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Procedia Engineering 118 (2015) 19 – 27

Procedia Engineering

www.elsevier.com/locate/procedia

International Conference on Sustainable Design, Engineering and Construction

A post occupancy evaluation framework for LEED certified U.S. higher education residence halls

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Abstract

Numerous higher education (HE) institutions in the United States have created sustainability agendas, including construction of certified sustainable buildings. More than 200 US HE institutions have at least one Leadership in Energy and Environmental Design (LEED) certified building on their campus. In order to assess if sustainable residence buildings are performing as expected, a post occupancy evaluation (POE) framework of indicators was developed and implemented. POE indicators were chosen through a review of sustainability rating systems, literature review, and surveys. The selected indicators address a range of parameters using quantitative and qualitative data collection methods via investigative and diagnostic techniques. The dataset includes temperature and relative humidity measurements, water and energy consumption, feedback from facility manager departments and almost 600 occupants. The findings highlight large variations in terms of energy and water consumption, and poor indoor air quality; moreover, LEED residence halls have also shown to be less sustainable over time. The findings also indicate the LEED rating system may generate skewed savings expectations, as occupant behaviours and feedback are poorly considered.

Peer-review under responsibility of organizing committee of the International Conference on Sustainable Design, Engineering and Construction 2015

Keywords: Post Occupancy Evaluation; Residence Halls; Occupant Feedback; Sustainability Rating Systems; LEED; Water and Energy consumption.

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Peer-review under responsibility of organizing committee of the International Conference on Sustainable Design, Engineering and Construction 2015
doi:10.1016/j.proeng.2015.08.399

1. Introduction

The United States (US) buildings sector is the national largest contributor of resource consumption and depletion, accounting for more than 30% of greenhouse gas emissions and 41% of primary national energy use [1]. In the US, the majority of Higher Education (HE) institutions have created sustainability agendas, adopting sustainability principles in their new facilities [2]. In fact, more than 200 higher education (HE) institutions have at least one LEED certified building on their campus [2].

In order to support this trend, the present study develops a post occupancy evaluation (POE) framework to assess the sustainability of residence halls in practice. LEED provides guidance on the design and construction of building projects targeting sustainable practices, but does not require extensive evaluation post construction and in operation [3]. For this reason, POEs are necessary to ensure sustainability of LEED buildings in practice. POEs provide a tool for measuring building performance in terms of meeting design intent, and identifying any gaps between actual and modelled performance [4]. Assumptions made by designers dictate the post occupancy state, but are rarely re-examined for accuracy and applicability in practice [4]. Furthermore since building performance is rarely monitored, correction measures are seldom implemented, perpetuating energy and water waste and potential occupant dissatisfaction [4, 5].

Even though POEs are invaluable performance measurement tools, uncertainty and difficulty in the selection of indicators and feedback techniques have slowed their adoption [6, 7]. Another obstacle to POE implementation is that a 'one-size fits all POE' framework does not exist, since POEs should be tailored to specific building typologies [8, 9]. Various types of POE criteria exist including: (1) indicative: general inspection of building performance; (2) investigative: in-depth study of building performance, surveys and interviews of stakeholders, and comparison of findings to similar facilities; and, (3) diagnostic: sophisticated data collection and analysis, physical measurements, surveys and interviews of stakeholders [8]. This study presents a comprehensive POE framework, composed of mixed methods to monitor the performance of HE residence halls. Feedback from key participants (designers, facilities managers, residential life and occupants) are a critical component in comparing quantitative and qualitative data collected [10].

2. Methodology

The selection of POE indicators in this study is based on: (1) recurrence in widely adopted sustainability rating systems, scientific studies and papers, (2) applicability in the post occupancy phase, and (3) survey results highlighting main areas of concern from building stakeholders (including 593 student surveys). The selected indicators address a range of topics including: water and energy consumption, occupant thermal comfort, occupant consumption behaviour and education, (indoor and outdoor) noise insulation, and facilities managers' (FM) operational feedback. Specific indicators such as Building Energy Management Systems (BEMS), Building Automation Control Systems (BACS) and Artificial Intelligence (AI) agents are also examined to identify if the benefits of these system have been realized.

