

## Article

# Unboxing Buildings: Engaging with Occupants during Design, Testing and Use

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**Abstract:** Current prioritization within EU funding sees technical requirements for sustainable buildings moving technologies closer to people's everyday lives, thereby increasing the need for interdisciplinary research, and placing occupant engagement high on the research agenda. This is not always reflected in building research. Results are often black boxed, and occupants are offered few opportunities for participation in design and development processes. The paper considers the unintended consequences of black boxing buildings. A black box is a complex system or object which is viewed in terms of its inputs and outputs, but where knowledge of the internal workings is not required. Using an experience-based analysis from a social science perspective, we go back and consider the controversies around black boxing the processes and results in three Norwegian building research projects. In the conclusion, we propose that some research projects should remain unboxed, making complexity visible and allowing more focus on the challenges faced by occupants. Not taking time to ask and to learn from those who will use new technical solutions hinders the design process and limits a building's chances of achieving its sustainable potential. Designing successful building solutions requires collaboration between disciplines and occupants, encouraging an alliance between people, technology, and buildings.



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## 1. Introduction

In building research, planning, designing, and testing is unthinkable without the involvement of engineers and architects. However, it is possible and even practiced without the involvement of occupants, building management, workers, and residents. This is surprising because occupants will spend most time interacting with the completed buildings. Current prioritization within EU funding sees technical requirements for sustainable buildings moving technologies closer to people's everyday lives, thereby increasing the need for interdisciplinary research and placing occupant engagement high on the research agenda [1,2]. Even so, social contexts and local practices are consistently played down in building research. Non-technical aspects are treated as obstacles [3] (p. 47) and occupants are given few opportunities for participation. Design and development processes are often black boxed before occupants are involved. When this happens, black boxes can function as barriers to efficient use and understanding of building systems by occupants.

The article presents examples of black boxes observed in three Norwegian research projects. The examples are considered from a social science perspective, in an analysis that is retrospective and experience-based. The studies were not originally about black boxing, all three were about the development and introduction of new building technology. The examples were chosen because they represent different stages in the research process: (1) the hand-over phase, when occupants take over their homes (low-energy housing), (2) evaluating a completed building (a school), and (3) planning an experiment (housing

cooperative). The re-analysis considers where controversies arose and the implications for occupants which meant that black boxing the technologies was not suitable.

In engineering sciences, black boxes are useful “whenever a piece of machinery or a set of commands is too complex. In its place they draw a little box about which they need to know nothing but its input and output.” [4] (p. 3). A black box is a means to tidy up and clarify, and it enables the engineer to avoid overcomplicating an analysis. This does not mean that developing the machinery was not time-consuming or important, but once the system has become a black box, the focus moves away from system design and emphasis is placed on inputs and outputs. Buildings can also be defined as black boxes. Inside the building, there are technical systems that support the efficient management of the building, but what goes on inside the black boxed building during use is not in focus. The inputs and outputs from buildings are, for example, measured energy use, daylight levels inside a building, or air quality.

Black boxes make science look convincing. The negotiations, uncertainties, and complexities that can distract from its function are tidied away. However, when doing research, it is not always possible to keep things tidily inside the black box. Systems fail and controversies arise, this can mean that the black box opens again or is never completely closed [3] (p. 13). In the case of buildings, unboxing can take place when a building is taken into use by occupants and controversies arise. This can challenge the ambitions of the sponsors of research projects, who desire success stories to promote the technologies being developed. Outside the research context where engineering science is applied, negotiations and controversies can be interpreted as failures and something to be avoided.

