Engaging Occupants in Green Building Performance: Addressing the Knowledge Gap

Zosia B. Brown, Institute for Resources Environment and Sustainability, The University of British Columbia
Raymond J. Cole, School of Architecture and Landscape Architecture, The University of British Columbia

ABSTRACT

Conventional building design assumes that occupants are passive recipients of indoor conditions, maintained within tight margins by automated, centralized systems. Building performance is typically invisible to the end-user, who – in turn – is given little opportunity to control or provide feedback on the indoor environment. In contrast, 'green' building design tends to view occupants as active participants, both in facilitating comfort and achieving optimal energy efficiency. This assumes that occupants have some understanding of the buildings they inhabit, and will make appropriate and intelligent choices when interacting with its systems (i.e. opening and closing windows, blinds, switches and other accessible manual controls).

In practice, very little is known about how the occupants of green buildings engage in comfort provisioning and the subsequent impact this has on overall building energy performance. Research to date has focused on the residential sector, examining the decision-making behavior of homeowners around thermal comfort and electricity consumption. This paper describes a current research project which investigates, in a commercial setting, occupants' knowledge of building environmental features and systems, and awareness of control and feedback opportunities available to them. A web-based survey has been designed to capture knowledge levels as compared to an expert baseline for six office buildings of varying degrees of energy efficiency. Preliminary results from the survey pilot are presented.

Introduction

As green building design becomes a more mainstream practice, new questions arise such as: How do buildings perform over time? What aspects of operation enhance or compromise their performance? What are the impacts on occupant comfort and productivity? Many green buildings rely on natural conditioning to meet the needs of occupants wherein indoor comfort conditions are provided by 'passive' strategies (e.g. thermal mass, passive solar heating, natural ventilation, and daylighting). Indoor conditions are more closely linked to variations in the conditions outside, and building occupants are typically expected to be more directly involved with building systems and operation by opening and closing windows, blinds, switches and other manual controls. Moreover, energy and water systems used in green buildings can involve new responsibilities on the part of occupants to engage with positive environmental practice.

Conventional building design has assumed that occupants are passive recipients of indoor conditions, maintained within narrow margins by automated systems. Building performance is often invisible to the end-user, who – in turn – is given little opportunity to control or provide feedback on the indoor environment. In contrast, 'green' building design tends to view occupants as active participants, both in terms of facilitating comfort and energy efficiency. This approach assumes that occupants have some understanding of the environmental systems of the buildings they inhabit, and will make appropriate and intelligent choices when interacting with them.

In practice, very little is known about the extent to which occupants understand the environmental features of the buildings they inhabit, and the role this knowledge plays in shaping comfort and energy use patterns. Contemporary green buildings seldom communicate how building systems function or broader "lessons" of their upstream and downstream ecological consequences (Orr 1999). This, combined with poor training, lack of information, and inadequate follow through from design to operation can lead to compromised building performance.

This paper describes the scope and emphasis of a current research project which investigates occupants' comfort, knowledge of building environmental features and systems, and engagement with control and feedback opportunities available to them, for office buildings of varying degrees of energy efficiency.

Knowledge, Comfort and Energy Use

The conventional realm of comfort provisioning evolved within a period of technological innovation and the widespread deployment of energy-intensive mechanical systems, accompanied by a shifting of design responsibility for comfort from architects to mechanical engineering consultants, and control responsibility from occupants to technology. Within this context, conventional approaches to comfort have been guided by several key assumptions:

- That occupants are passive recipients of the conditions provided in the workplace.
- That, although psychological and behavioural issues may play a role, the primary mechanism of comfort is physiological.
- That indoor environmental conditions should be held within relatively tight margins.
- That a globally applicable set of optimum comfort conditions should be incorporated into national standards, which in turn, shape and define acceptable indoor conditions for occupancy.

Such conventional assumptions have reinforced an approach to building design, management and operation which is oriented towards considerations of uniformity and predictability, rather than resilience and adaptation. The goal has been for buildings to perform within a prescribed set of narrowly defined standards, independent of the behavior of occupants. By contrast, the successful performance of green buildings, particularly where passive strategies are deployed, is largely dependent on variation and diversity in environmental conditions. The indoor environment can be considered a "creative achievement" shaped by the interaction of building occupants with control systems in response to changing external conditions and changing needs. This suggests a conceptual shift towards a broader experience of comfort, in which occupants are more directly engaged in the design and management of the building's systems, and psychological, social and behavioral aspects take on greater significance (Cole, Robinson, Brown et al. 2008).