The data collection method for each POE indicator varies between quantitative and/or qualitative techniques. Qualitative data techniques included face-to-face and online surveys, tied to Likert 7-point scales and open-ended questions to many stakeholders (facilities management personnel, designers, owners, residential life personnel and students). Quantitative data methods involved the collection of actual data through billing information, meter readings, physical measurements, review of design documents (plans and specifications) and LEED documentation. LEED documentation outlines the non-sustainable baseline design case (BDC) and sustainable proposed design case (PDC) calculation assumptions and incorporated sustainability features. This documentation provides valuable information for comparison to actual and benchmarking data. FM personnel provided actual consumption data through metering/billing information of water and energy, and operational feedback via a face-to-face survey. The surveys provided insight as to whether the residence hall had met design intent in practice, highlighting key areas of concern.

Residential life personnel document real occupancy, gender split, operational days, and any complaints or concerns reported by students. This allows comparison of actual consumption data to submitted LEED documentation, to develop accurate benchmarking metrics and post-examination of designer assumptions. Occupant feedback provided information on the actual human interaction with the building. Occupants of four residence halls answered an online survey with questions tied to Likert scales and open-ended questions. The total sample size consisted of 593 responses (34% overall response rate).

3. Results and Discussion

3.1. POE indicators and data collection methods

Based on the methodology previously discussed, twelve POE indicators were selected. Table 1 outlines them according to their quantitative and qualitative data collection methods, along with supporting literature and key participants in the data collection process.

Table 1-POE indicators requiring quantitative and qualitative data collection methods.

Selected POE indicator*			Papers supporting each indicator	Data collection method	Key participants for data collection
Quantitative	1-4	Building water, electricity, and gas consumption and On-site renewable energy generation	[11-20]	Metering/Billing Data (Monthly/Quarterly)	Designers and Facilities Management (FM) Personnel
	5	Building systems commissioning	[11-17, 20]	Commissioning Process Documentation	FM Personnel
	6	Monitoring of indoor air temperature and humidity	[16, 17, 20-22]	Building Automation Controls (BACs) readings or actual measurements	FM Personnel
	9	Preventative maintenance program for HVAC systems and building enclosure.	[17, 20, 23, 24]	Process documentation	FM Personnel
	11	Use of building automation control systems (BACS) or Building Energy Management Systems (BEMS)	[23-27]	Survey of facilities management	FM Personnel
Qualitative	7	Occupant satisfaction with the controllability of IAQ parameters	[7, 8, 21, 22, 28-31]	Survey-open ended questions, yes/no questions and 7-point Likert scale.	Designers (LEED pursuits) and Occupants
	8	Occupant satisfaction with building controls ease of use (lighting switches, thermostat etc.…)	[4, 32]	Survey-open ended questions, yes/no questions and 7-point Likert scale.	Designers (LEED pursuits), Occupants, and FM Personnel
	10	End-user consumption awareness education efforts by academic institutional owner	[4, 24, 33-36]	Documentation of educational methods employed and Student survey	Occupants, Residential Life Personnel and FM Personnel
	12	Indoor sound insulation		Student survey	Occupants

*Numbers designate POE indicator numbers

Indicators 1-6, 9 and 11 require involvement of designers and FM personnel to gather actual data. Indicators 1-4 may be collected through meter readings and billing data. Data from indicators 1-4 can be used to compare actual values to finalized LEED documentation from designers, informing them if their design assumptions are valid. This information can highlight monthly and yearly trends in consumption and aide in forecasting resource needs and stabilizing load requirements.

Indicator 5 provides insight into the commissioning process and any HVAC problems which may have translated into the operational phase of the residence hall. Commissioning information available from designers and FM personnel sheds light on actual energy consumption values experienced and potential issues with indoor air quality.

Indicator 6 focuses on indoor temperature (T) and relative humidity (RH) tracking and measurement, to ensure occupants are satisfied with their indoor air conditions. It may be collected through BACS if adopted and tracked by actual field logged measurements. Indicator 6 data was compared to ASHRAE Standard 55-2013 [37], checking validity of the standard in practice and whether course correction measures are required.