From an engineering perspective, it makes sense that completed buildings encourage conformity, discourage controversy, and define use. Sustainable buildings should be energy efficient, are ideally powered by renewable energy, and produce their own or even surplus energy. Building materials should be locally produced and have low greenhouse gas (GHG) emissions (<https://fmezen.no/about-us/> accessed on 04.03.2021). Their design is based on national construction guidelines and international thermal comfort standards that are normative and universal. However, well-functioning buildings are complex and depend on many other factors. Buildings are designed for a purpose such as dwelling or working in. Their design is defined by climate, social and cultural context, political decision making, building regulations, resource availability, aesthetic preferences, and technical innovation. In addition, buildings are suggestive not prescriptive; that is, they can be used for a variety of activities. A home can, for example, deal with storage, birth, mealtimes, parties, and death [5] (p. 295). This suggestive quality means that buildings can provoke differing attachments or commitments, although their material forms may initially appear to be the same [6]. Furthermore, the social and cultural requirements of occupants, the practices, and routines, enliven buildings and give them meaning. A building is therefore a “precarious alliance” [7] (p. 22) of technology, building components, people, and their actions.

In building research, the technical requirements of buildings are often considered independently of the social and cultural requirements, even though buildings are actually a “co-production between the material and the social” [7] (p.11). We suggest that black boxing building concepts before occupants have been engaged in design and testing can limit the chances of a building achieving its sustainable potential. It also has implications for knowledge transfer from professionals to the occupants during the hand-over phase.

Occupants are often described as slow to show interest, negative to change and lacking knowledge about the benefits of technical innovations [8] (p. 285). A common expectation is that occupants should learn to adapt their behavior to suit the requirements of buildings, and this will result for example in a reduction in energy use [9] (p. 101). This is encouraged because occupants are not always conscious of the built environment or interested in changes taking place. Vast amounts of energy, materials, and money, and as well as technical, organizational, regulatory detail that are invested in buildings can on occasion be forgotten, invisible or taken for granted by building users [10–12]. Occupants understand the material environment in terms of their use for it. A building can be useful,

likeable, or comfortable and it will still fade into the background. This is what Daniel Miller (2005) calls the “humility of things”—the less aware we are of objects, or, in this case, buildings, the more powerfully they can determine our expectations by setting the scene and encouraging normative behavior [13] (p. 5).

This useful, but perhaps humble, ability that buildings have during use, to fade into the background goes some way to explain why engineers and other building experts often have so little time for the experiences of occupants. The everyday use of material culture is often understood as “trivial” [13] (pp. 5–6), because occupants do not at first glance seem interested or knowledgeable. However, occupant behavior, preferences, and needs are not trivial. Buildings gain significance during use. They become extraordinary in an active and ongoing sense [14] (p. 112). Negotiations between buildings and occupants start as soon as buildings are taken into use. Buildings, technology, and occupants should be considered together [15] (p. 230) during all phases of their design, testing, and use.

## 2. Methods: A Retrospective Approach

The paper reconsiders data collected by social scientists, including the authors, in three building research projects over a five-year period. The data are considered through a meta-perspective where we look back at our experiences with the projects and reflect on when and why black boxing was attempted. The hand-over phase associated with low-energy housing, eight cases in five different locations in Norway is considered first. The second example is a secondary school in Trondheim, in central Norway, where new sun shading technology, electrochromatic glass (EG), was tested and evaluated in a post-occupancy study. The third example is a housing cooperative also in Trondheim, where changes to the energy supply system are planned.

The Norwegian Research Council and partners from the construction industry sponsored the three projects. Engineers were in the majority among project partners. The research teams included engineers and social scientists (the authors are an anthropologist and an architect/sociologist), but the balance of control when establishing research aims was placed with the engineers sponsoring the projects. This has an impact on methods used, the research process, the ability to include occupants and the impact of technical solutions on occupants [16,17]. Emphasizing and researching relationships between people, buildings, and technology requires mediation between the technical research aims associated with sustainable buildings and the everyday lives of occupants. Social science research can provide mediation. The fields of anthropology, sociology, and human geography are traditionally associated with participant observation and long periods of fieldwork alongside informants, on location, enabling them to understand the everyday lives of their informants [18] (p. 18). This slower in-depth pace enables the researcher to take the time to talk to and understand the requirements of building users. A slower in-depth pace is rarely used in interdisciplinary research. Instead, two main methodological themes are common when engaging with occupants in building research.