Evidence that such a shift is occurring can be found in the pioneering research of Brager and de Dear (2000) on thermal comfort, which led to the amendment of ASHRAE Standard 55 on *Thermal Environmental Conditions for Human Occupancy* (2004) to include a more 'adaptive' standard for occupants of naturally ventilated (NV) buildings. Occupants of NV buildings were found to accept a much wider range of indoor temperatures than those in air conditioned buildings, suggesting that "the [conventional] heat-balance model of thermal comfort… can not account for the complex ways people interact with their environments, modify their behaviors, or gradually adapt their expectations to match their surroundings" (Brager and de Dear 2000, 2). As further evidence of the shift towards a broader concept of comfort, the LEED®-NC (v2.2) green building rating system rewards occupant control over lighting and thermal comfort systems, and allows thermal comfort verification to be achieved by conducting a post-occupancy satisfaction survey as an alternative compliance path to establishing the ASHRAE Standard 55 comfort criteria (USGBC 2005).

In considering occupants as 'active' participants in building operation and management, one must also consider the role of users' expectations. As Leaman and Bordass (2007, 665) suggest, "if people understand how things are supposed to work and what they are for – window controls, perhaps, or thermostats – they tend to be more tolerant if things do not turn out quite as well as they should". Thus, a greater knowledge and understanding of building environmental features and controls can lead to a relaxation of comfort expectations, with significant implications for energy use.

Related Work

Related work in the residential sector has focused on the use of energy feedback and information to influence occupant behavior around thermal comfort and household electricity consumption. In the academic sector, the communication of responsibility can be increasingly observed particularly in green buildings, in the form of building information sessions, instructional signage (e.g. EduTracks™), and exposed and experiential building systems. Some of the most recent developments include smart meters, kiosks (e.g. GreenTouchScreen®) and real-time web-based feedback (e.g. Building Dashboard™) introduced at campuses across North America in an effort to make building performance factors more amenable to understanding and control. Oberlin College, for example, developed an automated data monitoring system to provide dormitory residents with real-time feedback on energy and water use. Students receiving web-based feedback achieved a 55% reduction in electricity consumption compared to 31% reduction achieved from meter reading alone (Petersen, Shunturov, Janda et al. 2007).

There are clearly savings to be made from engaging occupants in building environmental performance. However, placing the responsibility for comfort conditioning in the hand of building occupants implies that they will make appropriate and intelligent choices, and necessitates a shift in the quantity and quality of understanding and communication about the consequences of exerting environmental control. Green buildings are often "more fragile in their performance, so it is more important that everything works well together" (Leaman & Bordass 2007, 672). Even if occupants have an understanding of building environmental features, they may not behave in the way we expect. Leaman (1999) presents a set of 'real' building user interactions with environmental controls that stand in marked contrast to those typically assumed in design. Occupants tend to make decisions to use switches or controls only after an event has prompted them to do so and often wait for some time until taking action, typically acting only when they reach a "crisis of discomfort." Moreover, they can overcompensate in their reactions to relatively minor annoyances, operate the most convenient rather than logically appropriate controls and leave systems in their switched state rather than toggling them back again later, at least until another crisis of discomfort is reached.

More research is needed to improve our understanding of how occupants engage in comfort provisioning and the impact this has on overall building energy performance. The question of knowledge base is not included in existing post occupancy evaluation survey tools, despite the fact that it may play a significant role in how occupants experience psychological, behavioral and social dimensions of comfort. Finally, feedback tools that may be effective at influencing behavior change in the residential setting may not generate the desired effect in a commercial setting where occupants respond to different incentives (see for example Harris Interactive poll 2008), and often share the space they can control with a greater number of people, thereby creating a different social and behavioral dynamic.

Building Performance Evaluation

Building performance and its evaluation have earned increased attention in recent years, particularly as applied to green buildings (Bordass, Cohen & Field 2004; Hinge, Winston & Stigge 2006). Evidence suggests that building performance in use often differs markedly from that anticipated or predicted during design, both from an energy efficiency and human factors standpoint. In the United Kingdom, it has been noted that carbon dioxide emissions from green buildings are commonly two or even three times as much as predicted (Bordass 2001). In the United States, a study by the New Buildings Institute found that 30% of LEED® rated buildings perform better than expected, 25% perform worse than expected, and a handful of LEED® buildings have serious energy consumption problems (Owen, Frankel & Turner 2007).

