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Energy management systems — Evaluating energy performance using energy performance indicators and energy baselines

Systèmes de management de l'énergie — Évaluation de la performance énergétique à l'aide d'indicateurs de performance énergétique et de situations énergétiques de référence

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Contents

Page

Foreword ..... **v**

Introduction ..... **vi**

1 Scope **1**

2 Normative references **1**

3 Terms, definitions and abbreviated terms **1**
3.1 Terms and definitions 1
3.2 Abbreviated terms 4

4 Overview of EnPIs, EnBs and energy performance **4**

5 Obtaining relevant energy performance information **5**
5.1 Initial-energy-performance-related information 5
5.2 Determining users of energy performance indicators 6
5.3 Defining the energy performance indicator boundaries 6
5.4 Defining and quantifying energy flows 7
5.5 Defining and quantifying variables related to energy performance 8
5.6 Collecting data 9
5.6.1 Data collection 9
5.6.2 Data quality 9
5.6.3 Measurement 10
5.6.4 Data collection frequency 10
5.6.5 Identifying and analysing outliers 10

6 Determining energy performance indicators **11**
6.1 General 11
6.2 Expressing energy performance indicators 11
6.2.1 Statistical model 11
6.2.2 Aggregated models 13
6.2.3 Engineering model 13

7 Establishing energy baselines **14**
7.1 Concept of EnB 14
7.2 Determining baseline period 14

8 Normalization **15**
8.1 Concept of normalization 15
8.2 Uncertainty of model 15

9 Maintaining energy performance indicators and energy baselines **15**
9.1 General 15
9.2 Static factor changes 16

10 Monitoring and reporting of energy performance and demonstrating energy performance improvement **17**
10.1 General 17
10.2 Monitoring and reporting 17
10.3 Demonstrating energy performance improvement 17

Annex A (informative) **EnPI and EnB planning process** **19**

Annex B (informative) **Examples of EnPI boundaries** **21**

Annex C (informative) **Examples of energy performance indicators** **22**

Annex D (informative) **Example of normalization stepwise process** **25**

Annex E (informative) **Example of normalization** **27**

Annex F (informative) **Example of normalization — Multivariate–analysis** **31**

Annex G (informative) **Reporting aggregated information** **35**

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Bibliography **36**

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Foreword

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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 document 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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This document was prepared by Technical Committee ISO/TC 301, *Energy management and energy savings*.

This second edition cancels and replaces the first edition (ISO 50006:2014), which has been technically revised.

The main changes are as follows:

— concepts and technical aspects have been harmonized with the latest edition of ISO 50001:2018;

— definitions in Clause 3 have been updated in accordance with the latest edition of ISO 50001:2018 and considering a new approach for general harmonization under ISO/TC 301;

— upgrades have been made related to the normalization of energy performance indicators (EnPIs) and corresponding energy baselines (EnBs);

— upgrades and new considerations have been made related to the new definition and requirement to demonstrate energy performance improvement.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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Introduction

0.1 Background

Energy performance evaluation is a tool which applies to all types of organizations and can be used to evaluate the results of its efforts in energy management. Relevant variables affect the energy consumption and energy efficiency of organizations. To effectively evaluate energy performance under equivalent conditions, the effects of relevant variables should be taken into account by using the process of normalization.

Measuring and monitoring of energy performance and demonstration of energy performance improvement can be challenging because of the complexity of determining energy performance indicators (EnPIs) and corresponding energy baselines (EnBs) which are appropriate for an organization to better understand the energy consumed within the facilities, equipment, systems or energy-using processes.

Improving energy performance helps organizations to become more competitive by reducing their energy costs. In addition, improving energy performance can help organizations to reduce their energy-related greenhouse gas emissions. Climate change and the need for decarbonization are major global concerns. Reducing greenhouse gas emissions associated with energy consumption is a significant tool in tackling climate change. Methods for monitoring and measuring energy performance to ensure appropriate results are key aspects of this activity.

In those activities or processes in which no energy performance improvement has been planned, benefits can also be obtained by using EnPIs and EnBs to manage operational control, identify maintenance needs or identify significant deviations in energy performance.

