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General technical rules for measurement, calculation and verification of energy savings of projects

Règles techniques générales pour la mesure, le calcul et la vérification des économies d'énergie dans les projets

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 257, *Evaluation of energy savings*.

Introduction

The purpose of this International Standard is to establish a set of general rules for measurement, calculation and verification of energy savings of projects. These general rules are considered universal and are applicable irrespective of the measurement and verification (M&V) methodology used. This International Standard is designed to be used by all the project stakeholders that aim to quantify the energy savings over a specific period in the new projects or retrofit projects. It could reduce the technical and financial barriers in the measurement, calculation and verification for energy saving projects.

This International Standard specifies the basic procedure of M&V of energy savings of M&V plan. A common understanding of M&V on project level is established by outlining how calculation methods for M&V could be selected under different project scenarios. It is intended as a set of principles, guidance and methods for M&V of energy savings that can be applied to a broad variety of projects.

There are numerous calculation methods and M&V methodologies available to quantify energy savings but credible determination of energy savings is considered essential for all the project stakeholders to have a clear and correct understanding of the energy performance of project.

In this International Standard, energy savings are determined by comparing measured, calculated or simulated energy consumption before and after and/or with and without implementation of a project and making suitable adjustments for changes in relevant variables (routine adjustment) or suitable adjustments for changes in static factors (non-routine adjustment) and therefore energy savings are the difference between the adjusted energy baseline and the reporting period energy consumption.

This International Standard can be used by any interested party in order to apply M&V to the reporting of energy savings results.

General technical rules for measurement, calculation and verification of energy savings of projects

1 Scope

This International Standard specifies the general technical rules for measurement, calculation and verification of energy savings in retrofits projects or new projects.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EVO 10000-1:2014, *International Performance Measurement and Verification Protocol, Core Concepts*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
baseline period
specific period of time before the implementation of *energy performance improvement action* (3.8) selected for the comparison with the *reporting period* (3.19) and the calculation of *energy savings* (3.9)

[SOURCE: ISO/IEC 13273-1:2015, 3.3.8.1, modified — "energy performance" replaced by "energy savings" and deleted "and of energy performance improvement action"]

3.2
boundary
physical or virtual limit around *energy using systems* (3.11) or facilities which are related to (an) *energy performance improvement action(s)* (3.8)

Note 1 to entry: Project boundary is a boundary around (an) *energy performance improvement action(s)* (3.8).

Note 2 to entry: M&V boundary is a boundary which is affected by (an) *energy performance improvement action(s)* (3.8).

3.3
energy
capacity of a system to produce external activity or to perform work

Note 1 to entry: Commonly the term energy is used for electricity, fuel, steam, heat, compressed air and other like media.

Note 2 to entry: Energy is commonly expressed as a scalar quantity.

Note 3 to entry: Work as used in this definition means external supplied or extracted energy to a system. In mechanical systems, forces in or against direction of movement; in thermal systems, heat supply or heat removal.

[SOURCE: ISO/IEC 13273-1:2015, 3.1.1]

3.4
energy baseline
quantitative reference(s) providing a basis for comparison of *energy performance* (3.7)

Note 1 to entry: An energy baseline reflects a specified period of time.

Note 2 to entry: An energy baseline can be normalized using variables which affect *energy use* (3.10) and/or *consumption* (3.5) e.g. production level, degree days (outdoor temperature), etc.

Note 3 to entry: Energy baseline is also used for calculation of *energy savings* (3.9), as a reference before and after implementation of *energy performance improvement actions* (3.8).

[SOURCE: ISO 50001:2011, 3.6]

3.5
energy consumption
quantity of *energy* (3.3) applied

Note 1 to entry: Energy consumption can be quantified before/after or/and with/without any *energy performance improvement action* (3.8).

[SOURCE: ISO/IEC 13273-1:2015, 3.1.13, modified — the original Note 1 replaced by a new Note 1]

3.6
energy efficiency
ratio or other quantitative relationship between an output of performance, service, goods or *energy* (3.3) and an input of energy

EXAMPLE Conversion efficiency; energy required/energy used; output/input; theoretical energy used to operate/energy used to operate.

Note 1 to entry: Both input and output need to be clearly specified in quantity and quality, and be measurable.

[SOURCE: ISO/IEC 13273-1:2015, 3.4.1]

3.7
energy performance
measurable results related to *energy efficiency* (3.6), *energy use* (3.10) and *energy consumption* (3.5)

Note 1 to entry: In this International Standard, *energy performance* (3.7) is only for *energy consumption* (3.5).

[SOURCE: ISO/IEC 13273-1:2015, 3.3.1, modified — added Note 1 to entry]

3.8
energy performance improvement action
EPIA
action or measure (or group of actions or measures) implemented or planned within a project intended to achieve *energy performance* (3.7) improvement through technological, management, behavioural, economic, or other changes

[SOURCE: ISO 50015:2014, 3.5, modified — “an organization” replaced by “a project”]

3.9
energy savings
reduction of energy consumption (3.5) compared to an adjusted *energy baseline* (3.4)

Note 1 to entry: Energy savings may be the result of implementation of an action(s).