1. Post-occupancy evaluations: the aim is to engender critical insights into how buildings are put into use [19] (p. 36). Evaluations are a response to the design process and about avoiding expensive failures [20], but because they take place after the design team has left the building, influencing design choices is difficult.
2. Quick-time methods; questionnaires, interviews, and workshops. These are intended to supplement quantitative methods associated with engineering, simulations, models, or temperature measurements.

Quick-time collaboration and post-occupancy evaluation are often relevant, but can challenge the integrity of the qualitative data collected. Annette Henning (2005) questioned the expectation that social scientists should always adapt themselves to the time axis of a technical research process [16] (p. 11). Other timelines, methods, and forms of collaboration exist [21,22], but limited resources mean that quantifiable and quick time methods are most often prioritized. Post-occupancy and quick-time methods were also applied in the three examples presented in the next section.

The authors had significant roles in the data collection associated with the three research projects. The information about the data collection is given in Table 1. The article's interest is in what we can learn from the data collection process, and the insight gathered about the building expert's approach to the users of technologies and building occupants. From the data provided by the three projects, we can learn what happens when attempts are made to black box technologies without efforts being made to collaborate with the occupants.

**Table 1.** Overview of the three examples, explaining for each project the methodological approach, number of respondents, and role of authors in the data collection.

Low Energy Housing 2012–2016 [23]	No. of Households Interviewed	Interviews Professionals (Key Personnel Involved in Planning and Construction)	Role of the Authors in the Data Collection	Methodological Approach Post-Occupancy Evaluation. Semi-Structured Interviews.
Case 1	5 households	4 (project manager, project leader, architect, foreman builders, building manager)	One of the authors prepared the semi-structured interview guides and conducted all the interviews in case 1–8.	Occupants and professionals: face-to-face interviews. Recorded. Notes.
Case 2	4 households	3 (project manager, project leader, foreman builders)		3 face-to-face interviews occupants. 1 telephone interview. Professionals: Face-to-face. Recorded. Notes.
Case 3	2 households	2 (head of firm, project leader)		Occupants: telephone interview. Professionals: face-to-face interviews. Recorded. Notes.
Case 4	2 households	2 (project manager, project leader)		Occupants: telephone interview. Professionals: face-to-face interviews. Recorded. Notes.
Case 5	5 households	2 (project manager, project leader)		Occupants and professionals: face-to-face interviews. Recorded. Notes.
Case 6	12 households	2 (project manager, project leader)		6 face-to-face interviews with occupants, 6 telephone interviews. Professionals: face-to-face interviews. Recorded. Notes.
Case 7	3 households	3 (project manager/leader, architect, consultant energy)		Occupants and professionals: face-to-face interviews. Recorded. Notes.
Case 8	5 households	(same housing developer as in case 2)		Occupants and professionals: face-to-face interviews. Recorded. Notes.
School 2019 [24]	No of interviews with teachers/pupils	No. of interviews with professionals	Role of the authors in the data collection	Methodological approach Post-occupancy evaluation
Phase 1	2 teachers, 1 spontaneous conversation with teaching staff	4 technical staff 1 project leader technical management	Both authors participated in the preparation of interview guide and data collection.	Individual semi-structured interviews. Focus group interviews Interviews took place at school in rooms with EG. Site visit and walking-through included. Each interview took approximately 60–90 min. Recorded. Notes.

Table 1. Cont.

School 2019 [24]	No of interviews with teachers/pupils	No. of interviews with professionals	Role of the authors in the data collection	Methodological approach
				Post-occupancy evaluation
<i>Phase 2</i>	1 interview with a member of the teaching and administration staff. 2 Spontaneous conversations during site visits.	1 technical staff 1 observation of problem solving during a site visit that included daylight measurements by engineers.	One of the authors followed up the 2nd round of interviews.	Semi-structured interview. Recorded. Spontaneous conversations Focus group interview. Site visits, including observations. Notes
Housing cooperative 2019 [25]	No. of households interviewed	No. of interviews with professionals	Role of the authors in the data collection	Methodological approach
				Quick time methods used over a 3-month project period
<i>Phase 1</i>		6 focus group interviews with 17 people including the housing cooperatives administration (HCA) and board of directors (made up of residents), technical management team, a team of 2 consulting engineers (CE) and actors from energy supply companies.	One of the authors developed the interview guide, conducted all the interviews.	Focus group interviews. Each interview took 60–90 min. Recorded. Notes. 3 interviews took place onsite in the housing cooperative and 3 interviews were digital.
<i>Phase 2</i>		1 workshop with approx. 60 professionals from the construction industry. Experiment planning 2 meetings with representatives from HCA, CE and the research team.	One of the authors in followed up discussions in phase 2	Action research during workshops and meetings. Workshop approx. 7 h. Meetings were each approx. 60 min. No recordings. Notes.

