Available online at www.sciencedirect.com
ScienceDirect
Procedia Engineering 85 (2014) 132 – 139
Procedia Engineering
www.elsevier.com/locate/procedia

Creative Construction Conference 2014, CC2014

Leadership in Energy and Environmental Design (LEED) and its impact on building operational expenditures

Jiří Dobiáš[a,*], Daniel Macek[b]

[ab]*Faculty of Civil Engineering, CTU in Prague, Thákurova 7, 166 29 Prague 6; Czech Republic*

Abstract

Ever-changing needs in the built environment create new incentives for enhancements in the process of building design. Increasing prices of building operations and utilities have a profound impact on the conceptual design and implementation of sustainable architecture. Green building certifications have been initially implemented as a tool for creating more sustainable buildings. However, the real impact of green certification systems on building operations remains unclear. This article focuses mainly on water and energy consumption assessment of LEED certified buildings and to what degree certification systems achieve cost savings in building operations when implemented during the design and construction process. The method of estimating these effects is based on hard costs and soft costs linked not only to the certification cost itself but also on the economic impact of the construction costs designated for achieving the required certification level. Furthermore, the building projects investigated, have been selected according to a specific paradigm in order to include buildings with a different type of operation. Each selected building has been holistically differentiated and assessed according to its performance in the following categories: water usage and energy efficiency. The aim of this paper is to objectively assess buildings that were certified under the LEED certification system and to determine the financial effectiveness of the invested resources in the construction process in relation to the operational and environmental benefits. Moreover, the research is focused on determining the operational costs at a point in time. Because of this, a relevant discount factor has been determined and applied for the life cycle assessment of each researched project. The outcome of this paper is an objective assessment of six LEED certified buildings based on water and energy consumption compared to a reference buildings.

Peer-review under responsibility of the Diamond Congress Kft.

Keywords: green building certification; LEED; LCC; operational expenditures; sustainability

* Corresponding author. Tel.: +420 725 770 167; fax: +420 224 354 521.
E-mail address: jiri.dobias@fsv.cvut.cz

1877-7058
Peer-review under responsibility of the Diamond Congress Kft.
doi:10.1016/j.proeng.2014.10.537

1. Introduction

The building industry is continuously facing economical, technological and social challenges. The recent financial crisis caused changes in overall perception of building projects' design and construction. Almost every stakeholder within the construction process is seeking to make savings and reduce costs. Building contractors are being forced to reduce their bidding cost in order to maintain their competiveness, whereas project owners are experiencing difficulties in renting their assets to tenants who are looking for buildings with low operational costs and rent.

However, the financial crisis is not just the only reason for inevitable changes in the traditional conception of property development (Yudelson, 2008). Other strong incentives for enhancing the process of building construction are linked with the operational costs such as utilities, cleaning, security and rent. The scarcity of natural resources is placing pressure on the cost of both utilities and construction. Furthermore, it can be predicted that there will not be any decrease to the cost of utilities in the near future (Zuo & Zhao, 2014). Buildings must become more energy independent and resilient in the surrounding environment, which is very sensitive to political, environmental or economical impulses (Macek, 2011). Building users are often more interested in the overall performance of the building and increasingly are asking questions such as; "How much do I have to pay for utilities? How effective will my employees be while working inside? How long will the building retain its value?"

There is strong pressure on the implementation of sustainable development or the development of green buildings within the built environment. However, there is no official definition of what constitutes a "green building". EPA (Suh, Tomar, Leighton & Kneifel, 2014) defines green building as: "*a practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from siting to design, construction, operation, maintenance, renovation and deconstruction. This practice expands and complements the classical building design concerns of economy, utility, durability, and comfort. Green building is also known as a sustainable or high performance building"*. The term "green building" places emphasis on creating sustainable buildings and does not give a concrete construction description (Tywoniak, 2012).

In order to more clearly measure and emphasize building performance in terms of sustainability and green building techniques it is necessary to investigate not only materials and energy performance, but also location, indoor environment quality, management process or innovation enhanced by the development process.

