# Simplified measurement & verification + quality assurance instruments for energy, water and $CO_2$ savings. Methodologies and examples

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## 1. Abstract

Measurement & Verification (M&V) is a prerequisite to assess the quantitative outcomes of energy, water or $CO_2$ saving measures and to translate these into savings cash flows for energy efficiency financing and other purposes.

In practice M&V - if pursued at all in the case of in-house implementations – is often complicated by limited data availability or accuracy, a limited comparability between 'Baseline' and 'Reporting' periods or a lack of a clear M&V plan and having the resources to follow it up. If accomplished, understanding M&V reports requires expertise, which is not necessarily available with a facility owner. To make things worse, exercising M&V often is a rather boring topic - even within the professional energy community.

Furthermore, at least in many European countries, commonly acknowledges methods for M&V of energy, water or $CO_2$ savings are mostly based on utility meters and invoices – whereas in Anglo-Saxon influenced markets 'retrofit insulation techniques' for individual saving measures are accepted as good practice for the verification of energy savings cash flows (e.g. IPMVP Options A or B).

All of the aforementioned adds to the inherently complex nature of energy efficiency projects. And it often results in insecurity for energy managers, project developers, energy service providers (ESPs) and their (potential) ESP customers and financiers on verifiable future energy savings cash flows, which may lead to risk surcharges or no project implementation at all. Yet a full scale M&V plan is often not applicable or desired, due to its (perceived) complexity, lack of resources or its cost is prohibitive for smaller projects.

As a possible solution and often feasible compromise between no M&V at all and the effort and (perceived) accuracy of a full scale M&V approach, this paper proposes simplified M&V approaches for individual or groups of electricity, heat, water or $CO_2$ saving measures (ECM)

in combination with so called quality assurance instruments (QAI)[1]. QAIs shall verify the functionality and quality of ECMs, but not necessarily their exact quantitative outcome over an entire project cycle. In many cases the simplified M&V approaches proposed are combinations of savings calculations to determine savings cash flows backed up by QAIs.

We start with the key saving calculation basics and methods including formulae to than introduce the concept of QAIs to back up the quality of saving measures. Before the conclusions we provide examples both for electricity as well as thermal saving measures with a specific focus on industrial applications.

Methodologically, the paper is based on practical experiences with realized Integrated Energy-Contracting (IEC) projects, which apply simplified M&V in combination with QAIs for their saving measures [Bleyl_2011]. It is supplemented with expert inputs from IEA DSM Task 16 [Task 16 2013], the Energy-Contracting competence center of the German Energy Agency dena [dena 2013] and examples from colleagues in the field. And off course we draw on the „International Performance Measurement and Verification Protocol" [IPMVP_2012] and other literature sources.

## 2. Introduction

### Motivation

Measurement & Verification (M&V) is a prerequisite to assess the quantitative outcomes of energy, water or $CO_2$ saving measures. This applies both for 'in-house' (or 'do-it-yourself') implementation as well as through outsourcing to an energy service provider (ESP). Besides assessing physical savings, M&V is also the bases to translate savings into monetary units and to derive verifiable future energy savings cash flows for energy efficiency financing or other purposes.

In practice, M&V (if pursued at all, particularly in the case of in-house implementation) often encounters difficulties with the availability of relevant data or lack of a clear M&V plan and having the resources to follow it up. Furthermore, accuracy of savings estimations (which is what they really are, c.f. section 3.1) is almost always complicated by a lack of comparability between 'Baseline' and 'Reporting Periods', because utilization of the facility, energy prices or climate conditions deviate from one another. Or the savings may be small in relation to the overall consumption of the facility, which is observed at the utility meters.

Commonly acknowledges methods for M&V of energy or water savings are mostly based on utility meters and invoices - at least in many European countries, e.g. in established Energy-Contracting markets in Germany or Austria. This means that 'retrofit insulation techniques' for individual saving measures - as for example referred to in IPMVP as Options 'A' and 'B' - are either unknown or not accepted as good practice for the verification of energy savings cash flows.

All of the aforementioned adds to the anyway inherently complex nature of energy efficiency projects and may lead to insecurity for energy managers, project developers, ESPs and (potential) ESP customers. The same applies to other stakeholders like financiers with regard to verifiable future energy savings cash flows. As a result, this may entail additional efforts, risk surcharges or no project implementation at all.

A full scale M&V plan (which is still limited in accuracy for the reasons mentioned above) is often not suitable or desired, due to its (perceived) complexity, lack of resources or its cost are prohibitive for smaller projects. Sometimes M&V is driven by dedicated engineers, who thrive to be exact but loose sight of the overall business case. In any case understanding M&V

[1] QAIs have some similarity to the "operational verification" approach in IPMVP 2012 p. 9f

reports requires expertise, which is not necessarily available on the facility owner side. To make things worse, exercising M&V is a rather boring topic. At least for the majority of people - even within the professional energy community.

This leads us to the following research questions:

- What approaches are available to compromise between no M&V at all (as is common practice in many in-house implemented projects) and the (perceived) accuracy of a full scale M&V effort?
- How can efforts for M&V be reduced but a sufficient level of verification maintained?
- How can performance-based energy services be made better accessible for smaller projects through simplified M&V approaches?
- And last but not least: What is an understandable and sufficient level of M&V for a facility owners needs?