### 3. Three Examples from Interdisciplinary Norwegian Building Research

During the introduction of new technologies to buildings the different occupant groups affected are often not offered opportunities to express their needs and opinions. Henning (2018) proposes that knowing more about occupant experiences would encourage the development of more balanced solutions [17] (p. 6). There is an untapped potential in understanding the relationship between everyday practices and the technologies that support them when designing and implementing new technologies [8] in buildings.

#### 3.1. Handing over to Occupants

The Norwegian research project “Evaluation of housing with low energy needs” (2012–2016) [23,26], examined the building process, measured energy use and indoor climate parameters, and evaluated occupant experience in eight low-energy housing areas in Norway, including 74 households (59 passive houses, 5 zero-emission houses, and 10 low-energy houses) (see Table 1). The users were not involved in the early phase planning of the houses. Although in some of the cases they could influence material choices and adjust the floorplan. The hand-over phase from construction experts to occupants was among the topics investigated in the semi-structured interviews with professionals and occupants in the eight cases, conducted by the authors of this article. The hand-over phase is found to be critical for efficient operation of technical systems such as balanced ventilation, photovoltaics, or solar thermal technology in low-energy homes. The information provided by those responsible for the technical solution, construction, and development leads to

positive or negative end-user experiences and can in turn affect building performance [27]. During the period after first moving in, occupants adjust to their new home, developing habits and routines for the use of integrated technologies that can impact on building performance.

The findings reveal a gap between the attitudes of the professionals, the information they provided, and the needs of the occupants. The response of construction experts towards the expected need for information and training of the occupants in the hand-over phase varied. In four cases, housing developers did not adjust their hand-over procedures to zero emission or passive houses, which were new in the market at that time. The procedure was standard, even though several technical solutions applied (solar thermal, PV, floor heating powered by RES) were not common. The occupants interviewed were often interested in learning more about the specific technical standard of their new homes and whether it had implications for everyday use. According to housing developers, the technical standard was not in focus during the buying process, buyers placed a higher value on aspects such as comfort and location. After purchasing the house, buyers asked for information about the technical system. Interviews revealed that expectations towards an energy efficient home were high, especially in terms of thermal comfort. Interviewees also described the energy saving potential as a “bonus” for the environment and for the household economy, they expected reduced heating bills. The houses did not always achieve their expectations and the use and understanding of the technical systems was part of this. For example, the functions and importance of the ventilation system in highly insulated dwellings was often not clearly understood by occupants in the eight cases. An occupant stated,

“If we had received more information, I believe we could have used the ventilation system of the dwelling in a better way. We open the windows a lot to ventilate but I guess we could use the ventilation system more instead. It is a pity we did not learn more about the system possibilities.”

Problems, errors, and adjustments were common reasons why occupants switched off systems or asked for professional help. Several interviewees believe they could have used their house and the systems more efficiently if they had been given better instructions both written and verbal.

Practices adopted by occupants vary from not changing anything to daily adjustments to the heating and ventilation systems. In situations where people make fundamental changes to their lives, such as moving to a new dwelling, they may be more receptive to adapting their routines. Early introduction of information about the use and operation is essential, taking advantage of a rare opportunity because people only move to a new house four to five times during their lives [28] (p. 51, 56). Few occupants were motivated to find detailed information later. Much of the responsibility for information production and exchange lies in the hands of the experts, system designers and housing developers.