Communicating the energy performance of the organization and its processes to appropriate person(s) in the organization is a key element for success. It is also a key to building ongoing commitment and engagement of top management to allocate resources for energy management including the effective establishment of EnPIs and EnBs.

The technical information in this document enables an organization to meet the requirements of ISO 50001 including using normalization in measuring, monitoring, analysing and evaluating its energy performance and energy performance improvement. In this way, it can demonstrate continual improvement in energy performance using EnPIs and corresponding EnBs.

0.2 Overview of contents

This document provides an organization with practical guidance related to managing energy performance, including its evaluation, control and continual improvement through the establishment, use and maintenance of EnPIs and the corresponding EnBs.

This document gives guidance on the selection of appropriate EnPIs according to the objectives of the organizations which can achieve significant benefits by implementing them.

This document is intended to guide an organization in establishing, using and maintaining EnPIs and EnBs in accordance with the requirements in ISO 50001.

The process described in this document can provide benefits to any organization, including those that do not have an EnMS. Nevertheless, additional benefits can be obtained if this process is embedded within an EnMS in accordance with ISO 50001.

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Energy management systems — Evaluating energy performance using energy performance indicators and energy baselines

1 Scope

This document gives guidance on how to establish, use and maintain energy performance indicators (EnPIs) and energy baselines (EnBs) to evaluate energy performance in any organization including those using ISO 50001. Additional guidance is given on how to measure and monitor energy performance and demonstrate energy performance improvement.

This document is applicable to any organization, regardless of its type, size, complexity, geographical location, organizational culture, the products and services it provides or its level of maturity in the field of energy management.

2 Normative references

There are no normative references in this document.

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1.1
baseline period
period of time used for comparison with *reporting period* (3.1.16)

Note 1 to entry: The purpose of the comparison can be monitoring of performance, evaluation of performance improvement or determination of energy savings.

3.1.2
boundary
physical, virtual and/or organizational limits as defined by the entity for a stated purpose

Note 1 to entry: The entity may be an *organization* (3.1.14), group of organizations, region(s), subset of an organization or other depending on the application.

Note 2 to entry: Physical can be equipment, systems, a building, a process, a group of processes, a site, or multiple sites, under the control of an organization.

3.1.3
energy
electricity, fuels, steam, heat, compressed air and other similar media

Note 1 to entry: For the purposes of this document, energy refers to the various types of energy, including renewable, which can be purchased, stored, treated, used in equipment or in a process, or recovered.

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[SOURCE: ISO 50001:2018, 3.5.1]

3.1.4
energy baseline
EnB
value providing a basis for comparison of *energy performance* (3.1.9)

Note 1 to entry: The data and method used to determine the EnB shall be retained as documented information.

Note 2 to entry: If the process for determination of the EnB uses *relevant variables* (3.1.15) for *normalization* (3.1.13) or if the EnB is adjusted for changes in *static factors* (3.1.18), the information shall be retained as documented information.

3.1.5
energy consumption
quantity of *energy* (3.1.3) applied

Note 1 to entry: Energy consumption can be represented in volume (e.g. litres of fuel), mass, weight units or energy units (e.g. GJ, kWh).

[SOURCE: ISO 50001:2018, 3.5.2, modified — Note 1 to entry added.]

3.1.6
energy efficiency
ratio or other quantitative relationship between an output of process and an input of *energy* (3.1.3)

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

Note 1 to entry: The output of a process can be products, services, or energy.

Note 2 to entry: Both input and output should be clearly specified in terms of quantity and quality, and should be measurable.

3.1.7
energy use
energy end-use
application of *energy* (3.1.3)

EXAMPLE Ventilation, lighting, heating, cooling, transportation, processes, data storage.

Note 1 to entry: Energy use is based on "what the energy is used for" as compared to *energy consumption* (3.1.5) which is based on "how much energy is used".

Note 2 to entry: This application can be from any energy type including renewables.