The goal of this paper is to shed light on these questions. More concretely we want to introduce the concept of simplified M&V methods, which can optionally be backed up by quality assurance instruments (QAIs). We believe, that through this approach, M&V can be made accessible for in-house implementation as well as for smaller performance-based ESP projects, where often no M&V at all is performed. Furthermore we also want to encourage the introduction of M&V methodologies for individual retrofit measures (as are IPMVP options A and B) to European and other energy savings markets, where they are not common practice yet and to put their applicability and added value up for discussion.

The intention is to foster discussion and application of simplified M&V options, where these can create and added value and open up additional M&V solutions; e.g. for access of smaller projects to performance-based energy services, for 'retrofit insulation' of individual energy savings measures or for applying some degree of M&V for in-house projects. It is not intended against the application of full-scale IPMVP-compliant M&V approaches, wherever these are suitable.

**Structure of this paper**

The paper is structured as follows: We start out with the basics on energy savings calculations and give an overview of simplified measurement and verification options. We continue to introduce quality assurance instruments for saving measures to be used in combination with the simplified M&V options. Before the conclusions we give practical examples for simplified M&V options in combination with QAIs both for electricity as well as thermal saving measures with a focus on industrial applications.

**Method of approach**

The paper is based on practical experiences collected in the framework of Integrated Energy-Contracting (IEC) projects realized in Austria, which apply simplified M&V in combination with QAIs for their saving measures [Bleyl_2011][2]. Secondly it relies on inputs from IEA DSM Task 16 experts [Task 16 2013][3], the ESCo competence centre of the German Energy Agency dena [dena 2013][4] and examples from colleagues in the field. Thirdly we draw on the „International Performance Measurement and Verification Protocol" [IPMVP_2012][5] and other literature sources. In order to facilitate an easier discussion, the terminology in this paper is aligned or referenced with IPMVP's terminology where sensible.

[2] Bleyl, Jan W. *Conservation First! The New Integrated Energy-Contracting Model to Combine Energy Efficiency and Renewable Supply in Large Buildings and Industry* in ECEEE Summer Studies, paper ID 1-485, Belambra Presqu'île de Giens, France June 2011

[3] www.ieadsm.org/ViewTask.aspx?ID=17&Task=16&Sort=0

[4] www.kompetenzzentrum-contracting.de

[5] [IPMVP_2012] Efficiency Valuation Organization (EVO) *International Performance Measurement and Verification Protocol (IPMVP)* January 2012 download available from http://www.evo-world.org/index.php

# 3. Measurement and verification of savings: Basics

## *3.1. Indirect appraisal only. Comparability and adjustment issues*

Energy, water, $CO_2$ or any other savings cannot be measured directly[6]; instead they are always calculated, more precisely **estimated** indirectly by establishing the difference between an ex ante reference[7] and an ex post reporting period (c.f. figure 1). The ex ante period is mostly referred to as 'Baseline period' (Base) or 'business-as-usual' scenario, whereas the actual data ex post ECM ('after implementation of saving measures') is mostly referred to as 'Reporting period' (RP). As [Lacey 2013][8] put it: "Measuring efficiency really means calculating savings – no matter how exact you try to be and to find the delta between what "is" and what "would have been"" without taking measures. As a consequence, a direct 'Negawatthour'-meter (Amory Lovins) still waits to be invented.

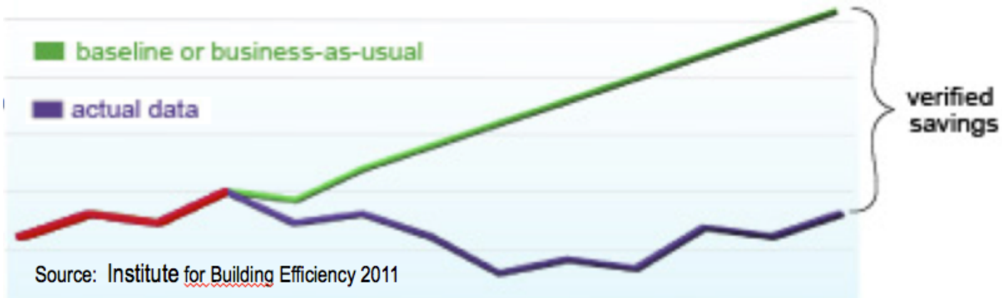


*Figure 2: Basic M&V concept: Indirect appraisal between Baseline and Reporting Periods*

A 'difference calculation method' presupposes that a valid comparison can be made between the two terms, that is the energy use (or demand) of the baseline and the reporting periods. This is a prerequisite in order to account for differences achieved through the saving measures only and to exclude differences due to alterations in external variables like energy prices, climate conditions or utilization of the facility or because of different accounting periods.

To achieve comparability in practice this requires adjustments to monitor the same accounting periods. Secondly, adjustments are made to compensate for differences in energy prices, climatic conditions and use of the facility. In the advanced EPC markets in Europe (e.g. Austria or Germany), adjustment of the RP to Base conditions[9] is prevailing (for more details on adjustment procedures see for example[10]).

In the IPMVP this need for adjustment to a comparable set of conditions is reflected in the introduction of an "Adjustment" term in the above general equation "to re-state the use or demand of the baseline and reporting periods under a common set of conditions".

## *3.2. What savings calculation methods are available: Overview*

The available methods for measurement and verification are shown in the following table.