Note 2 to entry: The energy baseline can be adjusted with routine adjustment (3.20) and/or *non-routine adjustment* (3.15).

[SOURCE: ISO 17742:2015, 2.19, modified — added ”adjusted” before “energy baseline”, notes 1 and 2 rewritten]

3.10
energy use
manner or kind of application of *energy* (3.3)

EXAMPLE Ventilation; lighting; heating; cooling; transportation; processes; production lines.

Note 1 to entry: Characteristics of energy use include, but are not limited to, the purpose of the use, source(s) choice and application.

[SOURCE: ISO/IEC 13273-1:2015, 3.1.12]

3.11
energy using system
physical items with defined *boundaries* (3.2), using *energy* (3.3)

EXAMPLE Facility, building, part of a building, machine, equipment, product, etc.

[SOURCE: ISO/IEC 13273-1:2015, 3.1.9, "system" deleted]

3.12
installation and commissioning period
specific period of time during which the *EPIA* (3.8) is put in place and inspection has been done on the equipment that is installed, including the operation procedures, to ensure that they conform to the design intent of the EPIA

3.13
interactive effect
significant energy result occurring beyond the *project* (3.16) *boundary* (3.2) as a consequence of action(s) within the project boundary

Note 1 to entry: When implementing multiple *EPIAs* (3.8) within one project boundary, correctly identifying and accounting for additive savings is important.

Note 2 to entry: "significant" is decided by the stakeholder.

EXAMPLE Changing the lighting system to be more efficient type will have an interactive effect on the HVAC system. If the project boundary is the lighting system only, the interactive effect on the HVAC system should be considered by choosing M&V boundary around the lighting and HVAC system.

3.14
measurement and verification
M&V
process of planning, measuring, collecting data, analysing, verifying, and reporting *energy performance* (3.7) or energy performance improvement for defined M&V *boundaries* (3.2)

[SOURCE: ISO 50015:2014, 3.13]

3.15
non-routine adjustment
adjustment made to the energy baseline to account for non-typical or non-predetermined changes in *relevant variables* (3.17) or *static factors* (3.21), outside the changes accounted for by *routine adjustment* (3.20)

Note 1 to entry: Non-routine adjustments may apply where the energy baseline no longer reflects current *energy use* (3.10) or *energy consumption* (3.5) patterns, or there have been major changes to the process, operational patterns, or energy systems.

[SOURCE: ISO 50015:2014, 3.16, modified — "unusual changes" replaced by "non-typical or non-predetermined changes"]

3.16
project
unique process consisting of a set of coordinated and controlled activities with start and finish dates, undertaken to achieve an objective conforming to specific requirements including constraints of time, cost and resources

Note 1 to entry: An individual project may form part of a larger project structure and may consist of two or more EPIAs.

Note 2 to entry: The complexity of the interactions among project activities is not necessarily related to the project size.

Note 3 to entry: *Energy savings* (3.9) is the quantitative result as the project activities bring about reduction in the *energy consumption* (3.5) of *energy using systems* (3.11) within the *project* (3.16) *boundary* (3.2).

Note 4 to entry: New project is a project involving an energy using system that has not been installed or commissioned, such that the project cannot be considered and treated as a retrofit.

Note 5 to entry: Retrofit project is a project conducted on an already existing energy using system.

[SOURCE: ISO 10006:2003, 3.5, modified — added "and may consist of two or more EPIAs." at the end of Note 1 to entry, removed NOTE 2, NOTE 3 and NOTE 4, made NOTE 5 the new Note 2 to entry, added new Note 3 to entry, Note 4 to entry and Note 5 to entry]

3.17
relevant variable
quantifiable factor that impacts *energy performance* (3.7) and routinely changes

EXAMPLE Production parameters (production volume, production rate); weather conditions (outdoor temperature, degree days); operating hours, operating parameters (operational temperature, light level).

[SOURCE: ISO 50015:2014, 3.18, modified — EXAMPLE rewritten]

3.18
reported energy savings
energy savings (3.9) reported as a result of the *M&V* (3.14) process

3.19
reporting period
defined period of time selected for the determination and reporting of energy savings.

[SOURCE: ISO 50006:2014, 3.15, modified — "calculation" replaced by "determination" and "energy performance" replaced by "energy savings"]

3.20
routine adjustment
adjustment made to the *energy baseline* (3.4) to account for changes in *relevant variables* (3.17) according to a predetermined method

Note 1 to entry: The predetermined method could be based on *reporting period* (3.19) conditions or any other referenced conditions.

Note 2 to entry: The term "normalization" is used in ISO 50006:2014 to refer to this concept; see Reference [4].

[SOURCE: ISO 50015:2014, 3.20, modified — note 1 deleted and new notes 1 and 2 added]

3.21
static factors
identified factor that impacts *energy performance* (3.7) and does not routinely change

EXAMPLE 1 Facility size; design of installed equipment; the number of weekly production shifts; the number or type of occupants, range of products.