Complex assessment tools and certification systems are focusing on measuring buildings from different points of view in order to provide information about a buildings' performance in terms of their location, energy efficiency, usage of potable water, used materials and the quality of the indoor environment. A third party, who is delegated for supervising the assessment process, verifies the final measurements.

2. Certification Systems

Certification systems have become more popular for complex building assessment and promoting aspects of sustainability and green building all over the word. This article focuses on assessing six real buildings using the same certification system, in this case, LEED (Leadership in Energy and Environmental Design). Nevertheless, it is vital to also mention other main players within the green certification business (Cole & Valdebenito, 2013). Those are:

- BREEAM (Building Research Establishment Environmental Assessment Method). Founded in the United Kingdoms. Used mostly in Europe.
- DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen). Founded in Deutschland.
- LEED was founded in the United States and it has spread over the whole world.

3. Operational Expenditures of Certified Buildings

Certification systems claim that certified buildings are achieving lower operational expenditures and therefore are more attractive for tenants (Matisoff, Noonan, & Mazzolini, 2014). However, there is a significant difference between the various certification systems (some specifically relate to environment rather than energy efficiency) and there is even a substantial difference in certification levels of the same certification system. In order to investigate the impact of green certification on the building's operational performance there have been six LEED certified buildings chosen and assessed, each built in the Czech Republic. The following buildings have been chosen because of the same certification level (all building have achieved LEED Gold) and because of their structural, construction and type of usage variety.

4. Assessing Criteria

This research is focusing on the impact of the certification systems on operational costs and only a few key LEED chapters have major impact on the wallet of the building users. It is interesting to apply the Pareto principle (also known as the 80-20 rule) to the assessment criteria and confirm that only one criterion has the major effect on operational costs. It is not surprising that the one (20 % of all criteria) mentioned criterion is the Energy consumption (approximately 80 % portion from the operational costs). Nevertheless, because of increasing cost and scarcity of potable water, the research also focuses in detail on the usage of potable water as well.

4.1. Projects

Table 1 defines the projects investigated, all of which are located in the Czech Republic, Central Europe. Each project has used the LEED certification system.

Table 1. Projects details (Arcadis CZ, 2014).

Project Name	Building 1	Building 2	Building 3	Building 4	Building 5	Building 6
Gross Area (sf)	125,365	106,149	114,950	80,4261	207,923	233,318
Gross Area (m2)	11,600	9,800	10,600	74,700	19,300	21,600
Site (sf)	36,800	14,200	15,800	152,300	504,200	29,400
Type of operation	Office Restaurant	Office Retail	Office	Office Retail Restaurant	Industrial Manufacturing	Office Retail Restaurant
Number of building users	528	663	450	3,512	152	1,326
Days of Operation	253	286	286	259	353	253
CAPEX (EUR)	10,454,500	9,373,000	17,015,600	79,310,000	13,554,800	35,112,700
Certification System	LEED 2009 for Core and Shell	LEED 2009 for Core and Shell	LEED 2009 for Core and Shell	LEED 2009 for Core and Shell	LEED 2009 for NC	LEED 2009 for Core and Shell

4.2. Location

The site conditions and surrounding services of a project can have a profound impact upon the comfort of the building users, but they do not directly influence the operational expenditure. Furthermore, the certification systems influence the interaction of the project with the surrounding ecosystem and stress the need of reducing heat islands and implementing greenery within the project scope.

4.3. Water

The usage of potable water is very often overlooked, since the cost of potable water has always been minor when compared to the other expenditures and investing into the hard, water-saving cost measures is not cost effective. However, the cost of potable water in the Czech Republic has risen significantly since 1999, which is presented in Fig. 1.