The methods have been classified according to their area of application and assigned number codes (e.g. M I.1). Respective calculation formulae for each method are mentioned (e.g. F E-1a) and explained in more detail in Section 2.3.

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[6] Only in some cases is it possible to directly measure energy savings: e.g. with measurable feed-in technologies like demand-side distributed solar thermal, photovoltaic or combined heat & power units but also standard heat or cold supplies. These meter readings can reflect a direct measurement of energy saved (c.f. M II-5 in Table 1).
[7] Possibly also a ‚control group' could be used (provided comparability), but this option is not investigated here
[8] Lacey, Stephen *A Step Forward for Efficiency Project Standards: Next Up, Securitization?* in www.greentechmedia.com December 2013
[9] refered to as "Normalized Savings" in IPMVP. In principle comparability of Base and RP periods can also be achieved through adjustment to another pre-agreed set of conditions, e.g. the RP period or a set of other design parameters (c.f. IPMVP 2012, section 4.5.3 p. 14f).

**Table 1: Savings calculations: Overview of options** (for all energy carriers, water or $CO_2$)

*Abbreviations: M: Method, F: Formula*

*The notes in the right-hand column refer to the IPMVP [IPMVP_2012].*

| Scope of application | Calculation method (M) and Calculation formula (F - *see Section 3.3*) | Examples of use (*more examples in Section 5*) *Notes* |
|---|---|---|
| **I. Whole Facility** (or site sections with their own utility/supplier meters) | M I-**1** Savings calculated from **suppliers invoices** (or **meter readings**) before and after saving measures (= retrofit) (⇨ F E-1, P-1) | Standard EPC method in Europe (not detailed here; c.f. e.g. [10]) *Corresponds to IPMVP Option C* |
| | M I-**2** Savings **computer simulation** before and after retrofit | *Corresponds to IPMVP Option D* |
| **II. Individual, isolated measures** (or sections/ systems) that can be metered or calculated separately | M II-**1** Savings calculated from **sub-meter** before and after retrofit (⇨ F E-1, P-1) | E.g. submitters for the boiler room or air conditioning system … *Corresponds to IPMVP Option B* |
| | M II-**2** Savings calculated from **measurements of all key parameters** (⇨ F E-1a, b) | E.g. metering of power savings and operating hours of ventilation system *Corresponds to IPMVP Option B* |
| | M II-**3** Saving calculated from **measurement**(s) in combination with **computational factors**[11]: | E.g.: Replacement of lights, fans … *Corresponds to IPMVP Option A* |
| | M II-**3a** Measured power demand before and after retrofit × calculated operation times (⇨ F E-1a) | |
| | M II-**3b** Measured power demand × calculated operation times before retrofit; sub-meter after retrofit (⇨ F E-1b) | |
| | M II-**3c** Measurement of proxy parameters correlated with energy use or demand (⇨ F E-1) | e.g. output signal of rpm controller (c.f. IPMVP 2012) |
| | M II-**4** Savings calculated from **computational verifications**11 | E.g. lighting retrofits, heating curve adjustments, simulation programmes (e.g. from pump manufacturers) … *Not covered or compliant with IPMVP ('lack of measurement')* |
| | M II-**4a** Power ratings before + after retrofit (from data sheets/ literature) × estimated operating times (⇨ F E-1.a) | |
| | M II-**4b** Baseline × %-savings rate[12] (⇨ F E-2) | |
| | M II-**4c** Baseline × % Baseline × %-savings rate (⇨ F E-2a) | |
| | M II-**4d** Calculated difference before and after retrofit using recognized calculation methods (⇨ F E-1 … E-2) | e.g. Building energy performance certificates before and after retrofit |
| | M II-**4e** Computer simulation (⇨ F E-1) | |
| | M II-**5** Savings calculated from **feed-in sub-meter** (electricity, heat or cold) after retrofit (⇨ F E-3, P-2) | For on-site generation e.g. solar or CHP systems, heat recovery … c.f[6] |

Besides the choice of calculation method also the verification intervals need to be defined, e.g. whether the M&V is done on a once-off basis (resulting in a flat rate without subsequent testing of the results of the ECM) or repeated on a periodic basis (e.g. annually).

To ensure proper implementation and effectiveness of the energy saving measures, especially the simplified verification of individual measures, we propose to define additional quality assurance instruments (QAI) (more details on QAIs in combination with M&V in Section 4).

### 3.3. Calculation formulae

The standard **indirect** calculation of energy, water or $CO_2$ savings explained in section 3.1 is done using the following basic equation (c.f. formulae F E-1 and F P-1):

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[10] [dena 2008] dena *Leitfaden Energiespar-Contracting* Berlin, February 2008 or [IPMVP_2012]

[11] Computational factors and parameters can be taken from engineering calculations, estimates, standards (e.g. DIN V 18599), manufacturer's information, literature or historical data.

[12] [DIN V 18599] refers to savings rates as „reduction values“: *Energy efficiency of buildings - Calculation of the net, final and primary energy demand for heating, cooling, ventilation, domestic hot water and lighting*

**Savings** = '**Baseline period**' (= reference period) – '**Reporting period**$^{*}$ use (or demand)

Prior to calculating savings, the uses (or demands) of the two periods must be adjusted to a comparable set of conditions (c.f. section 3.1). In the following equations, adjusted RP values are labelled with a "*".