Indicators 7 and 8 are to be collected from occupants, the result of the data collected highlight whether occupants are indeed satisfied with their ability to control their indoor air conditions and if the control systems are easy to operate.

Indicator 9 ensures residence hall envelope and HVAC systems are performing as intended by examining FM preventative maintenance practices. Indicator 10 requires the active involvement of residential life personnel and HE institutions as a whole, to educate occupants on sustainable behaviours. Indicator 10 can be implemented through monthly workshops, sustainability competitions, informational flyers and emails on sustainable behaviours. Such practices can be adopted to minimize consumption and promote sustainability by shifting institutional culture towards sustainable practices. Often comments and concerns are raised to residential life personnel first, followed by the involvement of FM personnel. Therefore collecting data from residential life personnel also allows comparison of data between FM personnel, and occupants.

Indicator 11 addresses the customization of BACS, BEMS and AI in tracking, measuring and reducing energy consumption. Manipulation of HVAC start-stop times along with space utilization programming can be done through these systems, to minimize energy consumption and model occupant behaviour.

Indicator 12, indoor sound insulation, was added to the POE indicator framework due to student survey results in this study. It entails a student survey on whether indoor sound conditions are comfortable. Initially it was thought noise levels only between the indoor and outdoor environment was of importance, however based on the results of the student survey indoor sound travel was more critical. Therefore this indicator examines sound travel between bedrooms, bathrooms and between floors.

3.1.1. Indicator 1-water consumption

Figure 1 (a) depicts the actual water consumption in order of highest performance (lowest consumption) in litres per person per day (LPD). The overall range of actual water consumption of HE residence halls (6 non-LEED, 3 LEED) was in the range of 85 and 175 LPD, with an average of 144 LPD and *stand. dev*. of 34 LPD. Hall EH (LEED) was the top performer followed by non-LEED residence halls WT and HH, while LEED residence hall PS performed slightly better than the poorest performer non-LEED residence hall MH1. Figure 1 (b) highlights the technologies implemented in terms of litres per minute (LPM) and litres per flush (LPF), even though LEED halls used less consuming fixtures they still underperformed non-LEED ones indicating technology alone is not the answer to reduced consumption.

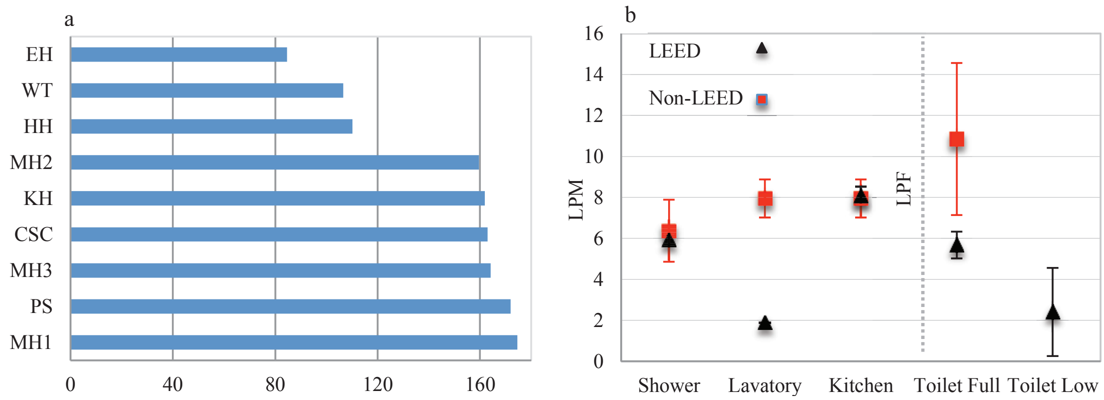

Figure 1- (a) Actual water consumption of LEED (EH, CSC, PS) and non-LEED (WT, HH, MH2, KH, MH3, MH1) residence halls in litres per person per day (LPD), and (b) Technologies implemented in LEED and non-LEED residence halls in terms of litres per flush (LPF) and litres per minute (LPM).