3.1.8
energy model
mathematical representation based on a data set describing the relationship between *relevant variables* (3.1.15) and *energy consumption* (3.1.5) or *energy efficiency* (3.1.6) over a specified period of time

Note 1 to entry: The specified period of time can represent different perspectives of time such as *baseline period* (3.1.1), *reporting period* (3.1.16), or period that reflects standard conditions.

3.1.9
energy performance
measurable result(s) related to *energy efficiency* (3.1.6), *energy use* (3.1.7) and *energy consumption* (3.1.5)

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3.1.10
energy performance indicator
EnPI
measure used to quantify *energy performance* (3.1.9)

Note 1 to entry: If the EnPI is used for the demonstration of *energy performance improvement* (3.1.11) it refers to *energy efficiency* (3.1.6) or *energy consumption* (3.1.5).

Note 2 to entry: The EnPI is defined by the *organization* (3.1.14).

Note 3 to entry: EnPI(s) can be calculated by using an *energy model* (3.1.8).

3.1.11
energy performance improvement
improvement in measurable results of *energy efficiency* (3.1.6) or *energy consumption* (3.1.5) related to *energy use* (3.1.7), compared to the *energy baseline* (3.1.4)

3.1.12
energy target
quantifiable objective of *energy performance improvement* (3.1.11)

Note 1 to entry: An energy target can be included within an objective.

[SOURCE: ISO 50001:2018, 3.4.15]

3.1.13
normalization
process to enable analysis under equivalent or standard conditions

Note 1 to entry: Normalization can be used for the purpose of comparison of *energy performance* (3.1.9) or *energy performance improvement* (3.1.11), which accounts for the changes in *relevant variables* (3.1.15).

3.1.14
organization
person or group of people that has its own functions with responsibilities, authorities and relationships to achieve its objectives

Note 1 to entry: The concept of organization includes, but is not limited to, sole-trader, company, corporation, firm, enterprise, authority, partnership, charity or institution, or part or combination thereof, whether incorporated or not, public or private.

3.1.15
relevant variable
quantifiable factor that significantly impacts *energy performance* (3.1.9) and routinely changes

Note 1 to entry: Significance criteria are determined by the *organization* (3.1.14).

Note 2 to entry: In a statistical approach, relevant variables are identified from independent variables by using significance criteria.

EXAMPLE Weather conditions, operating conditions (indoor temperature, light level), working hours, production output.

3.1.16
reporting period
defined period of time selected for evaluating *energy performance* (3.1.9) and *energy performance improvement* (3.1.11)

Note 1 to entry: In this document, the concept of reporting period includes the concept of monitoring period.

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3.1.17
significant energy use
SEU
energy use (3.1.7) accounting for substantial *energy consumption* (3.1.5) and/or offering considerable potential for *energy performance improvement* (3.1.11)

Note 1 to entry: Significance criteria are determined by the *organization* (3.1.14).

Note 2 to entry: SEUs can be related to facilities, systems, processes or equipment.

[SOURCE: ISO 50001:2018, 3.5.6]

3.1.18
static factor
identified factor that significantly impacts *energy performance* (3.1.9) and does not routinely change

Note 1 to entry: Significance criteria are determined by the organization.

EXAMPLE Facility size, design of installed equipment, number of weekly shifts, range of products.

[SOURCE: ISO 50001:2018, 3.4.8]

3.2 Abbreviated terms

CDD	cooling degree day
CUSUM	cumulative sum
EnB	energy baseline
EnMS	energy management system
EnPI	energy performance indicator
HDD	heating degree day
SEC	specific energy consumption
SEU	significant energy use

4 Overview of EnPIs, EnBs and energy performance

An organization establishes EnPIs and EnBs to measure and monitor energy performance and demonstrate energy performance improvement.

EnPIs provide relevant energy performance information to interested parties (e.g. internal users, supply chain), to understand energy performance and take actions to control and improve energy performance.

EnPI values quantify the energy performance of the entire organization or its various parts (e.g. facilities, equipment, systems or energy using processes). Potential EnPIs need to be analysed to decide if they are appropriate before being selected. EnPIs can be expressed by using an energy model and can be reported in units of energy consumption (e.g. GJ, kWh) or energy efficiency (e.g. km/l).