To calculate savings in practice, the following formulae can be derived:

**- Power savings** (applies to grid-bound energy carriers only):

$$\Delta P_{RP} = P_{Base} - P^{*}_{RP} \quad \text{(F P-1)}$$

1) Measured power feed-in:

$$\Delta P_{RP} = P^{*}_{RP\_Feed\text{-}in} \quad \text{(F P-2)}$$

*Legend:*

- $\Delta P_{RP}$: Power savings in 'Reporting' period (RP)
- $P_{Base}$: Power demand in 'Baseline' period (Base)
- $P^{*}_{RP}$: Power demand in 'Reporting' period, adjusted to 'Baseline' conditions
- $P^{*}_{RP\_Feed\text{-}in}$: Power feed-in in 'Reporting' period, adjusted to 'Baseline' conditions

**- Energy, water or $CO_2$ savings** (subsequently with 'energy' as collective term for all three):

$$\Delta E_{RP} = E_{Base} - E^{*}_{RP} \quad \text{(F E-1)}$$

*With the following variants:*

1a) Power demand × operating times (before and after retrofit):

$$\Delta E_{RP} = P_{Base} \times t_{Base} - P^{*}_{RP} \times t^{*}_{RP} \quad \text{(F E-1a)}$$

1b) Power demand × operating times before, metered after retrofit:

$$\Delta E_{RP} = P_{Base} \times t_{Base} - E^{*}_{RP} \quad \text{(F E-1b)}$$

2) Baseline × %-savings rate:

$$\Delta E_{RP} = E_{Base} \times \%_{Saved} \quad \text{(F E-2)}$$

2a) Relevant baseline fraction × %-savings rate:

$$\Delta E_{RP} = E_{Base} \times \%\, E_{Base} \times \%_{Saved} \quad \text{(F E-2a)}$$

3) Measured energy feed-in[13]:

$$\Delta E_{RP} = E_{RP\_Feed\text{-}in} \quad \text{(F E-3)}$$

*Legend (additional to previous only):*

- $\Delta E_{RP}$: Energy savings in 'Reporting' period
- $E_{Base}$: Energy use in 'Baseline' period
- $E^{*}_{RP}$: Energy use in 'Reporting' period (adjusted)
- $t_{Base}$: Operating time (full load hours) in 'Baseline' period
- $t^{*}_{RP}$: Operating time (full load hours) in 'Reporting' period (adjusted)
- $\%_{Saved}$: Savings rate in [%]
- $\%\, E_{Base}$: Share of baseline related to the energy-saving measure [%]
- $E^{*}_{RP\_Feed\text{-}in}$: Energy feed-in in 'Reporting' period, adjusted to 'Baseline' conditions

The above variants should cover a significant number of applications but is off course open to amendments.

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[13] Can be applied for distributed generation from CHP or solar systems as well as heat recovery systems equipped with electricity and heat meters

## 4. Quality Assurance Instruments (QAI)

The concept of QAIs is to assure the functionality and quality of a particular saving measure. Their role is to verify that a specific saving measure has been implemented correctly and that it is performing according to specifications. Then again QAIs cannot determine the exact quantitative outcome of an ECM, which is typically subject to a number of external and dynamic parameters like utilization of the facility or climate conditions, which may change over the course of the project cycle.

For simplified M&V approaches we propose to use (simplified) savings calculations to determine savings cash flows and to back these up with QAIs as a ‘safeguarding mechanism’. The concept is applicable for saving measurements as well, off course. For each ECM individual QAIs shall be devised. Here are two examples to illustrate saving calculations in combination with QAIs:

1. The savings of a thermal insulation measure are quantified through a heat-demand calculation before and after the measure. The implementation quality is verified using a blower-door-test and a thermographic analysis of the building after the retrofit.
2. For a street or indoor re-lighting project, the power demand by the system is measured in short once-off tests before and after the retrofit to verify the power savings. If the reduction in power demand is multiplied by previously measured or deemed operating hours, a figure for the energy savings over time can be calculated, and factored into a flat-rate remuneration. Additionally compliance with the illuminance specifications is measured.

More such combinations of (simplified) M&V calculations and QAIs are listed in Section 5.

The concept of QAIs to back up saving measure qualities is also applied in the ‘Integrated Energy-Contracting’[2] business model as illustrated in the figure below.