Examining yearly and monthly consumption, non-LEED residence halls depicted steadier consumption values with an overall 3% uptick for the entire time data was collected (5 years). However, LEED residence halls showed an increase of 5% over the years and, on average, higher variations in consumption patterns. The average water consumption of LEED halls was 60% higher when compared to their LEED PDCs. The data showed yearly decreases in savings, rendering LEED halls less sustainable every year. The results of the student survey indicate LEED and American Water Work Association (AWWA) shower frequency and toilet flushes per day are accurate, however shower duration assumptions are flawed [38]. The survey showed 67% of students shower daily and flush an average of 5 times a day, however on average students run the water in the shower for over 12 minutes with a *stand. dev*. of 5 minutes. This value is 50% higher than LEED and AWWA (8 minutes) assumptions. Such large variations in actual practice versus modelled assumptions result in substantial gaps in water-use estimation and performance evaluations. A major survey finding showed students (male and female) who frequently thought about their water consumption, were more likely to run the water for shorter durations in the shower. This analysis result indicates that educational efforts by HE institutions may result in more savings than the adoption of high-tech fixtures.

3.1.2. Indicator 2, 3 & 4-electricity, gas consumption and on-site renewable energy generation & use

The average actual energy consumption of 3 LEED and 1 non-LEED residence hall fell between 85 and 219 kWh/m^2/year, with an average of 167 kWh/m^2/year and *stand. dev*. of 31 kWh/m^2/year. Figure 2 (a) depicts the overall average energy consumption of each residence hall in terms of kWh/m^2/year, and (b) outlines the average yearly residence hall consumption in kWh/square meter.

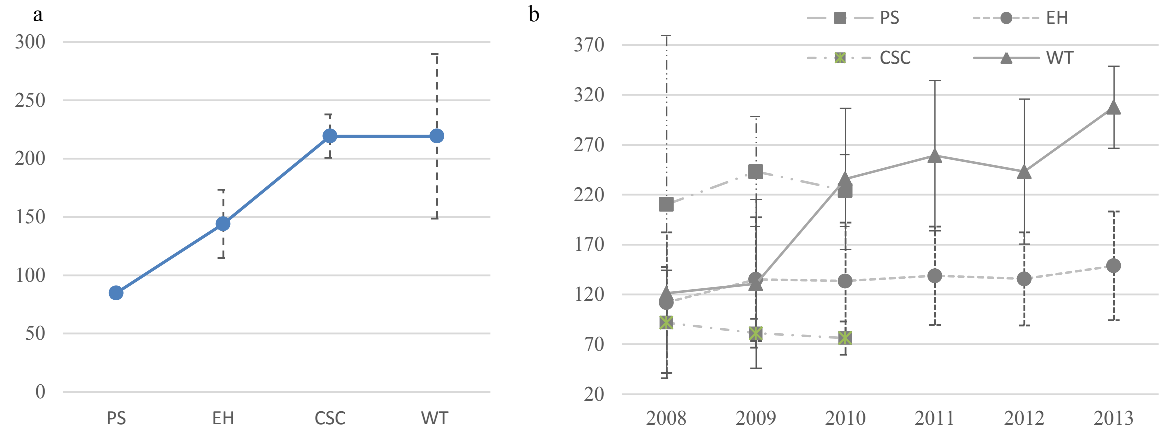

Figure 2-(a) overall average energy consumption and *stand. dev.* in kWh/m^2/year of LEED (PS, EH, CSC) and non-LEED (WT) and (b) average yearly energy consumption in kWh/m^2 of LEED and non-LEED residence halls.