EXAMPLE 2 A change in a static factor could be a change in a manufacturing process, raw material from aluminium to plastic, and can lead to a *non-routine adjustment* (3.15).

[SOURCE: ISO 50015:2014, 3.22]

4 Concept of energy savings of a project

Energy savings are the difference between the energy consumption during the baseline period adjusted with routine adjustments and/or non-routine adjustments (adjusted energy baseline) and the energy consumption during the reporting period.

The energy savings are expressed by Formula (1).

$$E_s = E_a - E_r \qquad (1)$$

where

E_s is the energy savings;

E_a is the adjusted energy baseline;

E_r is the energy consumption during the reporting period.

Figure 1 shows the energy savings as hatched area between the adjusted energy baseline and the energy consumption during the reporting period.

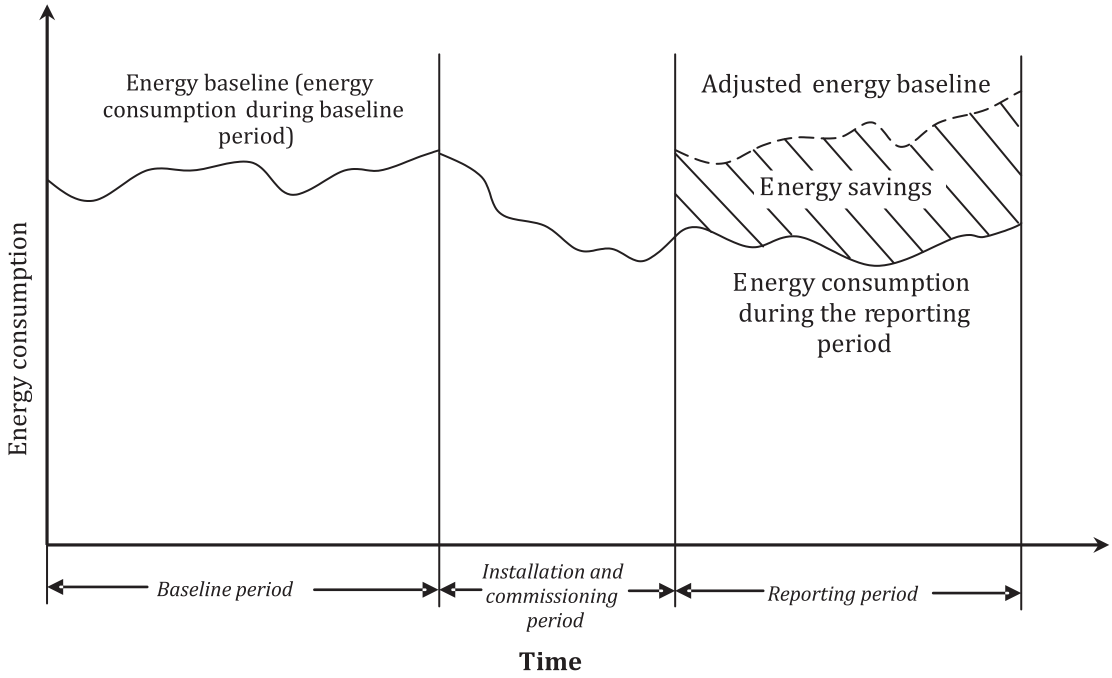

Figure 1 — Demonstration of energy savings of projects

5 Procedure of M&V of energy savings

5.1 General

Activities of M&V of energy savings of a project should follow the procedure as shown in Figure 2.

a) Preparation of M&V plan.

   The preparation of M&V plan mainly consists of four activities as follows:

   1) M&V boundary identification;

   2) determination of baseline and reporting period;

   3) selection of calculation method for M&V;

   4) determination of specification of data collection and uncertainty of result.

   The preparation of M&V plan is a dynamic cycle starting from and ending at 1) boundary identification, all these four activities are iterative until all the outputs of activities 2), 3) and 4) become technically feasible and accepted by the project stakeholders within the selected boundary.

b) Establishment and documentation of M&V plan.

c) Determination of energy baseline, including metered and operational data collection of relevant variables in baseline period, and analysis of the energy baseline, documentation of energy baseline.

   NOTE Analysis of the energy baseline may include development of a model (ratio-based, statistical-based or engineering-based, etc.).

d) Installation and commissioning, including the design, installation and deployment, and commissioning of the project and including metering system for M&V of energy savings if required in M&V plan.

   NOTE Design, installation and commissioning are not necessarily performed by the M&V professional although input on measurement systems can be included in the M&V report.

e) Determination of energy consumption in reporting period, including metered and operational data collection of reporting period, documentation and analysis of the energy consumption of reporting period.

f) Determination of energy savings, including analysis of adjusted energy baseline, determination of the non-routine adjustment and uncertainty of energy savings according to the M&V plan.

g) Report or verification of the determined energy savings.