The segregation of construction and operation phases is common and has negative effects on use and operation of new buildings [29]. It can be understood as a black boxing of system choices, we propose that keeping the box open whilst developing relevant information material for occupants in collaboration with them has the potential to reduce the number of problems, errors and adjustments. Addressing use and operation already in design and planning processes establishes continuity and responsibility, all the way through to the hand-over to occupants. Occupant representation and engagement avoids simplifications about who potential buyers are and their motivations.

### *3.2. The School and the Evaluation of Electrochromatic Glass*

The school, which is located in Trondheim, Norway, has space for 1020 pupils, is approximately 30,000 m<sup>2</sup> in area, and opened in 2018. It is also a zero-emission building and one of the first in Norway. As such the school is a test arena for advanced building systems. This includes electrochromic glass (EG), sun shading technology that is integrated in the insulated glazing unit of a window. EG has a number of useful qualities. It has no

moveable parts but by imposing an electrical current, the solar heat gain coefficient and visible light transmittance can be controlled. Sun shading is vital for the indoor climate and the comfort of occupants. Traditional sun shading blocks the view from a window, but an exterior view is still available when EG is activated, and windows are darkened. EG is integrated in the glazing unit and no externally mounted sun shading is in theory required. It has no moveable parts, and this implies less maintenance. In addition, any repairs that are needed can be done from inside the building. Testing the EG in the school provides an opportunity to learn about how the system functions in Scandinavian climate and daylight conditions. It can also tell us how the system functions in school buildings and if it meets the requirements of the occupants associated with this building type.

The EG was evaluated in 2019. Daylight measurements were carried out by measuring the daylight factor in two classrooms and two offices. According to the Norwegian Building Code TEK-17 the daylight factor should be larger than 2% in these types of rooms. Four rooms were chosen for the daylight measurement on the 3rd and 4th floors. A user evaluation was also carried out that included two groups of occupants (technical management and teaching and administration staff) [25]. The evaluation was organized by the building owner and the executing building contractor. The meta-analysis focuses on the occupant evaluation and why avoiding black boxes can be useful during the testing and early use phases.

The evaluation, in which the authors had a leading role, tells the story of low daylight measurements, system failure, and windows that have never worked, or only work partially, and require repairs by an expert who is flown in from abroad. The evaluation did not recommend that EG should be used in rooms intended for educational purposes [25]. During the re-analysis of the occupant evaluation, we have uncovered three factors associated with design and development, where the design and testing processes could have been strengthened by offering occupants the opportunity to state their requirements and discuss the functionality of the EG.

(1) Interviews with teaching and management staff point to a mismatch between the everyday requirements of occupants in the school and the EG. Slow response time and malfunctions meant that there was often glare on computer screens. In addition, solar heat gains meant indoor temperatures were greater than with external or internal sun shading. A representative from the teaching staff told us,

“It (EG) might have worked in a building with regular businesses. It’s perhaps more relevant in offices than schools. A school does not just need sun shading. Rooms need darkness for presentations. PC use and power point presentations are common in schools today and sun shading with a 20-min response time is too slow. We have to go to classrooms and turn it on before class starts.”

(2) The EG is not mounted on all facades or on all floors of the school. A representative from the teaching staff wondered about the design process, how was the system chosen and how the design team made decisions about where the EG was to be located, “How was it determined where EG is located? It is not consistent. Some rooms have partly EG and partly no sun protection.” To occupants, the design and decision-making process seems random.

(3) When problems arose in the school, rather than supplying technical management with more knowledge and training, the solution was to add additional internal and external sun shading. A solution that compromises the ambition to achieve zero emissions during the building’s life cycle.

“I don’t know enough about it (EG). We don’t really know how it should be run. A lot of people think it should be darker. No one has training and equipment. This is a pilot project, and the support is poor.” Representative from the technical management.

An evaluation can supply stories of success and failure. If a post-occupancy evaluation is negative, it can lead to system replacement. In the three examples and in other projects, experience by the authors the sponsor of an evaluation, not surprisingly, prefers success stories. In the case of the school, building owner representatives responded negatively to the memo’s findings. They stated that too few occupants were involved in the evaluation.