Similarly, occupant satisfaction studies indicate that green designed buildings do not lead de facto to better indoor environments. Leaman and Bordass (2007) compared occupant experiences in conventional buildings and buildings with ‘green intent’ in their design briefs. Green buildings scored better on ventilation/air, health, design, image, lighting, comfort overall, and perceived productivity. However, while the best green buildings ranked higher than the best conventional buildings, a few of the lowest scoring were also green buildings. Abbaszadeh, Zagreus, Lehrer et.al. (2006) compared occupant satisfaction in 21 LEED®-rated buildings to 160 non-green buildings using the Center for the Built Environment (CBE) occupant indoor environmental quality survey. Occupants in green buildings were more satisfied with thermal comfort, air quality, office furnishings, cleaning and maintenance, but dissatisfied with lighting and acoustics.

‘Gaps’ in Performance

Several authors have examined the nature of the 'performance gap' observed in green buildings. Hendricksen and Geelen (2004), in their evaluation of Dutch high performance buildings, found that energy consumption for traditional end-uses such as lighting, heating, cooling and ventilation correlated reasonably well to the predictions, but that the office equipment and other non-regulated end uses (including kitchens and elevator use) were significant and had not been accounted for. In reviewing this and other studies of building performance in use, Hinge, Winston and Stigge (2006, 135) conclude that “optimum design often fails to take into account realities of commercial operation… design intent must be carefully vetted with the owner’s operating personnel to ensure that the design takes into account the intended method of operation.”

In accordance with this view, and based on a wealth of experience in evaluating actual building performance, Bordass and Leaman (1997) point to overly-complex building systems as a major deterrent for efficient and effective building operation. Their work suggests that high-tech buildings are relatively complex to operate, so dedicated management is essential if they are to achieve optimal performance. The findings speak to an underlying irony, in that well-designed technically sophisticated buildings are intended to reduce – and not add to – complexity.

To enable occupants to solve operational problems, building systems must be readily accessible and comprehensible to users, and clearly accompanied by a willingness to use them. A key lesson is that the environmental success of a building depends on matching technological and management sophistication. As Cohen, Ruyssevelt, Standeven et al.(1999, 2) observe from their *Post-Occupancy Review of Buildings and their Engineering* (PROBE) studies, "notwithstanding all the implications of supposedly advance automation, our experience is that the best intelligence in most buildings lies in the occupants themselves… the challenge for designers and manufacturers is to support them with appropriate and understandable systems with readily-usable control interfaces, which give relevant and immediate feedback on performance".

'Gaps' in Knowledge?

A common recommendation made by POE researchers is that occupants need to be better educated about their building's environmental controls systems, and there is reason to believe that occupants in fact desire this knowledge. In a user feedback survey of a LEED® Silver building conducted as part of the project completion process (AERL Building Committee 2006), several comments were noted to this regard:

- "I invested time in learning about the design features of our building intended to promote an ethic of sustainability. With what I learned, I have come to appreciate the building as an architectural success with a few notable exceptions. It is a great shame that there has been NO explanation to the users of how the building has been designed to operate, and provide us with guidelines as to how we should we manage the lights, the heating system, and other environmental performance features."
- "I believe that a lot of money was used to create this building with Leeds[1] certification, I don't know that we actually received certification. It seems like that should have been one of the end goals if in fact the design was chosen for this – and further details (or/and an explanation) to this effect should have been more widely circulated".

There is a need for more post-occupancy research to provide validation to anecdotal evidence of occupants' knowledge gaps when it comes to green building performance. Understanding what occupants know about the buildings they inhabit and how they engage with the controls provided is a fundamental first step in providing meaningful and effective feedback on the environmental consequences of their actions. A host of questions can be raised regarding whether high performance buildings are actually being designed with occupant engagement in mind. How successful are building information sessions, user manuals, 'green' features signage and sustainability 'pledges' in instilling individual and collective commitment to, and engagement with, positive environmental practice? What is the appropriate balance between

[1] Original spelling from occupant, assumed to be referring to the LEED® Rating System

strategies aimed at informing and empowering occupants, and those that rely on automated controls and systems to provide and maintain occupant comfort, health and wellbeing? Should the strategies employed differ for different types of settings and workplace cultures? In what follows, we outline a research study designed to address several of these questions.