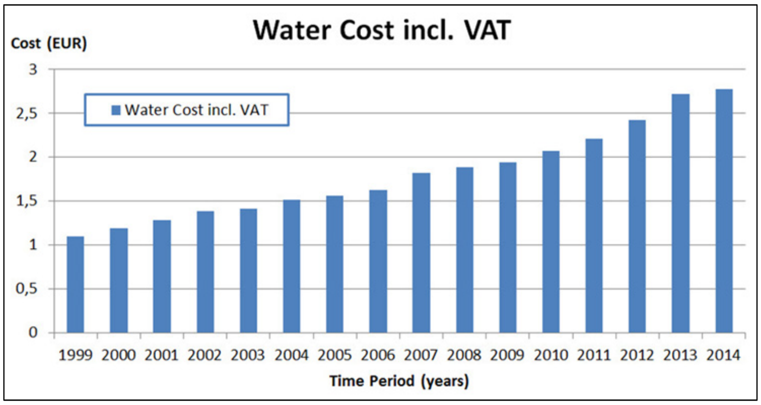

Fig. 1 Water Cost Trend in the Czech Republic (Prazske vodovody a kanalizace, 2014).

The chosen projects have been classified according to the water fixtures and fittings used and whether a rainwater collecting system is present in the building or not and how the retained rainwater is used. Subsequently, water usage for each building has been estimated based on number of building users, type of operation and type of lavatories, toilets, urinals (if present), kitchen sinks and showers used. The results are depicted in Table 2.

In order to identify reduction of potable water, the designed water appliances are compared to a baseline building. Baseline building for each building presents a reference building with the same type of operation, amount of building users and number of water fixtures and fittings, however the type of fittings is based on standard water flow rates and flushing volumes defined by the LEED standards.

Table 2. Water Usage for baselines and performance cases (Arcadis CZ, 2014).

Project Name	Building 1	Building 2	Building 3	Building 4	Building 5	Building 6
Rainwater Storage	YES	NO	YES	YES	YES	YES
Water Saving Fixtures	YES	YES	YES	YES	YES	YES
Rainwater Flushing	YES	NO	NO	YES	NO	YES
Total fixture water use annual volume, baseline case (kGal)	1,146	1,146	641	4,761	338	1,552
Total fixture water use annual volume, performance case (kGal)	640	683	355	2,025	156	752
Percent reduction of water use in all fixtures (%)	44	40	44	57	54	48
Irrigation saving (kGal)	0	0	10	0	0	0
Flushing saving (kGal)	43	0	0	659	0	160

The inputs from table 2 have been processed and the total water costs and savings have been estimated. Inflation was included and determined as 3.3%. The final cost savings are represented by the present value of the future expenditures over 25 years period. The discount rate of 5% reflects the present value of the future cash flows applied on the Czech market conditions.

The designed water appliances installed in all investigated buildings are water saving fixtures, which are defined as low flow fixtures with the following flow and flushing volumes:

- water closet with a dual flushing volume of 4.5 litres / 3 litres (full flush / small flush),
- urinal with flushing volume of 1 litre,
- lavatory with water flow of 2 liters/min or metering faucet,
- kitchen sink with water flow of 4 litres/min,
- shower with water flow of 8 liters/min.