The average energy consumption of LEED halls resulted in savings of 10% overall between yearly readings in the time data was collected (5 years). However, when compared to their LEED PDCs, average yearly savings were variable and unsteady. Typically facilities departments secure energy pricing based on their predictions of energy demand; therefore, stabilizing consumption is key to minimizing operating costs and attaining competitive energy pricing. To highlight if climate impacted the consumption patterns of the dataset, bivariate correlation analysis was carried out testing the relationship between month, REDTI[†] index and monthly energy consumption. The correlation results were weak and showed in the case of this dataset and specific building typology (HE residence halls), heated degree days did not aide in projecting energy consumption. Other variables such as student behaviour, and academic institution schedules may be the driving force behind consumption variations. Given the LEED dataset, did not employ any on-site renewable energy strategies, data for Indicator 4 could not be factored in. It must be noted even if these strategies are employed, they must have separate metering to allow for data collection on their individual contribution and consumption.

[†] National Oceanic and Atmospheric Administration's Residential Energy Demand Temperature Index (NOAA-REDTI)

3.1.3. Indicator 6, 7, & 8-indoor air temperature and relative humidity, occupant satisfaction, and ease of building control

Student feedback (n=593) indicated the area of concern was 'satisfaction with the level of control over changing indoor temperature'. Students prefer 'control' over 'parental control' by HE institutions. 58% indicated dissatisfaction with their ability to control their indoor temperature and 98% of their comments were negative on this parameter. Multivariable linear regression results showed: (1) students who were satisfied with their indoor temperature, were more likely to be satisfied with their level of control over changing their indoor temperature (thermostat controls), and (2) students who found temperature controls easy to use were more likely to be satisfied with the level of control over changing their indoor temperature than those who did not. The findings show that designers need to incorporate easier and more adaptive controls in their designs; and FM personnel need to provide more control to occupants.

In monitoring one LEED residence hall for a one month period (Nov. 2013-Dec. 2013), it was evident indoor T and RH conditions were below ASHRAE Standard 55 [37] acceptable levels. Majority of logged data representative of 63.12% of the time logged, fell under the 30% acceptable RH conditions and within the 1.0 clothing insulation zone. Figure 3 depicts the logged data on ASHRAE psychrometric acceptable indoor comfort charts for each week and for the period experiencing RH under 30%. The minimum recorded RH levels were 15.5% which may cause adverse health conditions such as respiratory and ocular illnesses [39]. Comparing logged data with student feedback (n=76), students complained indoor conditions were dry, cold, and offered poor ventilation (localized smog). In particular several students complained of nose bleeds, dry skin and eye irritations. The students' actual clothing insulation factor was 0.73 with a *stand. dev*. of 0.23, while the logged data fell in the 1.0 clothing zone of comfort per the temperature and relative humidity readings.