Engaging Occupants in Green Building Performance

This study builds on previous post-occupancy research of green buildings in use as compared to conventionally designed buildings (Abbaszadeh, Zagreus, Lehrer et al. 2006, Leaman and Bordass 2007). Like the previous work, we evaluate occupant satisfaction with the building overall (needs, image, safety, storage and cleaning), the individual workplace (layout, furnishings, space) and comfort (temperature, air quality, noise, lighting, personal control). In adding to previous work, we also ask occupants to rate their knowledge and perceptions of how the building performs and comfort is provided. We compare and contrast not only green and conventionally designed buildings, but also different types of workplace culture. While building design itself shapes how we experience space, in the workplace there are a whole host of other factors that play a role, such as: nature of work, individual vs. team-based, hours spent indoors, sense of community, flexibility, formality, and organizational attachment. We examine whether certain aspects of workplace culture facilitate green building performance better than others, and explore the implications.

While the research may be broader in scope, for the purposes of this paper we will focus on the relationship between occupants' knowledge, comfort and energy use.

Study Objectives

The aim of the research is to examine how well occupants understand the building they inhabit relative to an expert baseline. The study objectives and related hypotheses collectively provide a framing for the research design (Table 1):

Building Recruitment

Buildings were selected on the basis of meeting several key criteria that would allow both for individual feasibility as well as comparison across domains:

- Context, including building history, terms of tenure, physical and operational context.
- Degree of 'greenness' evident in the building's design and operation. The LEED® rating system was used as a framework of evaluation for 'greenness'. Buildings were identified as 'green' if they had made demonstrated and strategic commitments in the areas of energy and atmosphere, indoor environmental quality, and material finish, all areas which explicitly relate to occupants' comfort and interaction with space.
- Workplace culture – the norms and values attached to the workplace and its use, relating to nature of work, manner of work (i.e. individual, team or service-based), mobility, engagement with work/colleagues, flexibility, and formality. For the purposes of this study we defined three cultures of interest as "academic", "traditional", and "emerging" workplace culture.

Table 1: Study Objectives and Hypotheses

Objective 1: To assess occupants' level of knowledge of building environmental features and systems.	*H1:* Occupants are less knowledgeable about the environmental and energy systems of the buildings they inhabit than building system experts.
	H2: Green building occupants are more knowledgeable than occupants of conventionally designed buildings.
	H3: Occupants who are more knowledgeable about their building are more comfortable overall
	H4: Occupants who are more knowledgeable about their building use the building controls provided more often.
Objective 2: To assess occupants' awareness of personal control opportunities.	*H5:* Occupants are less aware of the extent of personal control available to them than building system experts.
	H6: Occupants rate their experience of control higher overall in green than conventionally designed buildings.
	H7: Occupants feel a greater sense of responsibility for control in green than conventionally designed buildings.
Objective 3: To assess occupants' level of engagement with personal controls.	*H8:* Occupants use personal controls more frequently in green than conventionally designed buildings.
	H9: Occupants engage with personal controls less in the workplace than at home.
Objective 4: To assess occupants' level of interest in learning about their building, and the effectiveness of educational strategies employed	*H10:* Occupants are more interested in learning about green than conventionally designed buildings. *H11:* Occupants who are uncomfortable are more interested in learning about their building than occupants who are comfortable. *H12:* Occupants exhibit different levels of engagement with user information sessions, building use manuals, handouts, emails, displays/signage, and web-based tools.

While most of the companies approached to participate in the study seemed to be interested, indicating that the timing was right and the research had value, several difficulties and delays occurred in recruiting case-study buildings. These difficulties related to: knowing which level of authority to initially approach; managing expectations of employees in terms of improvements to their workspace following survey completion; conflicting interest and timelines; concern over security; and concerns over disruption of the occupants. The difficulty was, therefore, not so much in garnering corporate interest in post-occupancy evaluation research, but rather seeing that interest through to commitment.

