Introduction to measurement and verification

EFFECT4buildings Toolbox:

Multi Service Contracting; Annex 6

The project “Effective Financing Tools for implementing Energy Efficiency in Buildings” (EFFECT4buildings) develops in collaboration with public building managers a comprehensive decision-making support toolbox with a set of financial instruments: **Financial calculation tools**; **Bundling**; **Funding**; **Convincing decision makers**; **Energy Performance Contract**; **Multi Service Contract**; **Green Lease Contract**; **Prosumerism**. The tools and instruments chosen by the project has the biggest potential to help building managers to overcome financial barriers, based on nearly 40 interviews with the target group. The project improves these tools through different real cases.

To make sure building managers invest in the best available solutions, more knowledge on different possibilities is needed as well as confirmation from colleagues that the solutions performs well. EFFECT4buildings mapped **technological solutions** for energy efficiency in buildings with the aim to share knowledge and experiences of energy efficiency solutions among building managers in the Baltic Sea Region.

This document is a part of the Multi Service Contracting (MSC) Toolbox and introduces methods for measurement and verification of performance. The guideline describes what measurement and verification is with relevant examples to illustrate the idea.

Partners

EFFECT4buildings project is implemented with the support from the EU funding Programme Interreg Baltic Sea Region (European Regional Development Fund) and Norwegian national funding. The aim of the project is to improve the capacity of public building managers in the Baltic Sea Region by providing them with a comprehensive decision-making support toolbox with a set of financial instruments to unlock the investments and lower the risks of implementing energy efficiency measures in buildings owned by public stakeholders. More information: http://www.effect4buildings.se/

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Introduction to measurement and verification of performance

Background

In the Multi Service Contract (MSC) model there is a focus on measurement and verification (M&V) of performance over time in a building in operation, not only to make sure that the expected performance from the energy efficiency project is met, but to ensure the best possible operation of the building.

This guide introduces what issues to consider when doing M&V and the importance of thinking in verification of performance from the starting point of the project. Focus from the beginning ensures that the necessary data, preconditions and systems to carry out M&V are in place, when the renovation project is handed over and operation begins. The M&V tasks also help align how to test and document the performance, how to train the operation personnel and how to maintain the obtained performance improvements. When keeping a focus on operation and performance both in the planning and implementation phases, the supplier is accountable for delivering solutions that meet the expectations.

Measurement and verification

Measurement and verification (M&V) cover the process of planning, measuring, collecting and analysing data for the purpose of verifying the performance of energy savings, indoor climate improvements, etc.

Different parameters demand different methods to verify the performance improvement. The performance improvement in forms of savings (energy, maintenance backlog, etc.) cannot always be directly measured since it represents the difference between the "before" situation and the "present" situation (when we evaluate the performance). Therefore, the improvement of performance is based on comparing the measured and mapped situations before and after implementation of the project, adjusting for changes in the conditions.

We use the term "*baseline"* to describe the performance situation before implementing any measures, *"performance goal*" to describe the objectives in the project and *"key performance indicator"* (KPI) to describe the expected performance of the measures and services. The term "*method of performance verification"* is used to describe how the verification is being done.

In table 1 below, examples of performance goals, methods of performance verification and KPIs are shown in relation to different services.

	Energy	Indoor climate	Maintenance	Operation
Example of performance goal	Energy saving with an average of max xx years Pay-back-time (PBT) CO_2 reduction xx% A more energy efficient operation	CO_2 in classrooms does not exceed limit values Temperatures in acceptable range and reduced complaints about drafts	Improved maintenance level to x with reduced backlog	A more energy efficient operation and improved response time to x
Example of method of performance verification	Energy monitoring with a performance budget in Energy Management System (EMS), monitoring of key factors with influence on EE in Building Management System (BMS)	Monitoring indoor measurements from sensors, yearly interviews, time registration	Follow up on condition level in FM system, calculation of reduction in maintenance backlog and budget for emergency maintenance	Alarms in BMS, monitoring in the helpdesk system, number of inquiries, plant failures and complaints from users, measurement of reaction time
Example of KPIs	Accepted limits for MWh, CO_2 emission, Flow, COP, SEL, number of alarms	Accepted limits for temperature, ppm, humidity, noise, sickness absence	Accepted limits for condition level, level of emergency maintenance, maintenance backlog	Accepted limits for number of complaints, alarms, reaction time, plant failures

Table 1 Examples of performance goals, KPIs and their corresponding methods for monitoring and evaluating performance

An important point about the M&V tasks is that the activities not only serve to follow up on performance, but properly integrated also serve to enhance and improve facility operation and maintain energy savings. The knowledge gained from M&V will only be valuable, if it is used to analyse, detect and solve the identified problems in obtaining performance. The M&V can also be used to find further improvements.

To ensure that the follow up is valuable, it is important that roles, responsibilities and procedures are in place from the beginning. Both in terms of who conduct the M&V task, and who reacts to identified discrepancies or problems with the performance.

How to set up key performance indicators

It is important to define KPIs based on the specific project. It must be clear that the requirements and acceptance criteria for e.g. indoor climate parameters and energy savings cannot be the same in an old and protected building as in a new building.

In most countries, there are building codes and standards which specify different classifications for buildings regarding indoor climate, the condition of maintenance and the energy performance (both for level of components and buildings).

As an example from Denmark, there is a standard on classification of the indoor climate called DS3033, with classification of the quality of the indoor climate in residential houses, schools, children's day-care facilities and offices.