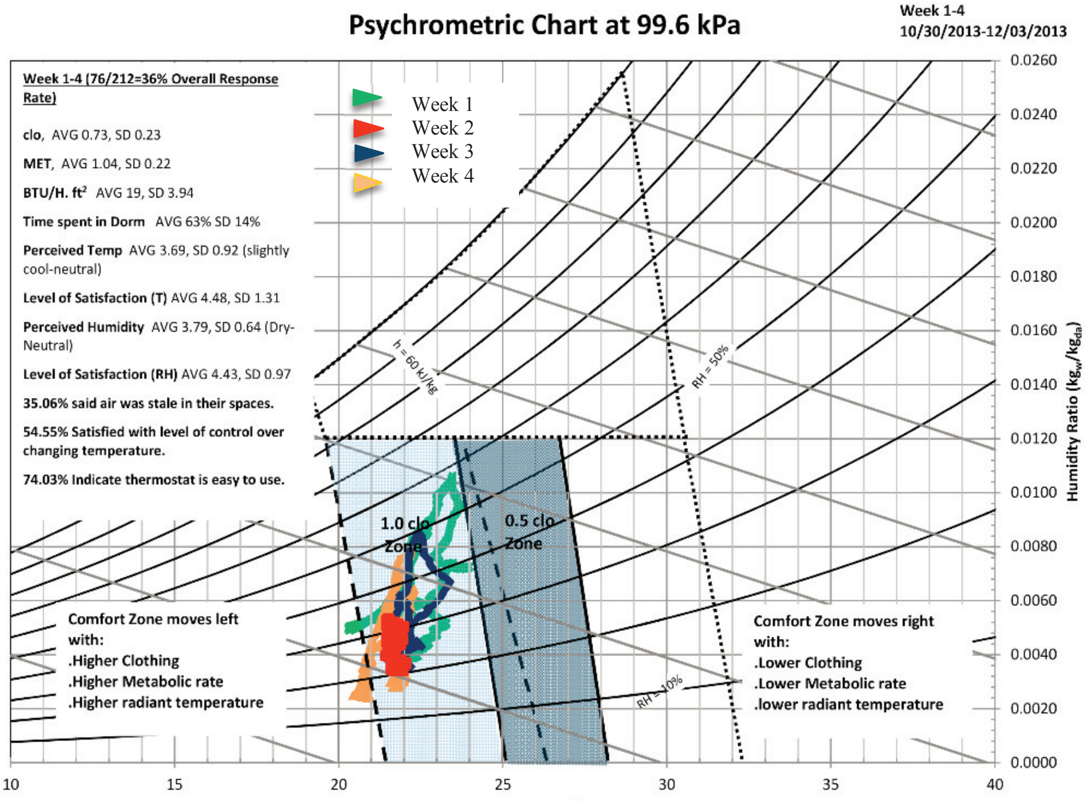

Figure 3- Results of indoor air temperature and relative humidity data plotted in psychrometric charts, indicating unacceptable indoor air conditions per ASHRAE standard 55.

3.1.4. Indicator 5, 9, & 11- building systems commissioning, routine preventative maintenance of HVAC systems and optimization of BACS, BEMS, AI

Feedback from four independent HE FM departments, indicated typically during the first year of operations, many adjustments are made to heating, ventilation and air conditioning (HVAC) and BACS systems. However on complex systems, FMs are hesitant to independently interfere due to the warranty related liability issues. Designers and manufacturers are solicited to remedy malfunctioning systems and in the interim systems run inefficiently and waste energy. A major concern of FM departments were about overtly complicated systems, and they stressed the need for simple equipment and systems. FM personnel indicated BACS, BEMS and AI systems, should be critically analysed for actual return on investment, as they do not perform as advertised. FM departments also indicated Artificial Intelligence (AI) systems were not installed in any of the residence halls, therefore no specific feedback on this parameter was collected. It must be noted in some cases, FM personnel preferred a lack of AI systems incorporation given the complexity in the operations and maintenance phases.

3.1.5. POE indicator 10-education efforts by HE owners to promote sustainable occupant behaviours

Only 36% of student occupant respondents indicated a presence of conservation awareness programs on campus and only 19% indicated participation in any such programs. The data showed no difference between LEED and non-LEED occupants, in terms of their cognizance on energy and water consumption. Based on the results it is clear an educational gap exists in all of the HE institutions surveyed. Based on the work of researchers educational efforts such as 'living lab' environments and awareness programs can motivate conservational behaviour and should be aggressively implemented to shift consumption cultures [36, 40].

3.1.6. POE indicator 12-indoor sound insulation

On average 18% of respondents commented on this parameter, of which 86% was negative feedback. Amongst some of their notable comments it was highlighted sound easily travels from the toilet, therefore increasing sound proofing would be welcomed to maintain privacy. Given student feedback on indoor sound insulation instead of outdoor sound insulation and infiltration, Indicator 12-indoor sound insulation, was added and monitored.

4. Conclusions

The lack of clarity on POE performance indicators for HE LEED residence halls has inhibited POE practices. However POE evaluations are key in improving the 'status quo', establishing 'best practices', 'lessons learned', and avoiding repeat design mistakes. Academic institutions are in a unique position to promote sustainability, as they have the ability and responsibility to change attitudes through education and awareness programs. Hence, it is critical HEs equip future generations with the knowledge required to promote sustainability in practice.

The most widely adopted sustainability rating systems of buildings focus on energy, water and indoor environmental quality measures but do not mandate occupant feedback. However, published research indicates a holistic approach should be taken in building performance evaluations. In order for sustainability goals to become a reality, feedback and daily practices of key participants (owners, designers, occupants, FM and residential life personnel) are critical. The results of this POE analysis showed that LEED labelling does not fully capture actual user behaviour. It is important to note technology alone does not guarantee savings, improvements in building performance need improved user attitudes and changes in occupant behaviours and institutional consumption cultures.