Energy consumption of an organization can be significantly affected by relevant variables such as weather, production, etc. If the organization has data which indicates that relevant variables significantly affect energy performance, normalization should be carried out to enable comparison of energy performance. Normalization is used to account for the changes in the relevant variables to monitor and evaluate energy performance, and evaluate and demonstrate energy performance improvement.

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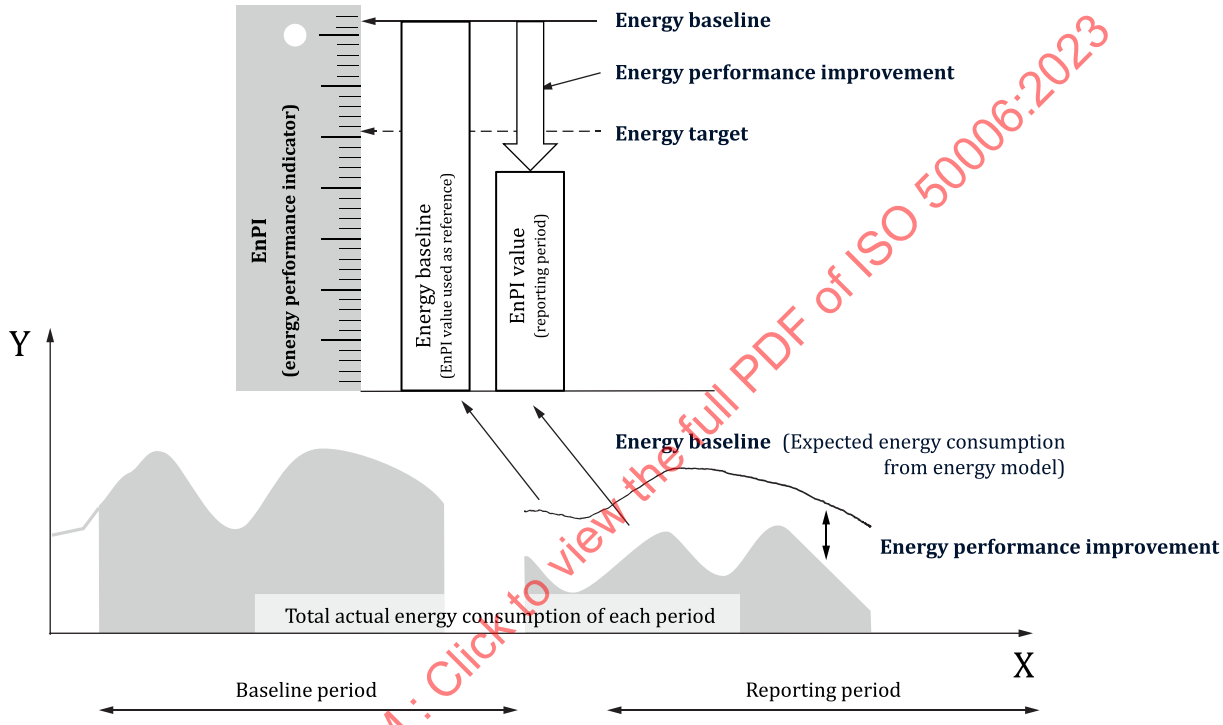
Energy targets are set by the organization and may be based on identified and planned energy performance improvement opportunities.

Figure 1 illustrates an example of the relationship between energy performance improvement, EnPIs, EnBs, EnPI values and energy targets. Figure 1 also illustrates how energy performance improvement is achieved when an EnPI value improves compared with the EnB, whether or not energy targets are met.

The process to develop, use and update EnPIs and EnBs is described in detail in Clauses 5 to 10. This process helps the organization to monitor and evaluate energy performance and demonstrate energy performance improvement. The processes within the EnPI and EnB planning are presented in Annex A.



Key

X time

Y energy consumption

NOTE The trend of changing energy consumption indicates that there is (are) relevant variable(s) and normalization is required.

Figure 1 — Example of conceptual relationship between energy performance, EnPIs, EnBs, EnPI values and energy targets

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5 Obtaining relevant energy performance information

5.1 Initial-energy-performance-related information

Organizations should identify current types of energy uses and evaluate current and past energy consumption and energy efficiency based on measurement and other data. Significant energy uses (SEUs) are identified by analysing this information together with factors that affect energy performance.