5.2 Logical relationship between the M&V and the project implementation

The implementation of a project is the premise of M&V of energy savings. The key steps of M&V should be implemented by following the corresponding key steps of project implementation as shown in Figure 2.

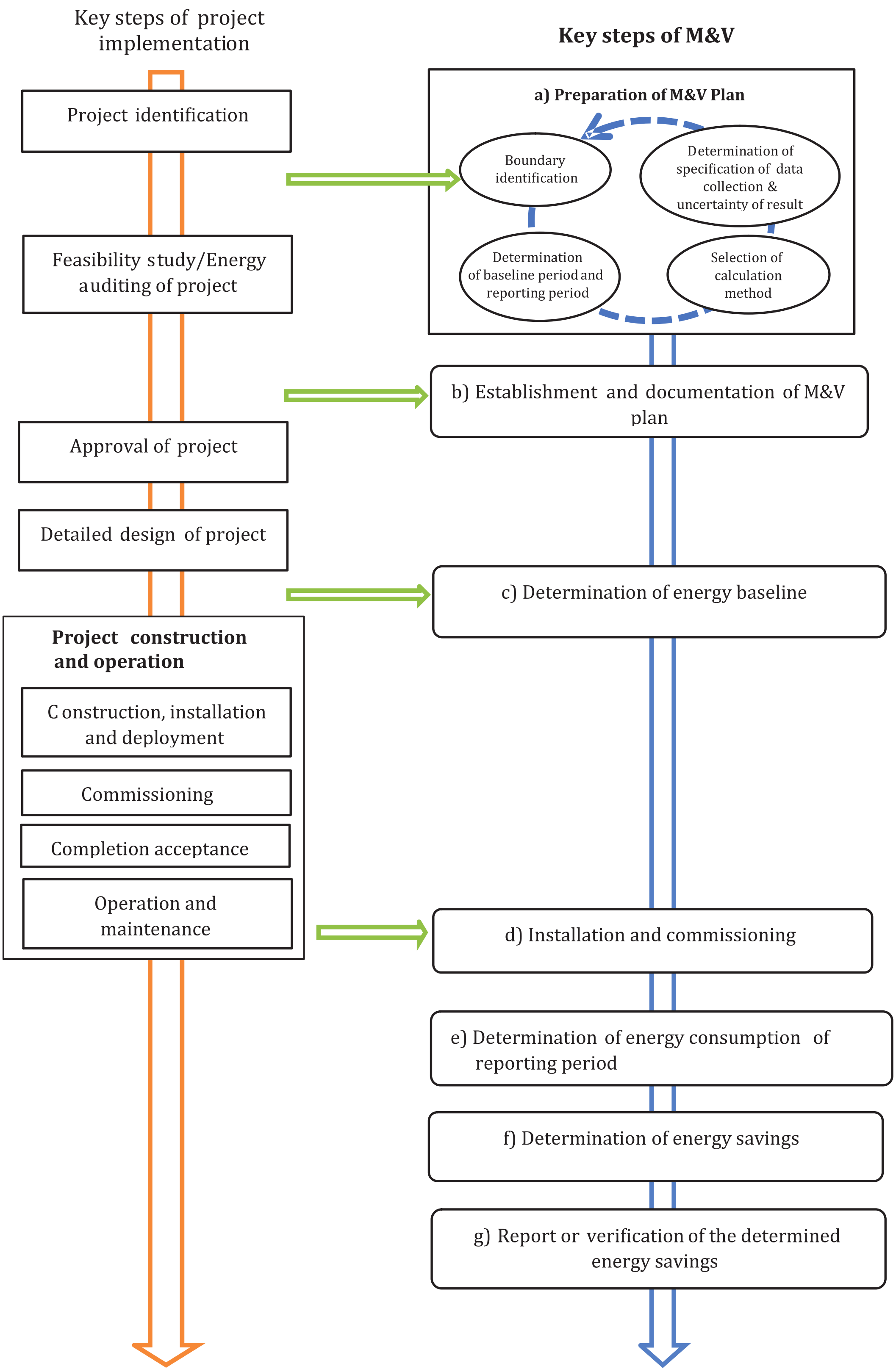

Figure 2 — Demonstration of the logical relationship between the M&V and the project implementation

For a new project, calibration of simulation should be done after the installation and commission (see 6.4.4.2).