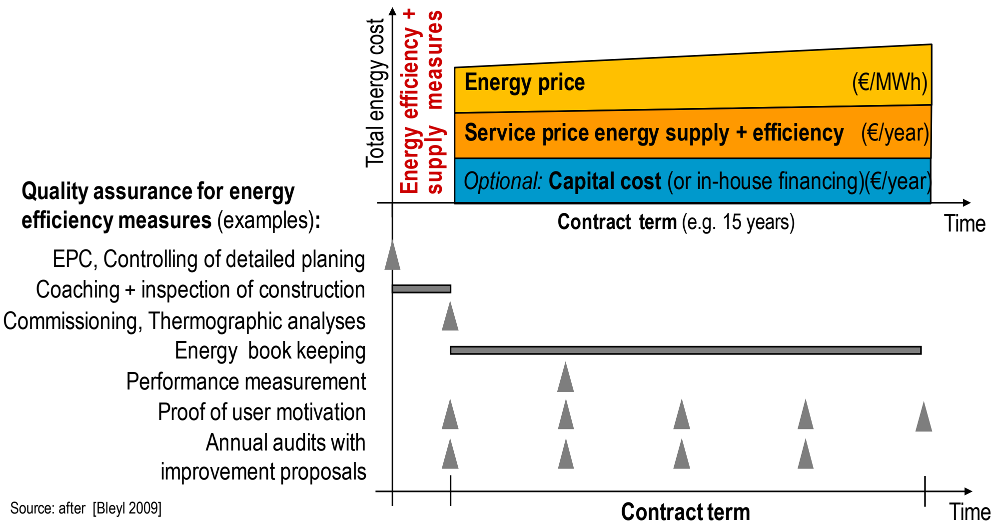


*Figure 2: IEC business model and sample QAIs to back up saving measure quality*

As can be seen in Figure 2, the once-off QAIs (e.g. on commissioning of the energy-efficiency measures) can be supplemented by periodic or on-going QAIs. The function of the latter is to maintain performance levels throughout the project cycle.

An important issue is to devise individual and practicable QAIs. The selection of QAIs as well as their exact design will depend on the specific requirements of the project scope and the parties involved. QAIs can either be specified in-house by a facility manager, by an ESP client or by an ESP (as part of the competition of solutions during the procurement process or the detailed project design). A number of possible QAIs are outlined in the following two subsections.

### *4.1. QAIs performed by facility owners (examples)*

Possible QAIs for individual energy-efficiency measures (which can be provided by the client or by third parties on behalf of the client) include:

1. (Functional) specifications to communicate and document energy-related objectives and requirements (e.g. quality standards, maximum energy indicators, request of renewable energy sources with proof of origin etc.);
2. Support of detailed planning by an (independent) energy consultant;
3. Third-party construction supervision by an (independent) energy consultant;
4. Commissioning ("acceptance") after the construction phase in order to verify compliance with functional specifications, involving e.g. thermography, blower-door tests, proof of function etc.;
5. Energy book-keeping – comparison of target and actual values (could also be provided by the ESP);
6. Survey by an (independent) energy consultant (2nd opinion report);
7. Building certification (like EPBD or Green Building; could also be provided by the ESP).

This list and the following list are intended as a basis for discussion, and do not claim to be complete.

### *4.2. QAIs performed by ESPs or in-house experts (examples)*

Examples of QAIs for energy-efficiency measures that can be provided by the ESP are:

1. Reports: detailed analysis (Detailed project reports (DPR), Investment-grade audits (IGA) etc.) of the planned measures as a verification of a preliminary analysis;
2. Proof of function: e.g. through commissioning, parameter and operating records etc.;
3. Once-off verifications, e.g. performance tests and measurements, thermographic analysis, blower-door tests, commissioning records etc.;
4. Periodic verifications, e.g. proof of user motivation, efficiency measurements, control of emission values, return temperature limitations, compliance with heating curves, parameter and operating records etc.;
5. Obligatory annual reporting (auditing): energy balances, comparison of target and actual values or benchmarks, suggestions for saving measures etc.;
6. Computational savings verifications, e.g. nominal power savings times operating hours;
7. Maintenance records, visual inspections etc.;

In the case of an external ESP, the fact that an ESP takes on technical and economic risks of construction and operation of the measures at its own expense (for the scope of services defined in the contract) for the duration of the contract period and therefore has a strong interest in ensuring that they are well implemented, is backing up the above quality assurance measures.

IPMVP takes a somewhat comparable approach and refers to it as "verification of the potential to achieve savings". After the 'Reporting' period 'operational verification' is recommended to "support energy savings persistence". The "Operational Verification" section in IPMVP (chapter 4.4) lists approaches like "visual inspection", "sample spot measurements", "short-term performance testing" or "data trending and control-logic review". However operational verification is formally not considered a part of the M&V process but "it reduces the risk of adverse shifts in performance associated with ECMs that can fail, fade or be bypassed".

# 5. Examples of simplified measurement and calculation methods combined with QAIs

In this section we have gathered simplified M&V examples in combination with QSIs for electricity, heat or $CO_2$ savings to illustrate and learn from good practice in different, predominantly industrial applications in the field. The case study examples are followed by two tables with electricity and heat saving M&V examples. For all examples, the M&V methodologies applied are referenced with the methodologies and formulae introduced in sections 3.2 and 3.3.

## *5.1. Industrial case studies*

**Opel, Vienna: Optimization of compressed air and heat supply in powertrain manufacturing**[14]

Opel Vienna GmbH (formally General Motors Powertrain Austria) is GM's largest powertrain manufacturing site with an annual production of about 1.5 million motors units. In 2012, Opel Vienna GmbH was ISO 50001 certified.

In 2011 and 2013 Opel implemented saving measures to reduce compressed air and heat energy demand: Amongst others, two new screw-type compressors, one of them equipped with a variable speed drive to better match demand and supply and thus to reduce no-load losses of the entire multiple compressor system were installed. To allow for a feed-in installation of the heat recovered from three compressors, the temperature level of the facilities heat supply system had to be reduced to 85°C, which required some unforeseen additional efforts.

Besides Opel's own interest to verify savings internally, e.g. for reporting towards the company's management, M&V is also a mandatory requirement by Kommunalkredit Public Consulting (KPC), the Austrian agency in charge of a national subsidy program for EE-measures, which supported the consultant's recommendation for M&V implementation.

