Commercial Buildings Energy Performance within Context
Occupants in Spotlight

Sanja Lazarova-Molnar, Mikkel Baun Kjærgaard, Hamid Reza Shaker and Bo Nørregaard Jørgensen
Center for Energy Informatics, University of Southern Denmark, Campusvej 55, Odense, Denmark

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Abstract: Existing commercial buildings represent a challenge in the energy efficiency domain. Energy efficiency of a building, very often equalized to a building's performance should not be observed as a standalone issue. For commercial buildings, energy efficiency needs to be observed and assessed within the context of performance of resident businesses. We examine both business performance and energy performance and how they relate to one another to conclude that building occupants, who are also employees, hold the key to optimizing both metrics in one of the most cost-efficient ways. Finally, the goal of our contribution is twofold: 1) to re-scope the concept of building performance to and show the importance to consider, hand-in-hand, both energy performance and performance of resident businesses, and 2) re-state the importance of the potential that lies in the active involvement of building occupants in optimizing overall building performance.

1 INTRODUCTION

Energy efficiency is becoming an increasingly critical issue and one of the most significant cost factors of existing buildings (Costa et al. 2013; Ma et al. 2012). It is also as a very complex issue because it is affected by a number of factors of various natures (Danov et al. 2013), such as environment, building structure and materials, occupants' behavior, etc. Energy efficiency is, however, only one of the factors that contributes to the overall building performance and has to be viewed within the context of a given building.

Building performance is very often defined and understood in terms of its energy performance (Schlueter and Thesseling 2009). However, in one of the very early works on this topic, it has been clearly pointed out that building performance needs to be assessed as "building's ability to contribute to fulfilling the functions of its intended use" (Douglas 1996). This implies that there is a lot more to *building performance* than the energy performance, and that the energy performance has to be observed within the context of a building's function and purpose. Commercial buildings typically host businesses or organizations that have various business performance goals, whose rate of success depends to a great extent on employees, i.e. building occupants. Building occupants at the same time hold the key to one of the most cost-efficient ways of enhancing energy performance of existing buildings, i.e. through exhibiting a more energy-conscious behaviour. The problem here is that occupants are not usually motivated to behave in an energy-conscious way due to the non-existing financial incentive to reduce energy use and no access to their levels of consumption. Moreover, energy management of a building can also affect employees' productivity both positively or negatively. Therefore, we believe that by developing building energy management systems (BEMS) that focus on building occupants and their active participation with a purpose to increase occupants' contentment levels, in a synergetic way could enhance the overall building performance.

In the following we provide more insight in assessment of buildings' energy performance, as well the links among building energy performance, building occupants and business performances of hosted businesses.

There are a great number of information and communication technology (ICT) methods and tools that aim to predict and benchmark energy performance of buildings (De Wilde 2014) using simulation or artificial intelligence methods. In spite of these advances, until now, we have not been able

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to identify tools that target and consider the performance of residential businesses as part of the overall building performance (Schlueter and Thesseling 2009; Attia et al. 2013), except for a few limited attempts (Iyer et al. 2013). We, however, believe that the only appropriate way to assess energy savings is to observe them within the context of the performance of residential businesses.

Therefore, the goal of our contribution is to re-scope (or scope back) the notion of *building performance*, such as to also encompass business climate and performance of hosted businesses, besides energy performance. We believe that both should be observed hand in hand. This would ultimately imply that a great focus and consideration needs to be given to building occupants and value the potential that lies in them for reaching both targets in a synergetic manner; thus, observing the energy-efficiency paradigm through the prism of buildings' purpose and buildings' occupants (Jain, Taylor, and Culligan 2013). Our motivation stems from the following three facts:

1) Occupants' behavior can significantly affect the energy efficiency of existing buildings (Masoso and Grobler 2010; Azar and Menassa 2011),

2) Energy performance of a building is only one aspect of the overall building performance (Douglas 1996), and

3) Buildings are ultimately there to serve their occupants, both in terms of people and organizations / businesses (Andrews et al. 2011; Kamaruzzaman and Sabrani 2011; Armitage and Murugan 2013).

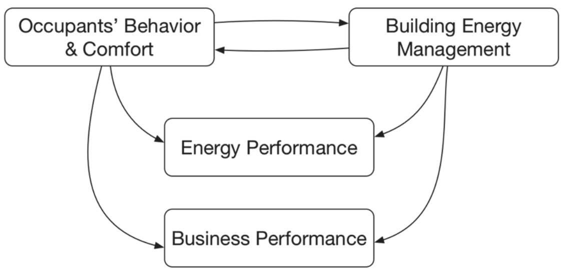

Figure 1: Influence diagram of occupants behavior, energy performance, business performance and energy management.

