WHY IS THERE A GAP FOR ENERGY PERFORMANCE? EVIDENCE FROM GREEN COMMERCIAL BUILDINGS IN ARIZONA

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Overview

Empirical studies have found out that green commercial buildings do not save as much as predicted. There is a gap between the predicted savings by engineering models and the empirical savings. The actual energy consumption are 1.5 to 3 times more than predicted (Grimes et al. 2016; De Wilde, 2014). Occupant behavioral change is the most acknowledged reason for the energy performance gap (De Wilde, 2014). Many other factors such as technology degradation, modeling and simulation gap, change in construction, exterior condition (e.g. weather, social-economic development) (De Wilde, 2014; Menezes et al., 2012), management practices (Oates and Sullivan, 2011; Kahn et al., 2014) are also responsible for the energy performance gap. Closing the performance gap requires addressing the complexity of organization, behavior and engineering factors.

While the technical or engineering dimension of energy use is more widely studied (De Wilde, 2014; Menezes et al., 2012), the social dimension of energy use is seriously undervalued, which could pose as much of a problem as the engineering factors. This study provides a complete picture of energy sustainability of green buildings by combining organizational and behavioral factors together with engineering factors. We collect data from people with professional knowledge on the facility (e.g. facility managers), and thus the experience of practitioners is taken advantage of. The findings of this study will be highly valuable to different stakeholders, including the policymakers, building owners, constructors, and occupants. The results could provide explanation to the general public on the performance gap, provide guidance to policymakers in making energy policy, and also guide building owners' decisions in managing energy performance.

Methods

We sent letters to the registered addresses of the LEED and Energy Star buildings in several states in the United States, complemented by sending emails. The participants must be actually managing a building in order to be eligible for the survey. 1852 surveys were mailed out to reach facility managers who are managing buildings in Arizona and three cities in Texas (Austin, Houston, and Dallas). The data collections last from December 2016 to July 2017. The response rate is about 11%, with 205 responses and 119 completed surveys. Survey collection is complemented by emails to facility managers across the country in IFMA. The survey has four aspects: (1) basic information about the buildings, (2) energy rules, policies, and managing practices in companies, (3) technologies and measures, and (4)occupants' behaviors.

Probit model is applied to further analyse the relationship between the different buildings and their driving factors of performance gap. The dependent variable is LEED (1) or energy star (0) building, and the independent variable sare the organizational, behavioral and engineering factors. The chi-square test is also employed to explore the difference in causes of performance gap for buildings of different certification levels. In this study, we relate threee certification levels: both LEED and Energy Star certified, only LEED or Energy Star certified, and no certification on different engineering, organizational and behavioral factors. Suppose there are two variables with the observations 1,2….I, and 1,2….J. The equation for the chi-square test is $X^2 = \sum \frac{(x_{ij}\text{-}e_{ij})^2}{e_{ij}}$, where $e_{ij} = \frac{x_{ij}x_j}{n}$, e_{ij} is the expected value of an observed value. The Pearson χ^2 statistic is with $(I-1)(J-1)$ degrees of freedom. The null hypothesis is that there is no association between certification levels and the factors. If the X^2 value is very large, we reject the null hypothesis. Meanwhile, Fisher's exact test is applied since some cells have small values.

Results

The survey results show that most green commercial buildings with energy efficiency measures are doing well from an engineering perspective. 68% of the buildings are reported to have participated in at least one energy efficiency/ renewable energy program. 84% of the buildings have temperature set-back settings when the building is not occupied. 70% of buildings have an energy efficient AC system. 51% report that technology failures happen rarely and 31% report technology failures happen sometimes. However, the commissioning is not well conducted for most buildings, as only 26% report that there is retro-commissioning, which is usually performed at least one year after occupancy. Besides, the penetration of distributed solar electricity generation is still comparatively low (20%) given the strong solar radiation of study area.

In terms of the policies, rules and managing practices in companies, there are some regulations to support energy savings for the buildings while some aspects of management practices are still flawed. The survey shows that 54% of the buildings have policy prohibiting non-essential personal appliances (e.g. personal fans). 43% of the buildings have energy targets set. Of this portion, 23% have targets seasonally or monthly and 20% have annual or biannual energy targets. Moreover, 41% of participants report that the facility managers/staff are required to summarize energy utilization, investigate unexpected spikes, or recommend improvements. Only 44% of facility managers previously have used online energy saving resources to obtain information. However, only 23% report that there are incentives for facility managers to save energy. This means there is high expectation from facility managers, but there is a lack of economic incentives to keep them highly motivated. Besides, only 14% of the buildings have an Energy Performance Contract (a promising business model with huge economic potential), and only 28% have tenant lease agreements, occupant handbooks, and staff training manuals to help newcomers.

The survey also demonstrates that the buildings have not explored occupants' full potential in saving energy. Sub-meters are common and critical tools for tracking and analyzing energy use and identifying occupant behavior. However, 30% of buildings are without any sub-metering installed. Besides, about 20% of entities require occupants have business attire all year around, which prohibits their behaviors and adaptation to the environment. 73% report there is no signage for occupants to save energy, such as turning off computers or task lights when leaving the workspaces. When it comes to the reasons that people are not attempting to save energy, 36% think it is because people do not believe their behaviors will make a difference, and 28% think it is because efforts to saving energy is an inconvenience. The most widely reasons for the energy performance gap are (1) building occupants use more energy (e.g. energy for cooling) ; (2) We have added more occupants; (3) there are failures with energy technologies in the buildings; (4) energy consumption estimate during design is not accurate.

The LEED rating system is different from the Energy Star rating system in that LEED buildings are certified based on credits from several categories with energy being one of the largest categories while Energy Star buildings are assessed by actual energy consumption for at least one year. The regression analysis indicates that LEED and Energy Star have many differences in terms of the driving factors of performance gap. The Energy Star certified buildings are more likely to be office buildings, compared to other functions such as education, retail stores, etc. LEED buildings are more likely to have requirements that the facility managers/staff summarize and investigate energy usage and recommend improvements. This is supported by the fact that there is a large number of LEED professionals with certificates than other green buildings. Furtheremore, LEED buildings are also more likely to have energy efficient AC and have solar panel installed. However, LEED buildings are less likely to have energy performance contract compared to Energy Star buildings. This indicates the LEED buildings, for which actual billing data is not required, are constructed to be energy efficient, however, the energy performance during operation is not well controlled. The chi-square test results show that different certification levels, i.e. both certified, single certified, and non-certified, are not statistically different based on many factors, such as the frequency of technology failures, temperature set-back, incentives for facility managers, although they are different in terms of solar panel installation, policies to prohibit personal appliance and setting energy targets. This indicates the green buildings are not different from the non-green buildings with respect to many aspects. This is probably the reason why green buildings are not performing as well as expected.

Conclusions

Study on the energy performance gap demands not only the technical/engineering perspective, but also the social and behavioral perspectives to understand the complete picture of energy sustainability. This study finds that the most important reasons for the performance gap are the rebound effect, the increasing occupants and frequent technology failures. Most green commercial buildings are doing well in terms of engineering aspects. However, generally only some good practices (e.g. policies, rules, and managing practices) are adopted by buildings while some practices still have great potential. The survey also demonstrates that the buildings have not explored occupants' full potential in saving energy. We sent mail to every registered address on the LEED and Energy Star official websites. However, our response rate is low because some addresses are not well documented and some buildings may not have available facility managers. It is worth noting that the participants respond to our survey are more likely to be these who believe their buildings perform well and thus their buildings may perform better than the average.

References

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