Monitoring Green Buildings: A Case Study of Solutions in Experimental Buildings

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Abstract

Today's buildings are becoming more technologically complex, which has given us an even better possibility to monitor the buildings in-use performance. This paper studies what key performance indicators real estate developers choose to monitor as well as how they go about to collect the necessary data. In addition, it is also discussed how the information from the monitor systems are integrated in the day-to-day maintenance of the building. The paper has a case study approach, in which two commercial developments, with high ambitions regarding the environmental profile, have been chosen.

Keywords

Green Building, Measure Performance, Environmental Certification System, Monitoring, Building Performance, Case Study

Introduction

The majority of new commercial developments being constructed today in Sweden have a Green/Sustainable aspiration. Even though no uniform definition of which building attributes to regard, most of these developments concern issues such as energy efficiency, avoid hazardous materials and a good indoor comfort. In order to evaluate these parameters, different environmental assessment schemes have been developed and are now used worldwide. In Sweden, the most common schemes for assessing commercial buildings are BREEAM, LEED and Miljöbyggnad[1] (Denell and Bonde, 2015). However, these schemes mainly focus on the construction process, and less on operating/maintenance phase (O'Sullivan et al., 2004). Therefore, it would be interesting to look into how the green buildings actual performance is monitored over time, in order to uphold the performance during the buildings lifecycle. The importance of such measurable metrics for monitoring the buildings (environmental) performance is also emphasized by (Crawley and Aho, 1999). From a life cycle analysis approach, this is also interesting as the operation phase of the buildings lifespan has an impact on the hole building life cycle energy usage; even though the size of it depends on building usage, type of construction etc. (Liljenström et al., 2015; Ramesh et al., 2010).

What is striking is that buildings most often do not perform as well as projected in the design phase (Hitchcock, 2002). Both (Mary Ann Piette et al., 2001) and (O'Sullivan et al., 2004) argue that a better monitoring of suitable performance metrics could lessen this difference, as it could provide the operating staff with the feedback it needs. This information could then be used as decision basis to modify building information/retrofit the building, as illustrated by Fig. 1. Such a systematic working procedure, using a systematic building management scheme, could bring about a better indoor environment (Mary Ann Piette et al., 2001), as well as potential energy savings (Andrea Costa et al., 2013). (Wang et al., 2012) also accentuate advantages with monitoring building energy usage, as it gives a more accurate overlook of the building's energy usage.

[1] Miljöbyggnad is a Swedish environmental assessment scheme, which assesses the following parameters: *Energy, Indoor Environment* and *construction materials*.

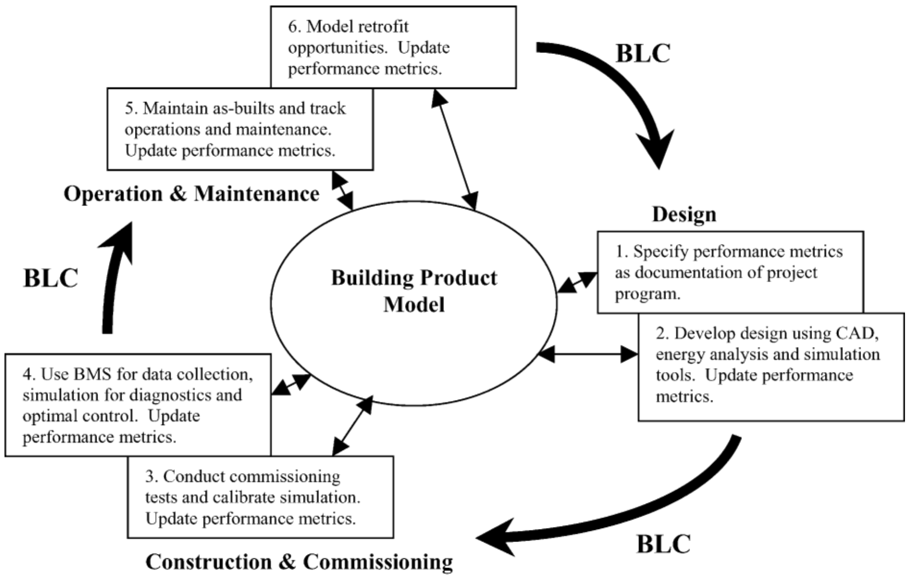

Fig. 1. Lifecycle performance metric tracking scenario. (O'Sullivan et al., 2004)