The concept of having contented occupants only gains in importance when focusing on commercial buildings, for the reason that these buildings are also supposed to provide a productive ambient, i.e. an ambient in which occupants will feel taken care of and motivated to accomplish their work goals.

In Figure 1 we present an influence diagram of energy performance and business performance of commercial buildings. The diagram shows that the influence goes in almost all directions. The way that occupants behave affects the energy performance of a building, as well as the building energy management. However, building energy management also affects behavior of occupants, and includes the complex behavior that can occur due to feelings of not being taken care of or being ignored, e.g., frustration. This, in turn, can negatively impact productivity, i.e. the business climate in the building, and, thus, imply a loss in profit or inability to meet business goals. To further aggravate the problem, commercial buildings occupants are currently not directly affected by their energy-consuming behavior, as they have no financial incentive to reduce energy use and no access to their levels of consumption.

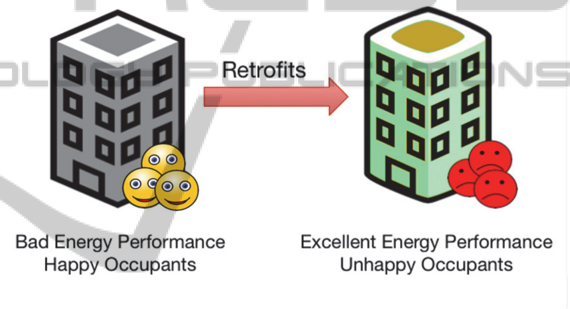

Figure 2: Possible effect of retrofits that could have dramatic impact on business productivity.

Figure 2 further illustrates our motivation where we present one possible outcome scenario of a retrofit. In this example, the retrofit greatly enhances building energy performance, however, it also makes occupants miserable and results in low productivity. Certainly, this "gain" is not really a gain, as resident businesses would be impaired by it. One could imagine a long list of potential consequences that would ultimately affect productivity, including employees consistently preferring to work at home if that is an option (which would again save energy, but could be damaging to productivity). To prevent this, we aim to more holistically assess a building's performance, and use this benchmark in selecting an optimal retrofit for a given case.

The implications of our position could be research directions that closely focus on the potential that lies in the active involvement of occupants, unlike the majority of current research that treats occupants as dynamic elements that are only to be observed and whose behavior needs to be predicted. In most of the approaches they are shown only as observed elements, and almost never as actively interacting elements (Yu et al. 2011; Azar and Menassa 2011). This implies that BEMS that supports the overall building performance need to communicate with occupants in a bi-directional user-friendly manner and maintain their contentment level, thereby maximizing meeting of two goals: business performance and energy performance.

Therefore, to sum it up, the goal of this paper is the following:
to re-scope the concept of building performance to include both building energy performance and business performance of residential businesses, and show the importance of actively involving occupants and placing occupants in the center of building management in order to utilize their full potential to increase the ***overall*** *building performance.*

The position that we present is based on findings from research performed in the areas of energy management of buildings, human factors in buildings energy management, as well as the effect of workplace on productivity, as presented in the following section.

The paper is structured as follows. In Section 2, we review the popular definitions of *building performance* and we explore the current state-of-the-art for the two related problem domains: human factors in building management, and workplace impact on productivity. We utilize the advances and findings in these areas as inspiration and basis to develop our position that we thoroughly present and assess in Section 3. In Section 4 we discuss the potential outcomes of our position. Finally, in Section 5 we conclude the paper.

2 STATE OF THE ART

In line with our presented position, buildings energy management systems need, besides other technical aspects, to significantly consider the contentment level of building occupants and provide them with a perception that their comfort is important. The ultimate goal of this is to maximize performance of residential businesses and organizations. To better understand this issue, in the following we provide an overview of the state-of-the-art of the importance of human factors in the energy performance of buildings, as well as the impact of the workplace on productivity. This section serves as an inspiration and basis for our presented view and position.