This process helps to identify the SEUs and prioritize opportunities for energy performance improvement.

NOTE This process is defined in ISO 50001:2018, 6.3 as “energy review”.

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5.2 Determining users of energy performance indicators

EnPIs should be developed to meet the needs and expectations of different users and should be easily understandable.

Multiple EnPIs can be required to meet user needs. Aligning the EnPI boundaries with functional roles can ensure that the EnPIs meet user needs and that responsibility for managing the EnPI can be effectively assigned.

EnPIs can be developed for internal or external users. Internal users can use EnPIs for a wide variety of purposes such as, but not limited to, maintenance, operation and energy performance evaluation. External users typically use EnPIs to meet information requirements derived from legal requirements and other requirements (e.g. sustainability reports).

NOTE EnPIs and EnBs required for external purposes, such as those for government reporting, are not always sufficient for managing energy performance improvement under ISO 50001 or for organizations wishing to understand their actual energy performance improvement.

Table 1 describes some common EnPI users.

Table 1 — EnPI users

Types of EnPI users	Typical needs
Top management	Top management needs information from EnPIs to understand the energy performance of the organization and to support energy performance improvement actions.
Energy management team	Group who supports the organization, including top management in: a) setting up an EnPI, b) maintaining an EnPI, c) monitoring EnBs, current EnPI values, values of all relevant variables in predetermined intervals, d) setting energy targets and calculating extent of achievement of energy target, e) conducting normalization and comparison of current EnPI values with EnBs and energy target, f) reporting of EnPI values and deviations, and g) interpreting the results.
Plant or facility management	Typically controls resources within the plant or facility and is responsible for results. The plant or facility manager should understand both planned energy performance and investigate and respond to significant deviations in energy performance and in financial terms. Plant or facility managers may use all of the EnPIs in their plant or facility including the EnPIs regarding their SEUs, and comparable EnPIs from other sites for benchmarking purposes.
Operation and maintenance personnel	Responsible for using EnPIs to control and ensure efficient operation by taking actions for significant deviations in energy performance, eliminating energy waste and undertaking preventive maintenance. Operation and maintenance personnel may use the EnPIs relevant to the process or equipment for which they have responsibility.
Engineers	Plan, execute and evaluate an energy performance improvement action using suitable EnPIs including the method(s) used to evaluate energy performance improvement.
External users	External users such as regulatory bodies, professional and sector associations, EnMS auditors, customers or other organizations can need information from EnPIs to feed into their relevant processes.
EnPI owner	Person who is responsible for monitoring, analysing and reporting an EnPI and its values.

5.3 Defining the energy performance indicator boundaries

To measure energy performance, suitable measurement boundaries for each EnPI should be specified. When specifying an EnPI boundary the organization should consider the user needs (see 5.2) and also:

— organizational responsibilities in relation to energy management, including the level of control and/or influence which the organization has over its energy performance;

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— the SEUs;

— facilities, equipment, systems or energy-using processes that the organization wishes to isolate and manage;

— the ease of isolating the EnPI boundary by measuring energy consumption and relevant variables;

— the EnMS boundary;

— available data for energy consumption and relevant variables.

The three primary EnPI boundary levels are individual, system and organizational as described in Table 2.

Additional information on EnPI boundaries can be found in Annex B.

Table 2 — The three EnPI boundary levels

EnPI boundary levels	Description and examples
Individual (facility/equipment/ energy-using process)	The EnPI boundary can be defined around the physical perimeter of a facility, equipment or energy-using process which the organization wishes to isolate and manage. EXAMPLE 1 The energy use of steam production equipment separate from other energy uses.
System	The EnPI boundary can be defined around the physical perimeter of a group of facilities/equipment/energy-using processes interacting with each other that the organization wants to control and improve. EXAMPLE 2 The steam production and the steam using equipment, such as a dryer.
Organizational	The EnPI boundary can be defined around the organization also taking into account the responsibility in energy management of individuals, teams, groups or business units as designated by the organization. EXAMPLE 3 Steam purchased for a factory(ies), or a department of the organization.