Purpose and Method

The main purpose of this study is to examine which building metrics Swedish developers focus on metering in newly constructed/undergoing green developments, and how they collect this information. In order to examine this, two newly constructed buildings and one projected developments was chosen, in corporation with Skanska. The cases, Uppsala Entré and Väla Gård, were chosen to represent the most resent green Skanska developments in Sweden. In accordance with (Stake, 1995) categorisation, the study has an *intrinsic* approach, as the main purpose is to describe and understand the cases studied. Using (Yin, 2009) classification, the study is categorised as a *single-case (embedded)* study, as different embedded units ("cases") are studied to in order to reveal information about the main research question (case).

The selected cases have been studied with different methods; interviews, participant observation and report/document review. The interviews were conducted in an unstructured format, in which the interviewer and the interviewee discussed the issues in a more casual manner (Kajornboon, 2005). Participant observation can be described as a combination of analysing documents, interviews and direct participation and observation, in which the researcher plays a more active role in the case.

This also gives the researcher the opportunity to observe the case “from the inside” (Flick, 2009; Yin, 2009).

Uppsala Entré

Uppsala Éntré[2], situated in central Uppsala, is a six floor building that was commissioned on the beginning of 2012. The rentable commercial area is approximately 12 500 square meters, consisting of office space, retail and cafés/restaurants. The building has a LEED (Core & Shell) Gold certificate, which is the second highest grade level in the LEED scheme.

In order to uphold the building performance over time, an extensive building monitoring system, consisting of 426 measuring points, was implemented. All data records are stored in a database which is managed by the developer Skanska. The system is not designed to alert if any measurement breach a threshold limit value, but instead to alert if the technical installations are malfunctioning. The data from the scheme is groundwork for the quarterly reports of the building performance, following the standard Energy Agreement 12 (Energiavtal 12), outlined by Sveby[3].

The energy metering is logged in different categories; electricity and heating/cooling. In order to separate the property energy[4] and operational energy[5] (in accordance with Swedish building code), several metering devices (EN-certified) have been placed throughout the building. As heating and cooling is provided via the district heating/cooling grid, the metering devises are supplied by the energy provider. In order to provide accurate data, both water temperature as well as the water flow has to be measured. These logs are then integrated into a software application which computes the transfer of heating/cooling for any given time.

[2] Real estate designation: FÅLHAGEN 70:1
[3] A cross sectional organisation with the purpose to standardise energy metering standards in the built environment
[4] Property energy – Energy for heating, cooling, hot water and electricity for building services necessary for the use of the building
[5] Operational energy – electricity used to operate computers, copiers, refrigerators/freezers, lighting etc.

The ventilation scheme recovers heat from the exhaust air to heat the supply air, using a heat exchanger. Metering devices are placed in the ducts to be able to monitor the air pressure. In addition; air humidity, air flow, CO_2-levels as well as air damper activity is recorded. The magnitude of the ventilation in the separate rooms is depending on the CO_2-levels, as this provides an appropriate estimator of the number of people present.

Water is registered through conventional water metering. However, as to separate the tenant usage from the remaining, multiple metering devices have been dispersed throughout the building. The metres, provided by the local water supplier, are EEG type approved. These are based on the EN1434 standard and revised by a third party accredited by SWEDAC (Swedish Board for Accreditation and Conformity Assessment) (Engström, 2014).

Väla Gård

This real estate consists of two separated two-story buildings, which have been connected via an annex in between. In all, the building consists of about 1 650 square meters (70 work stations). As for the technical installations, the building uses geothermal heating/cooling, solar cells to generate electricity and has a demand controlled ventilation scheme.

The building was commissioned in 2012, and had the ambition to be a net zero energy building, following the definition by (Sveriges Centrum för Nollenergihus, 2012). The criteria's is based on the work by (Sartori et al., 2012), which are summarized in Table 1. In addition, the building is certified LEED (New Construction) Platinum.