Given the challenges faced in POE adoption and the lack of occupant feedback solicitation; this research created a simple yet holistic POE framework to facilitate the performance evaluation process. The selected POE indicators and methods of data collection presented herein, included both quantitative and qualitative methods to allow for a truthful comparison of actual conditions within LEED residence halls and occupant interactions with the buildings. The triangulation of qualitative (feedback) and quantitative (actual consumption and design information) data through the inclusion of various participants provides different perspectives, which in aggregate paint a full picture of the performance of HE LEED residence halls. Data collected through the POE process can be further used to inform future design projects as well as improve current sustainability of residence halls.

References

[1] United States Department of Energy (US-DOE), Water, Buildings Energy Data Book, 2013, Chapter 8.
[2] The Princeton Review's Guide to 322 Green Colleges, 2012 Edition.
[3] United States Green Building Council (USGBC), LEED New Construction Design Guide, Version 3, 2009.
[4] W. Bordass, A. Leaman, F. Stevenson, Building evaluation: practice and principles, Building Research and Information, Vol. 38, Iss:5, 2010.
[5] W. Bordass, R. Cohen, J. Field, Energy Performance of Non-Domestic Buildings: Closing the Credibility Gap. Building Performance Congress, Frankfurt, 2004.
[6] W. Bordass, A. Leaman, P. Ruyssevelt, Assessing Building Performance in Use 5; Conclusions and Implications. Building Research and Information, Vol. 29, Iss:2, 2001, pp.144-157.
[7] A. Cicelsky, Y. Garb, D. Jiao, I. Meir, Post-occupancy evaluation: an inevitable step toward sustainability. Advances in Building Energy Research, Vol. 3, Iss:1, 2009, pp. 189-220.
[8] S. Turpin-Brooks, G. Viccars, The development of robust methods of post occupancy evaluation. Facilities, Vol. 24 Iss:5/6, 2006, pp.177-196.
[9] M. Riley, N. Kokkarinen, and M. Pitt, Assessing post occupancy evaluation in higher education facilities. Journal of Facilities Management, Vol. 8, Iss:3, 2010, pp. 202-213.
[10] C. Robson, Real World Research, Chichester, West Sussex, Wiley, 3rd Edition, 2011.
[11] United States Green Building Council (USGBC), LEED New Construction Design Guide, Version 3, 2009.
[12] BREEAM Rating System, 2008, Multi-Residential Scheme Document.
[13] CASBEE, 2010, Technical Manual for New Construction.
[14] Living Building Challenge (LBC), International Living Future Institute ILFI, 2012.
[15] Green Globes, 2012, New Construction criteria and Point Allocation.
[16] G. Augenbroe, C.S. Park, Quantification methods of technical building performance. Building Research & Information, Vol. 33, Iss:2, 2005, pp. 159-72.
[17] K.M. Fowler, A.E. Solana, K. Spees, Building Cost and Performance Metrics: Data Collection Protocol, Revision 1.1. Pacific Northwest National Laboratory, 2005, PNNL-15217.
[18] K. Gillespie, P. Haves, R. Hitchcock, J. Deringer, K. Kinney, Performance monitoring in commercial and institutional buildings. Heating/Piping/Air Conditioning Engineering: HPAC, Vol. 78, Iss:12, 2006, pp. 39-41, 43-44.
[19] J. Woods, Expanding the principles of performance to sustainable buildings. Real Estate Issues, Vol. 33, Iss:3, 2008, pp. 37-46.
[20] U. Berardi, Sustainability assessment in the construction sector: rating systems and rated buildings, Sustainable Development, vol. 20, n. 6, 2012 pp.411-424
[21] L.P. Warren, P. Taylor, A comparison of occupant comfort and satisfaction between a green building and a conventional building. Building and Environment, Vol. 43, Iss:11, 2008 pp. 1858-1870.
[22] J. Choi, V. Loftness, A. Aziz, Post-occupancy evaluation of 20 office buildings as basis for future IEQ standards and guidelines. Energy and Buildings, Vol. 46, 2012, pp. 167-175.
[23] E.H. Mathews, C.P. Botha, D.C. Arndt, A. Malan, HVAC control strategies to enhance comfort and minimize energy usage. Energy and Buildings, Vol. 33, Iss:8, 2001, pp. 853-63.
[24] T. Nguyen, M. Aiello, Energy intelligent buildings based on user activity: A survey. Energy and Buildings, Vol. 56, 2013, pp. 244-257
[25] C. Martani, D. Lee, P. Robinson, R. Britter, C. Ratti, ENERNET: Studying the dynamic relationship between building occupancy and energy consumption. Energy and Buildings, Vol. 47, 2012, pp. 584-591.
[26] L. Klein, J-Y Kwak, G. Kavulya, F. Jazizadeh, B. Becerik-Gerbe, P. Varakantha, M. Tambe, Coordinating occupant behavior for building energy and comfort management using multi-agent systems. Automation in construction, Vol. 22, 2012, pp. 525-536.
[27] A. GhaffarianHoseini, U. Berardi, N. Dahlan, A. GhaffarianHoseini, N. Makaremi, Essence of future smart houses: from embedding ict to adapting to sustainability principles, Renewable & Sustainable Energy Reviews, vol. 24, 2013, pp. 593-607.
[28] L. Zagreus, C. Huizenga, E. Arens, D. Lehrer, Listening to the occupants: A web-based indoor environmental quality survey. Indoor Air, Vol.14, 2004, pp. 65-74.
[29] T. Lützkendorf, D. Lorenz, Sustainable property investment: valuing sustainable buildings through property performance assessment. Building Research & Information Vol. 33, Iss:3, 2005, pp. 212-234.
[30] K. Steemers, G. Yun, Household energy consumption: a study of the role of occupants. Building Research & Information, Vol. 37, Iss:5/6, 2009, pp. 625-637.
[31] M. Deuble, R. de Dear, Mixed-mode buildings: A double standard in occupants' comfort expectations. Building and Environment, Vol. 54, 2012, pp. 53-60.
[32] O. Guerra-Santin, L. Itard, Occupants' behaviour: determinants and effects on residential heating consumption. Building Research & Information, Vol. 38, Iss:3, 2010, pp. 318-338.
[33] O.T. Masoso, The dark side of occupants' behavior on building energy use. Energy and Buildings, Vol. 42, Iss:2, 2010, pp. 173-177.