M&V is based on an isolated measure option (c.f. M II-1, which corresponds to IPMVP option B): Compressed air electricity demand and $m^3$-output quantities were sub-metered before and after the retrofit. To control sustainability of savings, continuous meter logging and ISO 50001 energy surveillance processes of specific energy use (in $kWh/m^3$) with built-in threshold values serve as quality assurance instruments (QSIs). As a result verified savings of 4% of the annual compressed air energy cost baseline at EUR 825,000 (equivalent to about 100,000,000 $m^3$ at a pressure level between 5.6 and 5.9 bar) were reported.

Heat savings amount to 2 GWh/a or 140,000 EUR/a, which represents 33% of the baseline demand supplied by district heat and were verified by a heat meter installed with the heat recovery system (c.f. M II-5). QSIs are analogous to the compressed air example above. The total savings investment was at 550,000 EUR with a payback time of 3.2 years. An additional beneficiary was the district heat supplier "Fernwärme Wien", who could lay off a boiler needed just for the supply of higher temperature level in Opel's heat supply network.

**Switzerland: M&V for $CO_2$ compensation projects**[15]

In Switzerland importers of transport fuel and operators of fossil-thermal power plants are

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[14] Source: Sattler, P. 2014. http://www.klimaaktiv.at/dms/klimaaktiv/presse/eebetriebe2013/PP-Opel-Wien-GmbH-2013-final/PP%20Opel%20Wien%20GmbH%202013%20final.pdf. Download February 7th 2014

[15] Source: Bareit, M. 2014 www.bafu.admin.ch/publikationen/publikation/01724/index.html?lang=de&download=NHzLpZig7t,lnp6I0NTU042l2Z6ln1acy4Zn4Z2qZpnO2Yuq2Z6gpJCHdXx8fGym162dpYbUzd,Gpd6emK2Oz9aGodetmqaN19XI2IdvoaCVZ,s-.pdf Download February 7th 2014

legally required to compensate their $CO_2$ emissions, e.g. by generating $CO_2$ certificates through conducting specific $CO_2$ compensation projects.

The general calculation formula for the ‘expected’ $CO_2$ savings is as follows:

$ER_{total}$ = $E_{RE} – E_P$ – Leakage (c.f. M I-1)

*Legend:*

$ER_{total}$ : expected emissions savings

$E_{RE}$ : expected emissions of the reference development *(equivalent to “$E_{Base}$“)*

$E_P$ : expected emissions of project *(equivalent to “$E_{RP}$“)*

Leakage secondary emissions, which occur because of the project

The expected reference emissions $E_{RE}$ during the project phase $t$ are calculated as follows:

$E_{RE}$ = $A_{RE}$ x t x EF

*Legend:*

$E_{RE}$ : annual emissions of reference [in t $CO_{2eq}$]

$A_{RE}$ : output per year [e.g. in MWh/a]

EF: specific emission factor
[in t $CO_{2eq}$ per output, e.g. t $CO_{2eq}$/MWh]

t: project period

The expected project emissions $E_P$ during the project phase $t$ are:

$E_P$ = $A_p$ x t x EF

*Legend:*

$E_P$ : expected annual emissions of project [in t $CO_{2eq}$]

$A_p$ : expected output in project period per year [e.g. in MWh/a]

In terms of quality assurance, the project plan needs to be validated and accepted by the responsible federal offices prior to project implementation. During the project phase the actual output quantities $A_P$ have to be monitored and reported annually (also a proof of economic additionality is required). These reports have to be verified by an independent authority at least every 3 years (which also needs to confirm additionality).

The following tables give an overview of further simplified M&V examples for typical individual energy saving measures, divided into methods for electricity and thermal energy.

### *5.2. Electricity-saving measures*

The following table gives an overview of M&V approaches in combination with QAIs for individual electricity saving measures.

**Table 2: Examples of simplified M&V approaches for electricity-saving measures**

| # | Electricity saving measure | **Verification method** (see Section 3.2) and **calculation examples** | **Quality assurance,** ***Comments*** |
|---|---|---|---|
| 2.1 | **Lighting retrofit** | **Measurement of power demand of lights combined with computational factors** + QAI (⇨ M II-3a)<br>*$\Delta E_{RP} = (P_{Base} – P^*_{RP}) \times t^*_{RP} \times$ Number of lights*<br>- Measure demand of three representative lights before and after replacement => average per light<br>- Estimate 1,800 hours of operation per year | QAI: Lux measurement before and after replacement + proof of replacement of all lights + annual audit<br>*Alternative: manufacturer data for power demand (⇨ M II-4a)* |