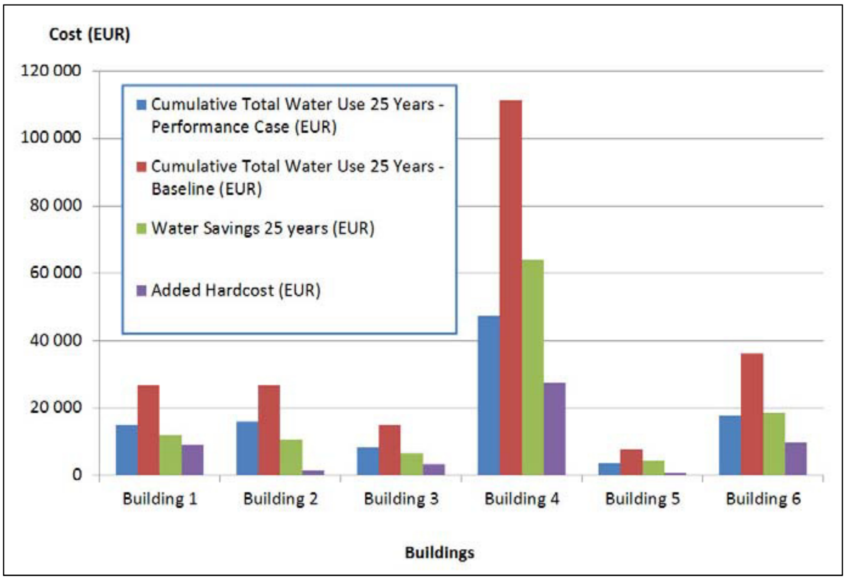

Fig. 2 Water Usage of the LEED certified buildings.

According to the results presented in Fig. 2, the certified buildings achieve significant savings due to implementation of low flow fixtures and fittings and due to the reuse of rainwater for flushing or irrigation of greenery. However, it is necessary to include the additional hard costs for procuring and installing the system and compare the water savings with the extra costs. The estimation proves that each building has achieved higher water savings after 25 years than the additional hard costs and therefore the certification system has positive impact of the building user cash flow. Furthermore, it is also essential to mention the contribution to reducing burden on public sewage systems and subsequent wastewater treatment, which is funded by a public sector.

4.4. Energy

It has been previously said that energy costs constitute a key and major portion of generated operational expenditures. This is mainly due to high-energy loads for heating, cooling and air conditioning (HVAC) (Pang, Wetter, Bhattacharya & Haves, 2012). LEED determines decrease in energy consumption as a mandatory requirement. To be more specific, it is necessary to prove, through building energy modeling, that the proposed case (building design including all HVAC and electrical equipment) demonstrates a 10% improvement in the building performance rating for new buildings (Scofield, 2013).

As per the mandatory requirement, an energy simulation has been completed for each building. The annual results are depicted in Table 3.

Table 3. Total Building Energy Cost Performance (Arcadis CZ, 2014).

Project Name	Building 1	Building 2	Building 3	Building 4	Building 5	Building 6
Process Electricity Cost - Baseline (EUR)	131,276	48,467	65,155	393,972	900,565	171,481
Electricity Cost - Baseline (EUR)	295,011	116,895	142,202	962,949	1,507,700	417,243
Natural Gas Cost - Baseline (EUR)	101,104	22,474	84,815	451,110	170,432	83,105
Electricity Cost - Proposed Case (EUR)	241,646	100,962	124,688	792,624	1,219,985	360,840
Natural Gas Cost - Proposed Case (EUR)	50,545	17,341	32,086	195,268	140,894	44,163
Energy Cost Savings (EUR)	103,924	21,065	70,243	426,167	317,253	95,344
Energy Cost Savings (%)	26	15	31	30	19	19

In order to accurately simulate the future building energetic performance, a dynamic energy simulation has been used for all six analyzed building. Dynamic simulation simulates the building operation in hourly intervals over the whole year. It is important to include all HVAC equipment, working schedules, building location, thermal insulation U-factors and lighting power density for each room in the building (O'Neill & Eisenhower, 2013). The simulation was performed by HAP (Hourly Analysis Program) software developed by Carrier, which is a company focusing on HVAC equipment manufacturing.