6 Measurement & verification plan (M&V plan)

6.1 General

The contents of M&V plan should include the following.

a) M&V boundary and project boundary

The geographical description of the M&V boundary and project boundary and the list of all the facilities and equipment within these boundaries should be recorded.

b) Baseline period

The description of selected baseline period including the energy use and energy consumption in baseline period should be recorded.

c) Reporting period

The description of selected reporting period should be recorded.

d) Calculation method of energy savings

Calculation method of energy savings should be selected and recorded.

e) Specification of data collection

For the calculation method of energy savings selected as 6.4.2 or 6.4.3, the M&V plan should identify the existing and additional data sources, including metering points and other non-metered sources of required data. For each metering data source, the M&V plan should specify the data collection period and frequency, sampling principle and procedure, metering instruments including meter accuracy and meter range, meter reading protocol, procedure of meter commissioning, calibration procedure and method of dealing with lost data. For the calculation method of energy savings selected as 6.4.3, the related information should be clarified including the estimated values and uncertainty of the relevant variables which cannot be measured.

f) Simulation

For the calculation method of energy savings selected as 6.4.4, the related information should be clarified including the name and version of simulation software, the hard copy and the electronic copy of the input and output files, the assumptions adopted in the software, the data acquisition means (measured or estimated), the acquisition process of measured data, calibration period and condition, and the required calibration accuracy between the simulation results and the energy data adopted for calibration.

The adoption of the simulation model should be agreed by the project stakeholders.

The simulation calculation method and conditions should be shared with the key project stakeholders.

g) Uncertainty

The M&V plan should address the expected accuracy of the results of conducting M&V by explicitly considering sources of uncertainty taking into account the specific situation of the project.

6.2 Boundary identification

The M&V boundary should be selected so as to ensure that interactions related to the project are included. The M&V boundary may differ from the boundary of the project and may include the facilities, systems and equipment affected by EPIA(s) implemented within the project. The M&V boundary may include measurements or calculations required to determine interactive effects of the implementation of the project.

The project boundary can be drawn around individual EPIA(s) if it is considered that there will be no interactive effects with other facilities, systems or equipment. In this case, the M&V boundary is the project boundary.

a) All the facilities, systems and equipment affected by EPIAs should be included within the M&V boundary.

b) According to the purpose of the project, the boundary could take various forms.

   1) If the purpose of the project is to improve the energy performance of the equipment, the project boundary should be drawn around that equipment.

   2) If the purpose of the project is to improve the energy performance of the total facility, the project boundary should be drawn around that total facility.

6.3 Determination of baseline period and reporting period

6.3.1 General

The determination of baseline period and reporting period should be recorded and agreed by the project stakeholders.

The selection of baseline period and reporting period should ensure that the M&V plan is technically and financially feasible.

6.3.2 Baseline period

The time span of the baseline period should be of sufficient length which reflect the typical energy consumption pattern of the energy using system affected by the project.

EXAMPLE 1 For the weather-sensitive projects, e.g. the commercial or office building, of which energy use and energy consumption are significantly affected by the whole cycle of weather, a period of one year is commonly used.

EXAMPLE 2 For the weather-sensitive projects, e.g. the central heating system, the skiing resort, the open pit mining, etc., of which energy use and energy consumption are significantly affected by season change, a period is commonly selected on a seasonal basis.

EXAMPLE 3 For the weather-insensitive projects, e.g. industrial facilities, of which energy use and energy consumption are closely related to the production process, a whole production cycle is commonly used.

6.4 Calculation methods of energy savings

6.4.1 General

As shown in Table 1, there are three calculation methods of energy savings to be selected. The description of these methods is shown in the following clauses.

Table 1 — Three calculation methods of energy savings

Method option	Description	Typical Application		
		New project	Retrofit project	Typical examples
I: Direct comparison	To determine energy savings when the energy performance improvement action (EPIA) can be turned on and off without affecting the energy using systems or equipment.		✓	— The previous equipment is left as a backup and can be switched from the new equipment. — In-service trials, e.g. of tyre inflation procedures for a trucking fleet. NOTE This method may be permitted when there is no relevant variable (for example, exchange of an electric light). However, it is not suitable for M&V of a boiler or facilities.
II: Adjusted calculation	— Applicable to most of retrofit projects. — To establish the relevant model between baseline period energy consumption and its relevant variables through engineering or statistical analysis and then use this model to estimate the energy consumption under the reporting period condition if there were no energy performance improvement action, that is, the adjusted energy baseline consumption.		✓	— Change of operational process (e.g. changing the procedure of heating pattern, changing sequence of machines.) — Implementation of a number of different EPIAs within the project, such as insulation, energy efficient boiler, improved maintenance.
III: Calibrated simulation	The simulation calculation is applicable where — baseline energy data does not exist or is unavailable, and — reporting period energy data is unavailable or obscured by factors that are difficult to quantify.	✓	✓	— New facility. — Building energy simulation. — Industrial process simulation.

6.4.2 Method I: Direct comparison

The direct comparison method can be used to determine energy savings when

— the EPIAs can be turned on and off without affecting the energy consumption of other systems or equipment,

— no relevant variable is found, and

— relevant variables or static factors in the periods involved in the direct comparison are similar.

Direct comparison method should be carried out with the following procedure.

EXAMPLE Comparison under the similar temperature in the same season and similar operating time. (In this case, temperature is corresponding to relevant variable and operating time is corresponding to static factor.)

a) Set the ON/OFF testing period with equivalent period and typical conditions.