| # | Electricity saving measure | **Verification method** (see Section 3.2) and **calculation examples** | **Quality assurance,** ***Comments*** |
|---|---|---|---|
| 2.2 | **Equip fan with variable-frequency drive** | **Measurement of electricity demand combined with computational parameter** + QAI (⇨ M II-3b)<br>$\Delta E_{RP} = P_{Base} \times t_{Base} - E^*_{RP}$<br>- Representative measurement before replacement<br>- 1,500 full load hours (based on operating records)<br>- New sub-meter for fan | QAI: Visual inspection + operational verification of equipment |
| 2.3 | **Pump optimization in boiler room** | **Metered difference in electricity use** + QAI (⇨ M II-1)<br>$\Delta E_{RP} = E_{Base} - E_{RP}$<br>- Measurement of $E_{Base}$ and $E_{RP}$ from sub-meter | QAI: Annual audit with functional tests |
| 2.4 | **Replacement of pumps in boiler room and other substations** | **Difference calculation by simulation** + QAI (⇨ M II-4e)<br>$\Delta E_{RP} = E_{Base} - E_{RP}$<br>- Calculation of $E_{Base}$ and $E_{RP}$ for all pumps using a suitable simulation program from pump manufacturer. | QAI: Inspection of pump settings (annually together with walk through audit) |
| 2.5 | **Lighting with movement sensors and daylight adaptation** | **Calculation of difference using recognized calculation method** + QAI (⇨ M II-4d)<br>- Calculation according to DIN V 18599-4 | QAI: Operational verification every 6 month |
| 2.6 | **On-site electricity generation from CHP, PV or others** | **Feed-in electricity meter** (⇨ M II-5)<br>$\Delta E_{RP} = Meter_{Supply\ unit}$<br>- $Meter_{Supply\ unit}$: Electricity meter of on-site supply unit | No QAI deemed necessary except for electricity meter inspection |

In general, savings in electricity use or demand from individual measures are easier to isolate and physically easier to measure (e.g. power × operating time), but simplified M&V methods, in particular with 'computational verifications' (c.f. M II-4) can also be demonstrated for thermal energy savings as displayed in the following section and Table 3.

### *5.3. Thermal energy-saving measures*

The following table gives an overview of simplified M&V approaches in combination with QAIs for individual thermal saving measures.

**Table 3: Examples of simplified M&V approaches for thermal energy savings**

| # | Thermal saving measures | **Verification method** (see Section 3.2) and **calculation examples** | **Quality assurance,** ***Notes*** |
|---|---|---|---|
| 3.1 | **On-site heat (or cold) generation from CHP, heat pump, solar thermal systems or others** | **Feed-in heat meter** (⇨ M II-5)<br>$\Delta E_{RP} = Meter_{Supply\ unit} \times 95\%$<br>- $Meter_{Supply\ unit}$: Heat (or cold) meter of on-site supply unit<br>- 95% flat rate correction factor for downstream losses | No QAI deemed necessary except heat meter calibration period inspection<br>*95% flat rate correction optional according to project specific set-up* |
| 3.2 | **Insulation of building envelope** | **Savings calculation based on computer simulation before and after retrofit** + QAI (⇨ M II-4e)<br>$\Delta E_{RP} = E_{Base} - E_{RP}$<br>- $E_{Base}$ = Building energy certificate before upgrade<br>- $E_{RP}$ = Building energy certificate after upgrade | QAI: Blower Door Test and thermography after upgrade to verify quality of the retrofit |

| # | Thermal saving measures | Verification method (see Section 3.2) and calculation examples | Quality assurance, *Notes* |
|---|---|---|---|
| 3.3 | **Installation of thermostatic valves** | **Baseline** x **%-savings rate: flat rate** + QAI (⇨ M II-4b)<br>*$\Delta E_{RP}$ = $E_{Base}$ x 80% thermal energy demand x 5%*<br>- 80%: calculated share of the energy used for heating<br>- 5%-savings rate corresponds to 1 K drop in average interior temperature | QAI: annual functional test + automatic surveillance of temperature in two sample rooms with alarm when limit values are exceeded |
| 3.4 | **Conversion of ventilation in wet rooms to hygroscopic control** | **Baseline share** x **%-savings rate: flat rate** + QAI (⇨ M II-4c)<br>*$\Delta E_{RP}$ = $E_{Base}$ x 10% thermal energy use x 5%*<br>- 10%: Calculated share of thermal energy in wet rooms<br>- 5%-savings rate | QAI: 6-monthly operational test |
| 3.5 | **Reduction of thermal losses through better heat pipe network** | **Calculated difference between heat loss before and after retrofit** + QAI (⇨ M II-4d)<br>*$\Delta E_{RP}$ = $E_{Base}$ – $E_{RP}$*<br>- Calculation of $E_{Base}$ and $E_{RP}$ with simulation programme of the pipe system manufacturer | QAI: Automatic leakage control |
| 3.6 | **Use-dependent temperature regulation with setback temperatures** | **Baseline share** x **%-savings rate: flat rate** + QAI (⇨ M II-4c)<br>*$\Delta E_{RP}$ = $E_{Base}$ x 80% thermal energy demand x 12%*<br>- 80%: Thermal energy demand for room heating<br>- 12%-savings rate from simulation | QAI: Recording of reference room sensors, on north and south sides of building |

Table 2 and Table 3 do not make any claim to completeness but are intended to present examples for consideration. Further examples can be found in the IPMVP documentation, in particular for Option A.

The measurement method and the (optional) additional quality assurance must be chosen on a project-specific basis.

# 6. Summary, discussion and outlook

## Summary

The very nature of energy, water or $CO_2$ emissions savings is not to be tangible or directly measurable. Furthermore to the disadvantage of demand side savings they typically come in (much) smaller orders of magnitude compared to supply side projects (even renewables), which are scattered and with a lot of (human) end user interfaces. But without some kind of M&V approach, saving achieved remain intangible, not quantified and last but not least respective savings cash flows cannot be determined.

In this paper we have structured and outlined available M&V methodologies and respective formulae, which in practice can be applied in energy service as well as in-house implementation projects to calculate – more honestly one should say to ‘estimate’ - savings cash flows.