[34] Y. Zhun, A systematic procedure to study the influence of occupant behavior on building energy consumption. Energy and Buildings, Vol. 43, Iss:6, 2011 pp. 1409-1417.
[35] A. Zalejska-Jonsson, Evaluation of low-energy and conventional residential buildings from occupants' perspective. Building and Environment, Vol. 58, 2012, pp. 135-144.
[36] S. Sterling, ed., L. Maxey, ed., H. Luna, ed., The Sustainable University: Progress and prospects. London: Routledge Taylor & Francis, 2013.
[37] ASHRAE Standard 55-2013, Thermal Environmental Conditions for Human Occupancy, 2013.
[38] U. Berardi, N. Alborzfard, Water Consumption In Dormitories: Insights From A Survey In The United States. Book: Sustainable Water Use And Management (ed.Leal Filho and Vakur Sumer), Springer, 2015, ISBN 978-3-319-12393-6.
[39] D.P. Wyon, L. Fang, L. Lagercrantz, and P.O. Fanger, Experimental Determination of the Limiting Criteria for Human Exposure to Low Winter Humidity Indoors (RP-1160). HVAC&R Research, Vol. 12, Iss:2, 2006, pp. 201-213.
[40] D. Streimikiene, A. Volochovic, The impact of household behavioral changes on GHG emission reduction in Lithuania. Renewable and Sustainable Energy Reviews, Vol. 15, Iss:8, 2011, pp. 4118-4124.