EXAMPLE Certain Tuesday for the on test and next Tuesday for the off test.

b) Measure the reporting period energy consumption: measure the energy consumption within the M&V boundary in reporting period when EPIAs are on or activated.

c) Calculate the adjusted energy baseline: measure the energy consumption within the M&V boundary under typical operating conditions in reporting period when EPIAs are off.

d) Calculate energy savings by following Formula (1) (see Clause 4).

When using Method I, the E_a in Formula (1) equals to the energy consumption under the condition of EPIA(s) being turned off.

NOTE Method I can be applied to Option A, B and C in EVO 10000-1:2014 with varying M&V boundary and degree of measurement.

6.4.3 Method II: Adjusted baseline calculation

6.4.3.1 Energy baseline

The data of energy baseline includes energy consumption data over a defined period of time, relevant variables and static factors. The energy baseline is the starting point for determination of energy savings over time and should be determined before the EPIA(s) are applied to the project. Sufficient operating records, static factors and test data related to relevant variables should be obtained in baseline period to conclude the quantitative relationships between the energy consumption of the energy using system and its relevant variables, given the requirements of the stakeholders.

EXAMPLE 1 In case of new construction project such as the installation of a higher efficiency condensing boiler, the energy baseline may be established based on the energy performance of a reference boiler which complies with the minimum energy performance standard.

EXAMPLE 2 The energy baseline may be the energy performance of a compressor without a variable frequency drive (VFD) when the project involves adding a VFD.

6.4.3.2 Establishment of "Baseline period energy consumption — Relevant variables" model

Relevant model between baseline period energy consumption and its relevant variables should be established through engineering or statistical analysis as Formula (2):

$$E_b = f(x_1, x_2, \cdots x_i) \tag{2}$$

where

E_b is the baseline period energy consumption;

x_i is the value of relevant variables in baseline period;

f is the function with a set of relevant variables and E_b.

NOTE 1 Relevant variables usually include climatic factors (such as indoor and outdoor temperature), operating factors (such as production, capacity utilization, and hotel occupancy rate), etc.

NOTE 2 Method II can be applied to Option A, B and C in EVO 10000-1:2014 with varying M&V boundary and degree of measurement.

6.4.3.3 Non-routine adjustments

The non-routine adjustments of baseline period energy consumption to reporting period conditions are needed where a significant change occurs to energy using system, static factors or operations within the M&V boundary.

EXAMPLE A manufacturing-department was established on a floor which was not previously being used. This increased the energy consumption of the facility; therefore, an adjustment is required to the energy baseline to reporting period conditions.

Careful and detailed determination of the M&V boundary can limit the need for adjustments. Examination of asset management or equipment replacement schedules could also identify changes in static factors that might need adjustment.

6.4.3.4 Calculation of adjusted energy baseline

The adjusted energy baseline is calculated by Formula (3) by using the values of relevant variables of the reporting period in Formula (2).

$$E_a = f(x'_1, x'_2, \cdots x'_i) + A_m \quad (3)$$

$$A_m = g(y_1, y_2, \cdots y_i) \quad (4)$$

where

x'_i is the value of relevant variable in reporting period;

A_m is the non-routine adjustments of the baseline period energy consumption to reporting period conditions;

y_i is the value of static factor in reporting period;

g is the function with a set of input ($y_1, y_2, ...y_i$) and A_m.

In reporting period, the value of relevant variable, x'_i, is obtained through measurement or estimation.

Values assumed for unmeasured variables, the adjustment method and assumption should be agreed to by the project stakeholders and documented.

NOTE Examples of non-EPIA related static factor is shown in 3.21.

6.4.3.5 Calculation of energy savings

Energy savings should be calculated by Formula (1) (see Clause 4).

6.4.4 Method III: Calibrated simulation

6.4.4.1 General

Method III involves using or developing a software simulation that can calculate energy consumption using inputs of relevant variables such as weather data and/or operating conditions within the M&V boundary. The simulation software that reflects specific conditions is called the simulation model. The following two simulation models are used:

— baseline period simulation model: the simulation model that does not include EPIA;

— reporting period simulation model: the simulation model that includes EPIA.

A simulation model has parameters to be set (e.g. area of the floor, operation schedule of facilities, performance of energy using equipment, insulation performance of buildings, location of the facility).

NOTE 1 Simulations can be performed using a range of software platforms, from simple mathematical simulation models to systems with Computer Aided Design (CAD) or graphics capabilities, etc. and can be static or dynamic depending on the circumstances.

NOTE 2 Method III can be applied to Option D in EVO 10000-1:2014.

The simulation calculation is applicable where

— baseline energy data are not sufficient for the Method II,

— reporting period energy data are not sufficient for the Method II, and

— Method I (see 6.4.2) and Method II (see 6.4.3) are not suitable.

NOTE 3 The examples of the case where baseline energy data are not sufficient for the Method II are as follows:

— data of energy consumption and relevant variable are unavailable;

— the number of samples does not meet the requirement agreed to by stakeholders;

— accuracy of measurements is not as specified in the agreement between stakeholders.

These can occur in the case where measurements are complex and/or entail high costs.