2.1 Building Performance

The concept of "building performance" has been defined throughout literature differently. Here, we would like to summarize the most popular ones. Therefore, the most pronounced definitions that we have encountered are the following:

- "we define building performance as related to energy consumption, the most important issue concerning CO_2 emissions" (Schlueter and Thesseling 2009), which is the most common way of understanding the term (Soebarto and Williamson 2001; Cohen et al. 2001), and
- "define building performance as an expression of measurable variables which affect a process or procedure. Common building performance factors are environmental factors, such as solar gain, aerodynamics, and heat loss, structural factors such as load and stress, and social factors such as view and privacy." (Tang et al. 2012)

In other words, most of the existing and recently used definitions of building performance focus on technical aspects of buildings, dominantly on the energy consumption. Very rarely the context of a building is taken into account when assessing energy performance, and yet the term building performance is used. In the following we review the human factors in management of buildings, in which we also provide an overview of the modes in which occupants can be involved in building management.

2.2 Human Factors in Buildings Management

Humans are the reason why buildings exist. In commercial buildings the comfort of occupants only gains in importance, as these buildings need to also support productivity. Apparently, some of these aspects can only be tackled during the design phase. Therefore, there has been a vast amount of research on the effect of materials, lighting, furnishing, space management, etc. on the productivity of employees (Hedge, SIMS JR, and Becker 1995; Fisk 2000; Veitch and Galasiu 2012). A significant amount of research has also focused on the effect of materials that are being used (Berge 2009).

As our focus is on existing commercial buildings, we are interested in the way that energy management can affect occupants, and how it can in turn affect the business performance. Therefore, we are interested in the modes of communication with occupants to develop cooperative energy-conscious behavior. Some of the most significant ways we have encountered in research literature are feedback and education (Arbuthnott 2009; Zografakis, Menegaki, and Tsagarakis 2008), whereby we place our attention on feedback as that represents an opportunity to actively involve occupants. It has also been noted that occupants' behavior changes have the potential to achieve about 25% energy use reduction (Ehrhardt-Martinez and Laitner 2010), which is a very significant saving.

An active communication with occupants can enhance the awareness of their energy-related behavior. In the work presented in (Carrico and Riemer 2011), the authors evaluate the group-level feedback on energy consumption and peer education and information dissemination. With the two simple measures they achieved 4% and 7% reduction in energy consumption. In the work presented in (Hall 2014) the authors present a tool to assist building stakeholders identify key energy performance issues with their buildings. The tool explores 5 key areas in buildings that influence energy performance: design elements, building management, occupant experience, agreements and culture and indoor environment quality. The authors conclude, among other things, that occupant feedback needs to be harnessed more in building rating tools, as it is a major factor to support sustainability of buildings.

The existing work in this domain shows how significant it is to actively communicate with the building occupants. It confirms the importance of feedback and the different types of visualization of feedback, and this needs to be utilized to enhance the communication loop with building occupants. Furthermore, we believe that explanation is also very important to keep occupants content and make them feel important. It can be especially helpful when unpopular measures need to be taken. Ultimately, communication with occupants needs to be customized, as there is nothing like "one size fits all" approach.

2.3 Workplace Impact on Productivity

There have been numerous studies that assess the impact of the workplace ambient on productivity. In one of the most recent works (Leblebici 2012) an analysis of working environment of a foreign private bank in Turkey is presented and the relationship between the workplace physical conditions and employees' productivity is examined. They conclude that the overall workplace environment significantly impacts employees' performance. In a similar study (Akimoto et al. 2010), the thermal comfort was being observed, and it was found that there is a tight link between employee's behavior, his/her thermal comfort and productivity.

Air quality is also seen as a significant factor to productivity, and it has been shown that poor indoor air quality can significantly decrease productivity, apparently to the size of 6-9 % (Wyon 2004). Many studies go even further and claim an average relationship of 2% decrement in work performance per degree ^{o}C when the temperature is above 25^{o}C (Seppanen, Fisk, and Faulkner 2004). In the same work, the study performed showed that the productivity increase by using night-time fans during work was 32 to 120 times greater than the cost of energy to run the fans. Therefore, it is evident that there is a strong link between workplace ambient and employees' productivity, and energy consumption savings have to be viewed in light of utilizing this connection.

3 CHALLENGE AND RESEARCH DIRECTIONS

As previously emphasized, energy consumption represents only a portion of the overall performance of a building. Buildings have various purposes, and when considering commercial buildings, which typically host businesses, one should be very careful about the trade-offs that could occur when optimizing building's energy performance. If building enhancements for improved energy efficiency create unhappy occupants, then the energy savings are meaningless and, even worse, damaging. This illustrates that occupants are a very significant parameter in this equation. The fact that buildings' occupants also represent the most cost-efficient solution to reducing the energy consumption of a building only points out that the equation is far from trivial, and needs to be carefully analyzed from all perspectives.