Criteria	Swedish definition
Physical boundary	In accordance to the Swedish building regulations. Hence, in general, the physical boundary is the building itself
Balance boundary	Energy used for heating, cooling and dehumidification, ventilation and humidification, hot water and permanently installed lighting of common spaces and utility rooms are included in the balance. Other services are not included in the balance (e.g. computers, copiers, TVs etc.)
Boundary conditions	Set point for heating (+21ºC) and internal heat gains is defined
Weighting system	Weighted energy is used, with static and symmetric weighting factors
Balancing period	1 year
Type of balance	Balance is calculated based on import/export
Energy efficiency	Fulfilment of Swedish Passive house criterion

Measurement and verification	To enable verification of the energy performance, energy metering must be separated into heat and electricity

Table 1: Summary of Swedish Net ZEB definition (Sartori et al., 2012)

The monitoring system consists of 300 measuring points, which was up and running in May 2013. The ventilation scheme is a Demand Controlled Ventilation system (DCV), which adjusts to motion (via presence sensors), air temperature and CO_2-levels. The DCV is interconnected with the ventilation decks, in which monitor instruments that measures air flows, duct pressure and air temperature are installed. In addition, the relative humidity (RH) is logged in the separate rooms.

To monitor the energy usage, 18 energy meters have been installed in the building. In accordance with Swedish building code, the property and operational energy is logged separately. The building uses geothermal energy to supply the building with heating and cooling, as well as to heat the tap water. The tap water consumption is, however, not actively monitored. As the building only has one tenant, there is no need to have more than the official water meter from the local water supplier.

All data is stored by the building's mainframe computer on an OPC[6] server, to be sent to a data base where it can be accessed and analyzed. Data from the DCV system (including ventilation engines) can also be accessed via a web based application. In order to minimize working hours, the real estate developer sought to implement a system which process and analyze the data into a weekly standardized report. These automated reports could then be complemented with a more thorough revision, produced manually with lesser intervals (Kempe, 2014).

Discussion and Outlook

Both these buildings present good cases for how monitoring of building performance can be outlined. Today, the technology is available to monitor (and assess) the majority of key building performance indicators, as to evaluate the building's sustainable features. The monitoring also makes it possible to more effectively fine-tune the building's installations in order to improve the building's energy performance and indoor environment. However, the interviews revealed that the

[6] OPC = OLE for Process Control

information from the monitoring is used a bit differently; while the maintenance staff at Väla Gård used it really fine-tune the building's installations, the operating staff at Uppsala Éntré mostly just checked that the building performed at an acceptable level (that is, in line with the agreement with the tenant).

Within the real estate sector today, there is no consensus in which performance indicators to assess and the interviewed real estate developers seemed to await a more standardized method to monitor the building performance. The lack of consensus could be due to the fact that the majority of environmental assessment schemes do not request any monitoring in their assessment criteria's. This is unfortunate, as it has been shown that a building's performance often underperform the intended performance levels. In addition, agreements where the developer has to provide reports on the completed building's ongoing performance is very seldom used, a least not in Sweden. What was also reveled in the interviews with the real estate developers is the confidence that the environmental certification process more or less ensure good building performance.

Earlier studies, for instance (Eichholtz et al., 2010; Fuerst and McAllister, 2011) indicate that sustainable building bring about an economic additional value, such as rent and sales price premiums. However, for these premiums to survive the test of time, the buildings have to show that the benefits of sustainability (lower energy usage, better indoor environment etc.) are constant and lasting over time. If these benefit's where to be uncertain, the tenants and real estate buyers will not be willing to pay any premiums.

Noteworthy in this study is that neither developer had decided to monitor the actual quality of the room air quality (with exception of CO_2-levels). This is probably due to that most ventilation systems do not have the capacity to monitor and log for instance particle levels, and therefore additional equipment would have to be used. However, form the authors' point of view this would be beneficial as to be able prove a good indoor air quality. What also been emphasized by (Anna Jarnehammar et al., 2015), is the monitoring of the building materials. As they deteriorate over time, they may cause unhealthy emissions in the future. However, in order to evaluate this monitoring devises would have to be built into the materials, a very complex procedure that would require a broad cooperation, involving real estate developers, construction entrepreneurs and suppliers.

Conclusion

This study is just a small step in reviewing how real estate developers monitor how the completed building is performing when constructed. It shows that today it is possible to monitor the large majority of building performance indicators. Nevertheless, for this to become everyday practice, this either has to be established in the major environmental schemes, national building code or as a part of the contract between the client and real estate developer/constructer. Even if no clear standard of what to monitor exist at present, three distinctive areas of concern can be observed; energy usage, the indoor environment (air temperature, CO_2-levels) and water consumption. This is a very good starting point from which to monitor, and assess, a sustainable building's as built performance.

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