The following points should be considered when using simulation calculation:

— Except for the baseline period simulation model of new facilities or equipment, the simulation model should be checked in advance to ensure the consistency between energy consumption simulation data and measured data.

  NOTE 1 For new systems, calibration might be possible by using data and measurements from a similar existing plant;

— The simulation condition (including survey data and the metering or monitoring data used to define input values), result and details of the model (including the model version and model type) should be documented.

  NOTE 2 Certain details (model, type, version, etc.) can be found in Reference [1];

— Except for the baseline period simulation model of new facilities or equipment, a simulation model should be calibrated so that it predicts the energy performance that matches actual metered data well enough to be accepted by the project stakeholders.

6.4.4.2 Calibration

The accuracy of energy savings calculated through simulation model depends on how well the simulation results fit to the actual energy consumption within the M&V boundary; therefore, calibration should be done to the simulation model by comparing the simulation results to the calibration data including measured energy data and relevant variables.

The procedure of calibration is as shown in Figure 3. The whole process of calibration goes with trial and error until the simulation results meet the required calibration accuracy.

The main content of simulation is as follows:

a) Define and document the simulation model

b) Collect calibration data

   Calibration data can be obtained from the operation logs, measurement to the existing facility, etc.

c) Assume or measure input parameters to the simulation model

   The input parameters obtained by means of assumption should be well accepted by the project stakeholders and actually widely used in the relevant project, such as the assumption of the annual operation hour of power plant or lighting system, etc.

d) Run simulation model

e) Verify the consistency between the simulation results and the measured energy data

The difference between the simulated energy results and the measured energy data used as calibration data should meet the calibration accuracy required by the stakeholders in the M&V plan, if not, return to step c) and revise the assumption to input parameters.

NOTE If there is no final agreement reached among stakeholders regarding the calibration results, then go back to a).

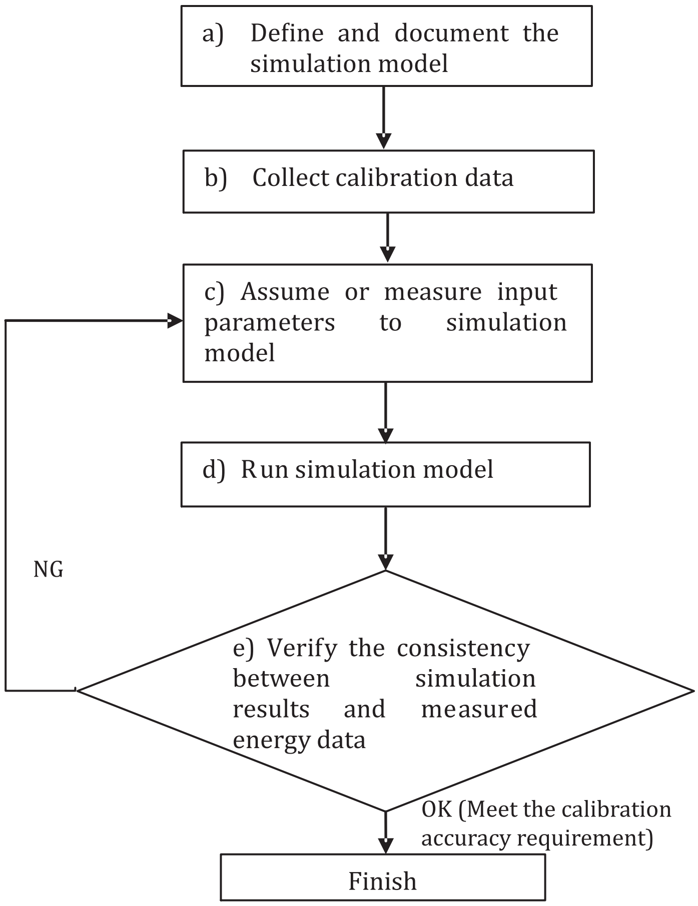

Figure 3 — Procedure of calibration

6.4.4.3 Calculation

Simulation calculation can be used to calculate the energy savings by involving the use of computer simulation software to predict the energy consumption for both of the terms in Formula (1) (see Clause 4). If there is actual data on the baseline period energy consumption or reporting period energy consumption, A_m can be calculated by simulation software according to the agreed conditions.

NOTE Calibration is not necessary where it is not required to achieve the calculation accuracy agreed with the project stakeholders in the M&V plan, or in cases where calibration is not applicable such as for some new facilities.