In this standard the indoor climate is divided into five quality classes, where A^{++} is the best and C the lowest. The limits in the classes are based on the Danish building code, where A corresponds with the demands to a new building.

In the standard of classification, it is described in detail how to measure the various parameters to ensure a uniform way of measuring.

The nine parameters used in the classification are ventilation ratio, ppm, thermal condition, radon, formaldehyde, particles, moisture, daylight and artificial lighting and acoustic condition.

An example of limits on three parameters is shown in table 2. For the parameter ventilation rate. The chart shows that to obtain the classification A in schools, the ventilation rate must be 2,5 l/s m^2.

Table 2 A translation of a part of the Danish standard DS3303, showing an example of parameter limits for each classification

Parameters/values	A^{++}	A^{+}	A	B	C
Ventilation rate: (l/s m^2)					
- Schools	2,5 + DC[1]	2,5 + DC[1]	2,5	1,9	<1,9
- Children's day-care facilities	2,0 + DC[1]	2,0 + DC[1]	2,0	1,4	<1,4
- Kindergartens	1,5 + DC[1]	1,5 + DC[1]	1,5	1,0	<1,0
CO_2 (ppm)	800	1.000	1.200	1.500	>1.500
Radon (Bq/m^3)	100	100	100	200	>200

Each building owner must thus design their performance goals and key performance indicators. It is important to think of what information is available or can be collected, e.g. during phase 1 in the mapping, and what information is available in phase 3, operation. Here the building owner has to consider, if information/data necessary for verification and follow-up can automatically be collected and provided in a system, e.g. using an energy management system (EMS), a facility management system (FMS) (e.g. helpdesk where inquiries are logged), a building management system (BMS), etc. If the systems and programmes have to be purchased or need some configuration, these investments and tasks

[1] With a demand control system

have to be planned and executed as part of the work the MSC supplier has to do in phase 1 and phase 2.

The ambition level will be re-visited during the project when more knowledge is available in phase 1. Maybe it is unrealistic to have an average of a max pay-back time of 12 years, so this might have to be changed.

Performance verification in implementation

In projects with little doubt about the outcome or no need to follow up on performance in time of operation, applying a full M&V with a close evaluation and verification of performance might not be necessary. An example can be construction of new buildings, exclusively maintenance projects or uncomplicated buildings with few technical installations.

However, it is still wise to verify (initially and repeatedly) that the installed equipment meets the performance requirements in handover and doing the initial operation where the building is in use and the installation runs with load. The same is applied in the MSC concept – we still want to verify and hold the MSC supplier responsible for documentation for fulfilment of the performance requirements. The turnkey contract includes the proper contractual elements for the building owner to ensure the supplier will resolve defects from handover.

Verification of the performance during the project can involve inspection, commissioning of equipment, functional performance testing and/or data trending. To support the task and activities during planning and implementation, tool 7, "Introduction to performance verification during implementation"[2], introduces two methods which focus on performance verification in the implementation of the project – *performance test* and *commissioning*. Both methods can be used in traditional building and energy efficiency (EE) projects.

In MSC tool 8, "Performance operation test"[2], you will find an introduction, based on a case, of how the building owner can follow up in an easy way on the performance in the project after handover and before one-year inspection. The tool demonstrates the potential value of testing the performance of some (chosen) parameters over an operating period using simple data sets.

[2] to be found on www.effect4buildings.se

Overview of tasks related to M&V in the MSC model

This document has introduced the thinking of M&V to support achievement and maintenance of the performance goals in a project. As introduced, MSC continues to focus on following-up and verifying the performance in operation, not only to maintain the performance achieved, but also to optimise and find new improvements.

In table 3 some of the recommended tasks related to M&V in the MSC phases are summed up and can be of value, whatever methods are used to support the M&V process.

Table 3 Overview of recommended tasks related to measurement and verification in MSC phases.

Phase 0 – Start up	Phase 1 – Planning	Phase 2 – Implementation	Phase 3 – Operation
Decision on M&V process Point out responsible resources in the organisation Description of before situation Objectives the project must meet First version of requirements to KPI and methods of performance verification as a part of the procurement.	Revisit the project's purpose, objectives, KPIs and methods of performance verification Settle M&V organisation with clear responsibilities between the involved parties Baseline with precondition Key performance indicators with acceptance criteria for performance A plan for test and verification of performance in phase 2 A plan for test and verification (M&V) in phase 3, including necessary configuration of support systems A program for metering to be installed in phase 2	Revisit the project's purpose, objectives, KPIs and methods of performance verification Test and verification of performance requirements both in handover and one-year inspection Configuration of systems like BMS and EMS to support M&V Education	Revisit the project's purpose, objectives, KPIs and methods of performance verification Workshop to align M&V working procedures and organisation in operation Follow-up on performance as a part of daily operation according to agreed methods Act on deviance in performance Optimise and improve performance

Appendix – relevant links

For more information on M&V see:

- International performance M&V protocol (IPMVP). Includes both operational verification and an account of savings based on site energy measurements before and after implementation of a project. (IPMVP available for free at www.evo-world.org)
- M&V Guidelines: Measurement and Verification for Performance-Based Contracts https://www.energy.gov/sites/prod/files/2016/01/f28/mv_guide_4_0.pdf
- Guidebook for energy efficiency evaluation measurement methods: https://www.epa.gov/sites/production/files/2019-06/documents/guidebook_for_energy_efficiency_evaluation_measurement_verification.pdf

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