The research team agreed that a larger group of informants would have been better, but all informants had extensive experience with the EG. They were either responsible for maintenance, had offices or regularly taught in rooms with EG installed. Qualitative research does not call for a large number of informants, but it does require in-depth interviews and taking time to listen to the feedback from occupants. This was the case at the school, for example technical management representatives were followed up three times during the research period. In addition, the feedback from informants was very clear and cannot easily be discounted.

The story about the EG is a “learning story” [30] (p. 516). The EG within the school is subject to system failures and maintenance problems and in this context is not ready to become a black box. Challenges highlighted by the evaluation should be shared with the construction industry, thereby helping to avoid similar problems in other buildings and contributing to further development of the technology. Feedback from occupants could be used to develop guidelines about where EG could be used in the future, for management of the system and to propose system changes.

### *3.3. Switching Energy Systems in a Housing Cooperative*

The Norwegian housing cooperative is located in Trondheim, was built in the 1970s, and has 1113 apartments, organized as two-story apartment buildings and row houses. The economic status and cultural background of the residents is various, as such the cooperative represents a broad section of society. Each apartment pays a set price for energy to the housing cooperative covering heating and hot water supplied by district heating. The price is independent of the size of the apartment or household. Residents have little influence on how heat or hot water is supplied or responsibility for regulating how much they use. After 50 years of use, the system offers an inefficient heat supply and leaking pipes have caused some water damage.

A short three-month preliminary project that did not involve occupants or households analyzed the potential costs for customers and the socio-economic cost of changes to the energy supply system. Two scenarios were proposed, (1) upgrading the existing district heating system, (2) all-electric, including panel heaters, hot water tanks and an automatic control system for load management in each apartment. In addition, the potential barriers to the decision-making process were studied by one of the authors. The analyses found that the all-electric scenario is the most cost effective for individual homes and the energy supply to the housing estate [23]. Upgrading the existing district heating will require new heating systems and pipes in each apartment and the improvement to the infrastructure connecting apartment blocks. Replacing district heating with an electric system for hot water and heating would mean installing new panel heaters and hot water tanks, but otherwise the infrastructure is already in place. The old district heating system outside the apartments could be left underground. The meta-analysis focuses on the consequences of not including occupant representatives from the 1113 apartments in an experiment intended to gather information about the impact on households of installing a new energy supply system.

The housing cooperative administration (HCA) decided that more information about household energy consumption was needed before plans for an all-electric system in apartments were presented to the 1113 households. An experiment was proposed which included the installation of equipment to measure energy consumption in eight households in a two-story apartment building. Energy use associated with three different energy supply systems was to be tracked (the existing district heating system, a hybrid system, and an all-electrical system) over a one-year period. Follow-up of households associated with the apartment building experiment using a series of semi-structured interviews was proposed but was cancelled a month before start by the HCA and the consulting engineers (CE). They stated that interviews would be intrusive and influence the behavior of occupants.

“It is important that the researchers do not create thoughts or attitudes in advance of the experiment—which can make the residents change consumption patterns because they

think that they should. Behavioral changes must come naturally. You cannot ask about something they do not have the prerequisites to answer—then you create attitudes that influence the behavior.” A CE representative.

Energy practices are often established, based on long-term household routines [31–33]. It is unlikely that the cancelled semi-structured interviews would have had a long-term effect. However, the proposed changes to the energy supply system will have implications for 1113 households. Pre-existing energy routines and comfort requirements (how homes are heated, how much hot water is used and engaging with a new billing system) could hinder efficient use of an all-electric system after installation. Occupants will require support during the transition. The cancellation of the qualitative analysis suggests that a black box is to be established before the energy supply system has been tested by occupants.

Black boxes enable a focus on inputs and outputs. In this example the CE’s focus is on energy supply and use. They saw this a necessarily simplification, enabling them to avoid misunderstandings by occupants. The black box also limits the occupant’s ability to engage with the planned changes and prevents an exchange of knowledge between occupants and experts. The cancellation of the qualitative process represents a missed opportunity for engagement with households, one that will limit the chances of a successful transition from one energy system to another.