Our particular focus is on simplified M&V approaches, which applies mainly to ‘retrofit insulation techniques’ for individual saving measures. In this context a broad spectrum of simplified saving calculation options are available, which encompass sub-metering (M II-1), combinations of metering with computational factors (M II-3), purely computational verifications (M II-4) or savings calculated from feed-in submeters after retrofit (M II-5).

As a rather new feature, we propose to systematically back up (particularly) simplified M&V approaches with so-called quality assurance instruments (QAIs). Their role is to verify the functionality and quality of a particular saving measure but not necessarily its exact quantitative outcome over the entire project cycle, which may largely depend on a number of external factors like utilization of a facility or climate conditions (c.f. section 3.1).

Combining simplified calculations of savings with QAIs has proven to be a practicable and sufficiently effective approach to M&V to determine saving cash flows in about a dozen of so-called Integrated Energy Contracting (IEC) projects in Austria.[2] QAI approaches can also be found in in-house implemented projects, public funding and $CO_2$ saving schemes as documented in our field examples.

**Discussion**

Simplified approaches should be seen as additional M&V options. They are not meant to replace utility meter based ('IPMVP Option C') or other comprehensive M&V methodologies, wherever these are suitable, feasible and desired by the project stakeholders.

The selection of an appropriate M&V approach can be decided project by project. Among others it will depend on the type of saving measures and on meter and data availability. It also depends on the size of a project to justify M&V efforts and the availability of know how, resources or even willingness of the project stakeholders to engage in an M&V plan and to follow it up.

There are a number of reasons to expand the scope of M&V methodologies towards simplified options. For smaller scale EPC, combinations of ESC and EPC and other energy service projects, the initial and periodic time and effort e.g. for an IPMVP compatible M&V methodology may be prohibitively high[16] or simply not desired for various reasons. The same rational may apply to in-house implemented projects. In this context simplified approaches can open up the option for performance based smaller scale energy service projects or in-house implemented projects, which is a prerequisite for evaluating saving cash flows.

When discussing M&V approaches to be used for projects involving an external energy service provider (ESP), it is also good to remember that often, when same energy-savings measures are implemented in-house, only a very light M&V programme or indeed, none at all, is typically used. In this sense simplified approaches can be a reasonable compromise between no M&V at all and a comprehensive approach.

Applying M&V procedures for individual saving measures creates the option of using different time schedules for each one – from a once-off measurement resulting in a constant flat rate ('deemed savings') to periodic tests, at annual or monthly intervals.

An advantage of a once-off measurement is that it saves the effort and expense but also the uncertainties of the corrections for price, climate conditions and use of the buildings (the factors which are external to the savings project and cannot be controlled e.g. by an ESP). This allows the flexibility to decide on the frequency of M&V in a way that suits the individual project, having regard to the needs of all project stakeholders involved.

From a European perspective it is interesting to note, that the use of isolated measure savings verifications is the exception rather than the rule, whereas "IPMVP Options A or B" are common practice in many other (Anglo-Saxon influenced) markets. There, the IPMVP has the status of a quasi-technical standard. Accordingly, we have included references to the IPMVP methods in this paper[17].

The former is particularly interesting because it applies to rather developed energy service markets, e.g. in Germany or Austria just as well. Here the common approach is utility meter

[16] This may also be one of the reason why the existing and widely acknowledged minimum threshold for energy cost baselines of a few hundred thousand Euros is as high as it is, which in practice is very exclusive for many potential saving projects.

[17] The IPMVP has been available in German translation since 2012 (http://www.evo-world.org/index.php)

based (IPMVP Option C) and using corrections for the time, price, climatic conditions and use of the building. This (good?) practice is also reflected in the publicly available procurement guidelines and model contracts (e.g. dena, Hessenleitfaden etc.).

**Outlook**

The authors would like to encourage a broader discussion on awareness, acceptability and added value of simplified M&V approaches both for in-house implemented projects as well as in energy service markets. We would also like to invite feedback in particular with regard to the proposed combination of simplified M&V approaches backed by QSIs. From a financing institutions perspective it would be interesting to discuss, if simplified approaches are sufficient for financing institutions (technically they probably do not care as long as cash flows are secure)?

For further discussions it would be useful to estimate and quantify the possible sources and margins of error resulting from simplified methods. E.g. the IPMVP proposes methodological approaches for doing this. In the light of such error margins it would be possible to discuss the costs and benefits of the precision of different kinds of M&V strategies. This should allow us to formulate some rules of thumb about the kinds of approach that is most efficient for different sizes and types of project.

With regard to sources for computational factors (M II-3 and M II-4) it would probably be worthwhile to study related norms and standards such as DIN V 18599. We would also like to investigate other M&V approaches and experiences like ASHRAE Guideline 14, building certification schemes like BREEAM or LEED or related UNFCC methodologies developed in the framework of international climate policy negotiations.

Last but not least, it should not be forgotten that so called non-energy-benefits (NEB) like increased productivity or comfort, better air quality or a green image may constitute bigger added values than energy savings by themselves. If this hypothesis holds true, we should put more focus on factoring NEBs into the business case than trying to quantify savings too exactly (provided implementation decisions are based on an economic rational at all). In other words: EE is often not a stand alone business or project case but in order to develop from individual projects to mass roll outs needed to make meaningful contributions towards energy policy goals, actors will need to open up from narrow energy perspectives and join forces with other project drivers.

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