At the time of writing, five buildings have been recruited for participation in the study, with negotiations under way to for a further two buildings to be included. Two buildings are located at the University of British Columbia in Vancouver, B.C.: One is a 9,026-sq.-metre, five-storey green building that uses radiant heating/cooling slab ceiling combined with natural ventilation as the primary means of thermal comfort control; the other is a forty-year old, 4,929-sq.-metre brick office and classroom building. A third building, located in Sidney, B.C. on Vancouver Island, is smaller in scale, yet employs an ocean-based geo-thermal system for heating requirements, photovoltaic panels to meet energy needs, and a large rain-water harvesting system. A fourth building is a traditionally-designed office tower located in Torono, Ontario, currently headquarters to one of Canada's largest restaurant and catering service operators. The fifth building, owned by the same company, is a new green office building scheduled to open in the Fall 2008, into which all staff from the current headquarters will move. The latter set of buildings will provide a unique opportunity to evaluate occupant comfort and engagement with building environmental systems pre- and post- move into a new building.

Survey Design and Implementation

While there is no industry-accepted definition or standardized method for conducting post-occupancy evaluation, all approaches necessarily contain two components: measurement and assessment. Measurement involves the identification and gathering of relevant information/data, while assessment is the comparison of findings with pre-determined levels of performance. Several authors have worked to incorporate various psychological, behavioral and social factors of occupant satisfaction. Heerwagen, Johnson and Brothers et al.'s (1998) work includes environmental distraction, habitability, cognitive support, personal preferences and mood in terms of their influence on productivity and well-being in the workplace. Leaman and Bordass (1999) have focused on density, working group size, and social dynamics in assessing what they call 'killer variables' of productivity in buildings, those factors within the control of building designers and managers that best contribute to human productivity. None of the existing satisfaction survey tools deal explicitly with the knowledge of building occupants.

For the purposes of the study, the following information/data were included:

- Background information
- Occupant satisfaction with building and workplace
  - Building design, space, image, safety, storage and cleaning
  - Workplace layout, furnishings, space
- Occupant comfort (summer and winter)
  - Temperature, air quality, noise, and lighting
- Personal control
  - Perceived control
  - Use of personal controls
- Workplace culture
  - Mobility, engagement, flexibility, and formality
- Knowledge of building environmental features and systems

Due to a strong interest on the part of study participants to know how well their building was performing with respect to a benchmark, the Building Use Studies (BUS) Ltd. occupant survey was selected to capture background data, occupant satisfaction/comfort and perceived personal control portions of the study. The BUS survey was developed by and for a U.K. consortium (including Building Use Studies Ltd. and William Bordass Associates) as part of the PROBE series carried out from 1995-2000. The survey is now widely used in post-occupancy evaluations around the world, with over 350 buildings comprising the BUS performance benchmark, and a separate international benchmark for green buildings. To accompany the BUS occupant survey, a new module was developed that addressed occupants' knowledge of building environmental features and systems, perception of building environmental performance, and awareness and engagement with control opportunities available to them.

The sample population included all permanent occupants in the recruited buildings. In the case of academic office buildings, ‘permanent’ referred to full time graduate students and staff. Initial contact with potential subjects was done through an email invitation, with names and addresses being provided by building administrators, and those who agreed to participate were then given the option to complete the online survey.

In order to generate an expert baseline against which to compare occupants’ responses, the survey was also administered to one facilities manager or ‘resident expert’ (e.g. operations manager, property manager, or administrator) for each building. Experts were identified through personal recommendation followed by an informal interview process. The comparison of so-called ‘lay’ knowledge to an expert baseline to elicit mental models is a standard procedure commonly employed in the risk perception and risk communication literature (see for example Slovic 1987; Bostrom, Morgan, Fishoff et al. 1994).

Data was coded and used to analyze occupants’ comfort, knowledge and awareness for conventional and green buildings, across three different workplace cultures. Demographic data as well as data on social and psychological aspects of the work environment were used to strengthen the analysis and results.

Preliminary Results

The survey was pilot tested in April 2008, revised, and then implemented in full from April to May 2008 in the two University of British Columbia (UBC) buildings – the data from which is currently in the process of being analyzed. However, preliminary findings from the pilot study offer valuable insight. The pilot study was conducted in a four-storey, 4,200-sq.-metre, LEED® Silver certified building that employs extensive daylighting strategies, and a stack-driven natural ventilation system to provide cooling and fresh air to occupants. It was purpose-built in 2005 to house researchers, staff and graduate students of the UBC Fisheries Centre, and Institute for Resources Environment and Sustainability.