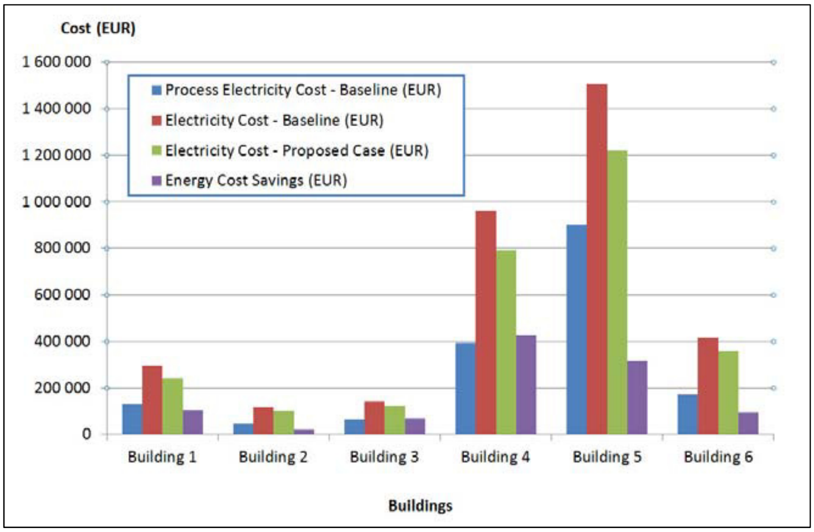

Fig. 3 Total Building Electricity Cost Performance.

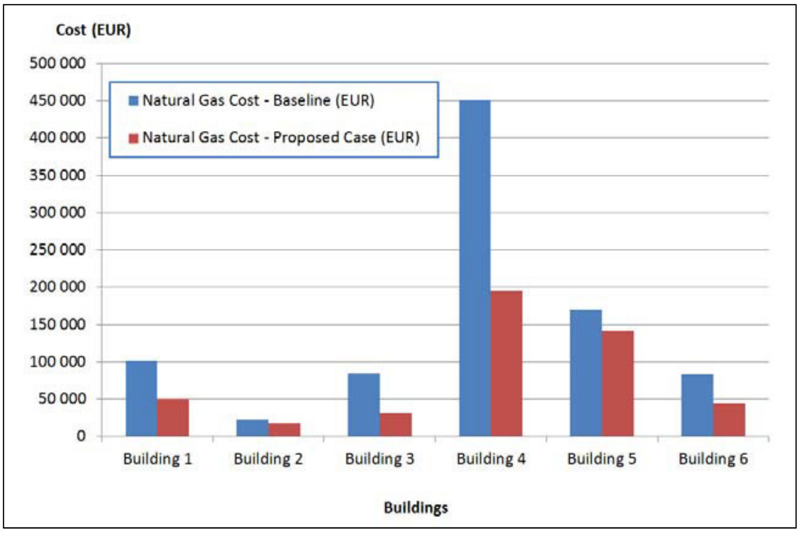

Fig. 4 Total Building Natural Gas Cost Performance.

Particular annual electricity and natural gas costs are more clearly shown in Fig. 3 and Fig. 4 respectively. Energy cost savings symbolizes percentage differences between the particular building and a traditionally designed reference building that is represented by ASHRAE standards and guidelines.

4.5. Indoor Environmental Quality

Proactive building designers and owners have realized that creating a healthy indoor environment contributes to the overall working effectiveness of the building users, and since the workforce presents the most significant expense for most companies, the provision of an effective indoor environment must not be underestimated (Schiavon, Hoyt, & Piccioli, 2014).

A healthy indoor environment is sustained by providing high quality fresh outdoor air, maintaining thermal comfort, using no added VOCs (Volatile Organic Compounds), measuring and verifying performance of all installed HVAC systems and providing building occupants with thermal and lighting user controls. Building operation is tightly linked with the indoor environmental quality, but is shown in the form of capital expenditures for required equipment rather than in operational expenditures itself.

5. Conclusion

Despite the advantages and disadvantages of the various green certification systems, it is crucial to realize that the complex building assessment is only a tool, and must be managed by experienced professionals with the experience and knowhow to implement it. Even a certified building, and thus labeled as a green building, is not required to achieve significant operational expenditures savings.

One of the most challenging obstacles during the green building certification is the lack of knowledge of building practitioners, coincidence or unexpected events that increase the risk of not achieving operational savings and reducing financial effectiveness of a particular building asset. Given that the green certification must deal with prediction of future cash flows and the life cycle cost analysis (LCC), it is vital to include the Black Swan theory that was hypothesized by Taleb (2007). The black swan is an unpredictable event that deviates from the common events based on human knowledge and experiences. Such an event has immense effects. Further, the black swan is even more important during implementation of the new certification process and techniques, where stereotypes or complete ignorance of the newly implemented systems can have serious consequences.