#### 4. Discussion

In the three research projects, attempts have been made to black box buildings and technologies during planning, evaluation, and hand-over phases. The examples show a separation between experts and occupants, one that is an ongoing challenge in interdisciplinary building research [3,16,17,34]. Post-occupancy evaluations and the cancellation of qualitative research during experiment planning uncovered an aversion to controversy and/or a lack of interest in what happens after occupants take over the projects.

Post-occupancy evaluations are common in building research projects in combination with quick-time methods, such as workshops and semi-structured interviews. Evaluations can provide feedback for designers and knowledge gathered can be used in other locations during design and development processes. They can provide information useful to other groups of building occupants such as technical management, who require information for efficient system support. The examples re-analyzed in this paper describe problems, errors, adjustments, system failures, and a lack of training for different groups of occupants. There also existed a tension between the expectations of the sponsors who desired success stories and the challenges experienced by occupants. It is suggested here that during the interaction between buildings and their occupants, the “interpretative flexibility” that is part of what buildings offer during use [35] means that the negotiations and controversies are almost unavoidable. Creating stable, closed black boxes that enable the follow-up of inputs and outputs is difficult in buildings that are part of the everyday lives of different groups of occupants.

There is much that can be learned from system failure or controversy. Science and technology studies (STS) use them as a way of investigating how things work or “normally hold together” [7] (p. 19). A system failure often marks the point where allies stop working together [15] (p. 19). It is also the point where the search for who is responsible starts because placing responsibility is often part of the explanation [36] (pp. 2, 11). It is not surprising that sponsors of technical innovations prefer to present success stories [30] (p. 516). The assumptions are that there will be more faith in the new technology if failure is avoided and that there will be less failure if controversy is avoided. However, there are other kinds of stories that are useful in design and development processes, such as learning or caring stories. In these kinds of stories, there is more room to describe how things developed and to engage with occupants’ experiences [37,38]. Learning and caring stories include things that go wrong or are seen to fail. They are useful because previously invisible associations between technology and their context are, “at the moment of failure, revealed” [10] (p. 613).

Designers and experts by treating completed buildings as “stable, safe, and static black boxes” avoid controversy [15] (p. 226). However, our examples show, and this is also supported by results from projects that measure energy use, that there is often no correlation between results in building research and what was originally predicted or proposed [30,39].

Building research projects can have direct implications for everyday lives. The three examples point to the importance of including occupants during design, development, testing and use and grasping all opportunities to engage and exchange information. Furthermore, universal goals and standards that guide the development of buildings and their technologies are often made up of many examples of situatedness and specificity [36]. In the search for universal solutions engineering practice often neglects the importance of the details of everyday life. Qualities that are personal, practical, and emotional represent the embodied experiences that are relevant for implementation and use [17] (pp. 4–5).

## 5. Conclusions

Developing sustainable building solutions requires input from numerous disciplines. The universals associated with values for energy use and indoor climate should be supported with qualitative, context-specific investigations. Innovative solutions should remain unboxed until occupants have engaged with and provided feedback about the buildings and their technologies. Solutions that are flexible in terms of local realities have a greater chance of being used efficiently and achieving their sustainable potential. Including occupants in building research requires mediation from social science disciplines, supporting engagement and the follow-up of feedback from occupants. We suggest that the research process should be reordered, allowing occupants and social scientists to engage earlier and for a greater part of the design, testing, and development.

A sustainable design and development process is encouraged by allocating resources for

- Testing in a variety of contexts with diverse groups of occupants.
- Occupants should be included in all stages of research projects.
- Quantitative and qualitative results should be given equal importance in building research, bringing new technological solutions closer to home.
- Feedback from occupants should be part of iterative processes where the ultimate aim is the co-production of solutions.

A diversity of feedback should be embraced, avoiding the burden of responsibility for dysfunctionality being placed with the occupants, the users of buildings and consumers of energy.

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