Forty people completed the online survey over a two-day period. Respondents were well distributed in terms of age (48% under the age of 30 and 52% over 30), while more females responded to the survey than males (67% and 33% respectively). The majority (79%) of respondents had worked in the buildings for a year or more.

When asked whether they considered the building to be a “green” building, 55% answered Yes, 25% answered No, and 22.5% didn’t know. Respondents had specific and very personal definitions of what respondents considered to be “green”. Those who responded Yes had either been told that the building was LEED®-Silver or designed to be green, or described specific (and typically visible) green strategies employed in the building (e.g. natural lighting, low flush toilets, and concrete slab floors). Those who responded No based their answers on building performance in use, and gave comments such as “in a green building, I would expect more control of heating/cooling than we are afforded”, and “I would [consider it to be ‘green’] if it a) made use of geothermal heat, b) had more automated lighting controls/sensors to turn off when nobody is there, and c) allowed bicycles to be placed next to desks”.

When asked whether they would like to learn more about how the building performs and comfort was provided, 65% answered Yes, 22.5% answered No, and 12.5% didn’t know. Qualitative analysis revealed a three-way split in responses, between: 1) those who wanted to learn more and provided specific examples of (e.g. "Yes – it's relevant and important knowledge", "Yes – I'm interested in energy use and impacts"); 2) those who may have wanted to learn more but didn't think it would make a difference (e.g. "No – it wouldn't change the building", "No – UBC wouldn't give me the power to do anything anyway, so why should I learn more"); and 3) those who didn't want to learn more because they simply didn't have time.

In general respondents had a poor level of knowledge about how the building worked, with the majority (52.5%) ranking their knowledge as 2 or less on a scale of 1-5 (1 = not at all knowledgeable, 5 = very knowledgeable). Interestingly, 17.9% thought the building had a mechanical cooling system and 12% thought it had a mechanical ventilation system, when the building is entirely naturally ventilated. This is significant given that a critical component of such a passive system is the involvement of the occupants in opening and closing of windows.

Occupants who were less knowledgeable (1-2/5) overwhelmingly *never* used building controls for heating, cooling, ventilation, lighting or noise. When asked why they never used controls the most common answer was "I don't know where they are". Occupants who were more knowledgeable (4-5/5) in general used building controls more often, and for controls they never used the most common reason given was "Controls are inconveniently located", followed by "Controls don't exist".

Finally, results suggest that occupants who had a moderate knowledge (3/5) of how the building performed, had the highest overall satisfaction with comfort, with an average rating of 5.6 on a scale of 1-7 (1 = unsatisfactory, 7 = satisfactory) (Table 2). Those with lower knowledge of the building (1-2/5) had a wide distribution of comfort ratings, while those who were more knowledgeable (4-5/5) tended to be split in their rating of comfort between high and low overall satisfaction. In general, respondents were moderately satisfied with the overall comfort of the building environment (rating average 4.95/7).

Table 2. Relationship between Occupant Knowledge and Comfort

	Not at all knowledgeable				Very knowledgeable
Knowledge rating	1	2	3	4	5
N	8	13	11	3	2
% of Total	20.0	32.5	27.5	7.5	5.0
Average overall comfort score (scale of 1-7, 1=unsatisfactory 7=satisfactory)	4.71	4.64	**5.36**	4.0	5.0

Conclusion

The transition from high energy, tightly controlled, automated buildings, to low energy, passively-conditioned buildings will require an equivalent transition of occupants' expectations to accommodate new indoor environments, systems and responsibilities. To this end, new communication and feedback tools are needed informed by a better understanding of the knowledge, behaviour and practice of end-users.

This paper has presented the background and theoretical underpinnings for a research project currently underway that examines occupants' knowledge and engagement with building environmental features and systems. Previous work has focused on the residential sector, where feedback mechanisms (and their ability to influence behaviour) may have fundamentally different qualities and attributes to that which is relevant to the commercial sector. Understanding what occupants know about the buildings they inhabit and how they engage with the controls provided is a fundamental first step in providing meaningful and effective feedback on the short and long term environmental consequences of their actions. More importantly, improving occupant knowledge may have significant implications for comfort provision and the energy efficiency of buildings.

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