6.5 Specification of data collection

Specification of data collection includes the following:

a) Data types

Different types of data should be collected for M&V, mainly including the following:

1) energy consumption data;

2) measurement data, provided by utility companies;

3) relevant variables data, such as weather data, production volumes, floor areas, customer numbers, etc.

b) Data collection means

The data may be acquired from different means, including, but not limited to the following:

1) metered data provided by utility companies;

2) measurement, such as readings on energy and/or relevant variable measuring meters or other instruments;

3) simulation, such as energy consumption data of energy using equipment or systems obtained through computer simulation and calibration;

4) estimation/assumption;

The estimated or assumed data used for M&V should be the data which are usually well accepted as some fixed number and does not need to be metered or measured, such as the annual operation hours of a power plant or a supermarket;

5) manufacturers' data, such as pump curves;

6) handbooks, standards or typical operating procedures for new plant, such as design temperatures or pressures.

c) Data accuracy

The requirements for data accuracy should be determined in consultation with the project stakeholders.

d) Data collection frequency

Collection frequency of different types of data should match each other. Data frequency should be sufficient to capture operating conditions and provide an adequate number of data points for analysis.

EXAMPLE Where monthly energy measurements are used, weather data could be recorded daily so it can be matched to the actual energy-metering reading dates and then averaged over the month.

NOTE Measurement can be done through sampling as per agreed uncertainty.

6.6 Uncertainty

The accuracy of the result is affected by uncertainty. There is a trade-off between uncertainty levels and M&V cost. Full quantification of uncertainty may not be required if this is prohibitively expensive in relation to the M&V objectives. Where a rigorous, metrological and statistically valid evaluation of uncertainty is not feasible, potential contributors to uncertainty should be identified with reasonable estimates of the magnitude of each component's uncertainty[5].

Energy savings cannot be exactly determined because there will always be some uncertainty.

The uncertainty of energy savings can be managed by controlling random errors and non-random events such as data bias, drift, complete failure and precision degradation.

Management of uncertainty is a balance between cost and accuracy, that should be agreed by stakeholders.

When using any method, the sources of uncertainty may include, but not limited to, the following:

— modelling uncertainty;

— measurement, metering or statistics both in baseline period and reporting period;

— sampling;

— non-routine adjustment uncertainty.

Other uncertainty sources can be discussed using qualitative statements or analyses.

NOTE 1 Some sources of error are unknown and unquantifiable, for example, poor meter selection or placement, inaccurate estimates or mis-estimation of interactive effects. Unknown or unquantifiable uncertainties can only be managed by following industry best practices.

NOTE 2 ISO/IEC GUIDE 98-3-2008 can be used to evaluate uncertainty of the measurement, metering or statistics.

NOTE 3 EVO 10100-1:2014 can be used to evaluate the uncertainty of modelling and sampling.

In the statistical expression, results of energy savings can be expressed as a confidence interval of energy savings under a certain confidence level.

Uncertainty of energy savings could be analysed to illustrate the reliability of energy savings according to the determined measurement & verification plan (including baseline data, cost of M&V, objectives). Analysis of uncertainty should include, but not limited to, the following:

a) data quality of all values, whether measured or estimated;

b) M&V boundary chosen;

c) baseline period and reporting period selected

   NOTE Errors could emerge if the baseline period and reporting period does not account for the full range of typical operating conditions;

d) calculation method selected;

e) relevant variables and static factors considered;

f) estimation of interactive effects;

g) frequency of data collection

   NOTE Analysis might be inaccurate if the frequency of data is insufficient to capture the range of operating conditions;

h) data collection period

   NOTE Errors could emerge if the data collection period does not account for the full range of typical operating conditions;

i) data bias

   The M&V plan should include a description of the methods used to mitigate and adjust for the potential types of bias resulting from statistical methods.

   The M&V plan should identify methods for controlling bias in sample selection including, but not limited to random sampling, census or rolling census for each sample and strata used.

   NOTE Data bias can be introduced by various influences on measurement data, assumptions and analysis.

EXAMPLE Each element of the population has an equal chance of been selected by using random sampling strategy; however, in the lighting retrofit project, bias will be introduced if the items with longer operating time are mainly selected;

j) measurements taken during the M&V process.

6.7 Measurement & verification options (M&V options)

A measurement & verification option (M&V option) is the combination of specific M&V boundary, calculation methods (Method I, II and III), baseline period and reporting period, and specification of data collection. One or more M&V options may be available when determining energy savings of a project. Users can select a conventional M&V option or establish a new M&V option when preparing the M&V plan.

EVO 10000-1:2014 provides four conventional M&V options for determining energy savings.

Contents of new M&V option should be consistent with the guidance of 6.2, 6.3, 6.4 and 6.5.

Feasibility, cost and accuracy should be taken into consideration to select or establish an M&V option.

7 Report

The report of the energy savings may include following information:

a) purpose of the energy saving determination (intended use and scope);

b) identification of the energy performance improvement action(s);

c) who ordered;

d) who performed the M&V of energy savings;

e) period of time when the energy savings are accounted for;

f) M&V/project boundary(ies);

g) energy consumption, relevant variable and static factor during the baseline period (energy baseline);

h) energy consumption, relevant variable and static factor during the reporting period;

i) calculation method used, including adjustment and simulation method (if applicable);

j) data sources:

   1) type of data (measured, calculated including simulation);

   2) data collection approaches (e.g. periodicity, sampling characteristics);

k) Uncertainty of the results;

l) the change in conditions since the M&V plan was authorized.

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