The question that is typically addressed is the following:

"What modifications to perform on an existing building such that its energy performance is optimal?"

There are a plentitude of ICT methods that predict buildings' energy performance, based on various assumptions and parameters. These are utilized to assess suggested building modifications. There are also methods that consider occupants' behavior, albeit only observing and modeling them.

We suggest that the basic question is changed to the following:

"What modifications to perform on an existing building such that its energy performance is optimal and it stimulates (or at least does not negatively impact) residential businesses?"

This, certainly, would affect the calculations and prediction models, and one of the major implications of it would be focusing on occupants and exhibiting more care for them. With this shift of focus we wish to see building occupants being given a more active role and building BEMS with primary focus on occupants' comfort.

A significant implication of this revised view of building *performance* would be development of measures and benchmarking methods to assess buildings' performance within a given context, i.e. in terms of meeting business performance goals. This would also imply that different types of buildings would need different benchmarking measures, as schools, supermarkets or office buildings would definitely need different ways of assessing their overall building performance.

4 POTENTIAL OUTCOMES AND IMPLICATIONS

Our presented position suggests viewing energy performance of buildings within the actual context of each and every building, i.e. within performance goals of hosted businesses and organizations. This, furthermore, leads towards highlighting occupants as significant contributors towards both business goals and energy performance goals. This shift of focus in energy management of buildings towards goals of resident businesses and occupants opens up new way of looking at buildings, and returning to their original purpose, i.e. serving occupants by creating a productive and caring ambient.

Apparently, buildings enhancement under this assumption would imply involvement of a significant number of researchers in psychology and user experience (human-computer interaction) for design of building energy management systems. Potential outcome of research under the presented assumptions would be BEMSs that center occupants, provide customized control and high level of interaction, and learn from occupants' behavior in order to adjust controls to support the business climate of hosted organizations and businesses.

The potential resulting BEMS would exhibit a perception of a caring system towards occupants, by collecting their feedback. An example for feedback on how occupants feel with respect to office conditions would be a simple perception, such as "I am hot" or "It is dark", from which the BEMS would learn and build a model of how occupants perceive a certain combinations of settings (Krioukov and Culler 2012). Furthermore, this perception might vary if the occupant has Scandinavian or Middle East background, so occupant background would need to be taken into consideration as well. A combination of settings would consist of occupant's description, heating/cooling level, outside temperature, time of the day, date in the calendar, etc. This will help in classification and future decision-making processes.

Finally, two major outcomes that we can see taking place as a result of our proposed position are the following:

1. Development of new metrics, methods and tools to combine energy performance and business performance measures, considering their interdependencies, to yield *overall building performance.*
2. Development of new concept for BEMS that actively involves occupants, in order to fully utilize their potential.

These possible outcomes would significantly impact decisions when selecting a retrofit for a given building, and would contribute towards a more holistic view of buildings, such as to make decisions that minimize trade-offs.

5 SUMMARY AND OUTLOOK

We have emphasized the importance of extending the definition of the concept of *building performance*, which is usually equated to building *energy* performance. Our goal is to argue that energy performance cannot be viewed as an isolated issue, and has to be observed hand in hand with the performance of businesses, hosted by a given building. This in turn means reaching out and assessing the potential that lies in occupants and researching ways of how they can be actively involved to improve *overall* building performance, i.e. to both improve energy performance as well as meet business performance goals of resident businesses. All of this need to be incorporated in future BEMSs.

This implies that future BEMSs should support operating buildings in energy-efficient manner, thereby maximizing the cooperation level and contentment level of occupants, as one of the main contributors in saving energy of existing buildings, but also in the productivity of residential businesses.

To achieve this goal, we believe that it is important to accommodate occupants and enable active communication between them and building energy management systems. This can be achieved through explaining and informing occupants, as well as receiving feedback and other relevant type of information for successful operation of the system. Certainly, for development of such features, psychologists, UX (user experience) and HCI (human-computer interaction) experts will need to be highly involved, which is not the case now.

Finally, we believe that placing a high value on occupants' contentment level will provide for a more truthful and holistic view of the overall building performance, and contribute towards a more accurate assessment of potential energy performance enhancements of existing commercial buildings.

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