Nevertheless, the comparison of the chosen certified buildings has proved that LEED certified buildings achieve energy and water savings because of the LEED mandatory requirements. In order to certify a building by LEED, the building must achieve as a minimum, 10% reduction of energy cost savings and achieve 20% reduction of the potable water usage. Generally, projects aim for a higher certification score and as a result, must achieve more than the mandatory amount of points. Furthermore, building owners, who decided to have their buildings certified, are more willing to invest their resources for the LEED points that generate operational savings. Examples of this include more efficient air handling units, building façade with higher insulating characteristics (U-values) or technologically advanced cooling systems. Unfortunately, there are very few enlightened building owners who have realized this importance of the operational expenditures and most are not willing to risk the immediate financial effectiveness of the project by increasing the capital cost to allow for more efficient equipment etc.

All six LEED certified buildings researched, performed significantly better than the traditionally designed construction projects. Green certification enhances innovation and motivation for more energy and water efficient equipment. It is a driver for implementing at least a basic sustainable solution, in order to achieve the lowest certification level because of the mandatory certification provisions. Nevertheless, it has been said that green certification is just a tool and if not handled properly, will not deliver a real beneficial outcome.

Acknowledgement

This paper originated as a part of a Czech Technical University in Prague, Faculty of Civil Engineering research project SGS14/013/OHK1/1T/11.

References

[1] Arcadis CZ (2014). Green Buildings: Case Studies. Prague.

[2] Asdrubali, F., Buratti, C., Cotana, F., et al. (2013). Evaluation of Green Buildings' Overall Performance through in Situ Monitoring and Simulations. Energies*,6(12),* 6525-6547.

[3] Cole, R.J., & Valdebenito, M.J. (2013). The importation of building environmental certification systems: international usages of BREEAM and LEED. *Building Research, 41(6)*, 662-676.

[4] Macek, D. (2011). Renovation and Maitenance Planning for Buildings. *VI International Eurasian Symposium* (pp. 63-68). Ekaterinburg: Ural University Publisher.

[5] Matisoff, D.C., Noonan, DS., & Mazzolini, AM. (2014). Performance or Marketing Benefits? The Case of LEED Certification. *Environmental Science*, *48(3)*, 2001-2007.

[6] O'Neill, Z., & Eisenhower, B. (2013). Leveraging the analysis of parametric uncertainty for building energy model calibration. *Building Simulation, 6(4)*, 365-377.

[7] Pang, X., Wetter, M., Bhattacharya, P., & Haves, P. (2012). A framework for simulation-based real-time whole building performance assessment. *Building and Environment, 54*,100-108.

[8] Prazske vodovody a kanalizace (2014). Vyvoj vodneho a stocneho v Praze [online]. Available at: http://www.pvk.cz/vyvoj-vodneho-a-stocneho-v-praze.html

[9] Schiavon, S., Hoyt, T., & Piccioli, A. (2014). Web application for thermal comfort visualization and calculation according to ASHRAE Standard 55. *Building Simulation*, *7(4)*, 321-334.

[10] Scofield, J.H. (2013). Efficacy of LEED-certification in reducing energy consumption and greenhouse gas emission for large New York City office buildings. *Energy and Buildings, 67*, 517-524.

[11] Suh, S., Tomar, S., Leighton, M., & Kneifel, J. (2014). Environmental Performance of Green Building Code and Certification Systems. *Environmental Science, 48(5)*, 2551-2560.

[12] Taleb, N. (2007). The black swan: the impact of the highly improbable (1st ed). New York: Random House.

[13] Tywoniak, J. (2012). Nízkoenergetické domy 3: nulové, pasivní a další (1st ed). Prague: Grada.

[14] Yudelson, J. (2008). Marketing green building services: strategies for success. (1st ed). Amsterdam: Elsevier/Architectural Press.

[15] Zuo, J. & Zhao, Z., (2014). Green building research–current status and future agenda: A review. *Renewable and Sustainable Energy Reviews, 30,* 271-281.