers at Marienlyst School report that the knowledge they have now has come mostly from the media. The passive-house at Dragen was also in the local newspapers and other media. Most of the respondents evaluated the public interest as positive for the kindergarten, and they were proud to work there or to have their children there. All interviewees at Løvåshagen seem to be flattered by the attention their housing area has received. They express that they find it "cool" to live here due to the positive publicity, visitors, and curiosity among friends and colleagues. One stated that "It feels great to be in the forefront!" and they are proud of living there. During the planning process of Marche´, suddenly all employees were all in for the concept. One woman says that becoming the first zero energy building in Switzerland was something that everybody wanted and felt proud of. At Marienlyst School there were similar statements and the pupils are proud that they have the first passive house school in Norway.

Passive houses and zero energy buildings are not the norm, yet, and these types of buildings still have a special position to promote awareness, stir up curiosity, and get media response. The public interest in these buildings seems in some cases to create a sense of community among the users/residents, who are among the first to live or work in these types of buildings. The respondents feel proud to being associated with the building. Public interest – even though it may wear off after a while – appears a good opportunity to spread knowledge and experiences on energy efficient building types. People with prior knowledge of these buildings may also be more interested and able to operate them according to "the script" (Berker, 2011).

Conclusions

The interviews showed a generally high level of satisfaction among the occupants regarding the different passive and zero energy buildings.

In most of the case studies, there were some concerns about thermal comfort. Informants often experienced the building as too hot in the summer and/or too cold in the winter. This perceived discomfort caused different types of personal actions, which interfered with the intended concept.

Many users have received too little information on operational systems or they did not function the way they were assumed to. In order to improve their situation, the occupants often intervened with the planned use. Even though we have no indication that the outcome of these adaptations was negative in every case, a use that is in line with the expectations would still be the preferable option. More detailed information and training will not be able to neutralize the effects of bad design completely. But it would be equally naı¨ve to expect that good design automatically creates the knowledge necessary to use a new technology. The need for more detailed information on operation seems to be more crucial for passive- and zero-energy buildings, than for "conventional" buildings.

Users in the case studies also had high expectations regarding the performance of these new buildings. These expectations were often created through media and through the information they have gotten through the operational staff/project managers. Brown and Cole (2009) found that high-performance expectations met with lower perceived performance leading users to complain more, or to take matters into their own hands to influence their perceived comfort by applying other solutions than the ones given in the building.

Still, the tolerance for the buildings' performance seemed to be high in all case studies, as the partly perceived thermal discomfort does not significantly influence the high level of satisfaction with the buildings.

Naturally, also other aspects than comfort such as pride and commitment, and also ownership (residential buildings) influenced the relationship the users have to the building. Living or working in an energy efficient building had made many of the respondents more aware of environmental questions, and several have tried to reduce their energy consumption both at work/school and at home.

The studies also showed that some operational aspects are important for people to control. Sometimes the users were frustrated if their environment on different levels, for example, the heating or the sun shading system. Regardless of the level of advancement of the operational systems, simplicity, understanding, and giving control to its users is a clue for performance.

It seems often to be assumed that living or working in a passive house or zero energy buildings represents new challenges for the user, and that it is more complicated. However, when looking at earlier evaluations of the interaction between user and building (e.g. useablebuildings.co.uk), the topics are not entirely new. What seems, however, to be a great challenge is to learn from previous experience and to transfer knowledge to today's context.

We still need to better understand the users' needs and preferences. There are specific topics that should be paid more attention to in new energy efficient buildings.

According to our findings these are:

- level of end-user control and adaptability of the building;
- level of complexity of systems enabling/supporting adequate operation, maintenance, and tuning of technical installations; and
- the need for adequate levels of information/knowledge.

A high level of control, well-informed users, sufficient maintenance, and well-functioning technical installations should be a good basis for experiencing a comfortable housing or working environment.

Further research

As indicated in the section on methods, this study only marks the beginning of an iterative process in which our results will be used to create research designs. According to our findings further research should deal with information and demonstration processes for better use of energy efficient housing, as well as with a better integration of planning and design, management and operation, and follow-up processes. Questions asked in this research will be: How can we give laypeople the opportunity to operate the buildings more effectively and how can we build buildings and systems that are robust and flexible enough to deal with different types of users and uses? What aspects of an energy-efficient building are necessary for the users to control individually in order to achieve optimal comfort? How can we follow-up building performance better after buildings are finished and overtaken by the users? Post- evaluation studies should include measurements of indoor environmental qualities, qualitative or quantitative information, users' experiences, and an assessment of the type of technologies and products used in the respective buildings.

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