5.4 Defining and quantifying energy flows

The organization should identify energy flows across the boundary. The organization can use a diagram (e.g. see Figure 2) to determine the energy information required to establish EnPIs. The diagram shows energy flows within and across the EnPI boundaries. They can also include additional information, such as metering points and product flows which are important for energy analysis and establishment of EnPIs.

The organization should measure energy flows across each EnPI boundary. This includes delivered and on-site generated energy. Consideration should be given to energy which crosses the EnPI boundary and is stored.

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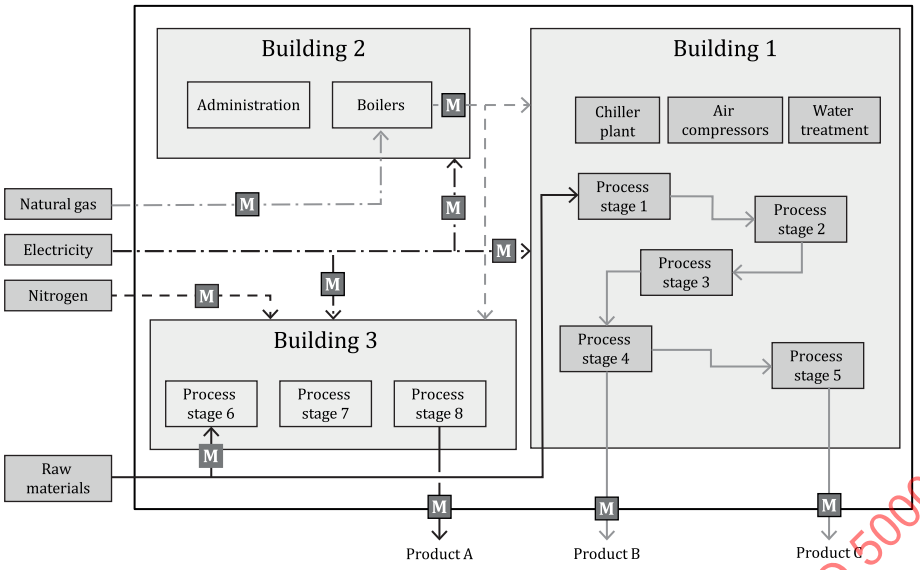

Key

M measurement

Figure 2 — Energy, raw material and product flow diagram

5.5 Defining and quantifying variables related to energy performance

Organizations should determine relevant variables for each EnPI boundary. For example:

a) using more electricity to produce some products compared to another, the organization should consider using product mix as a relevant variable;

b) using more natural gas in the winter, the organization should consider using heating degree days as a relevant variable.

The factor that affects the amount of energy consumption required should be considered for relevant variables.

Table 3 presents considerations that are used to identify variables.

Table 3 — Considerations used to identify variables

Aspects	Description
Inputs	Input-related variables are based on the quality and/or quantity of inputs which enter the boundary (e.g. milk entering a pasteurization process).
Process	Process-related variables relate to the activities within the boundary. An example can be the different process temperatures and residence times required to complete process steps. In a building, a process related variable can be occupancy.
Outputs	Output-related variables are outputs which exit the boundary. In a manufacturing process, an output related variable can be the quantity of product produced.
Environment	Environment-related variables are based on the external environment (e.g. heating degree days, cooling degree days, relative humidity).

The variables may be directly measured or derived from measurements (e.g. production is directly measured whereas heating degree days is derived from measurements of outside environment temperature and base temperature).

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Analysis of data collected by the organization can indicate relevant variables. A methodology to determine which variables are relevant is described in Annex D.

If the determination of relevant variables within a selected boundary is difficult, the boundary can be adjusted (e.g. subdivided).

5.6 Collecting data

5.6.1 Data collection

The organization should specify and collect the data related to energy consumption and relevant variables for each EnPI. It should plan the access to the collected data, the timing of collection, the process of collection and storage, and any pre-analysis cleaning or manipulation of the data.

It is possible that an organization will find that some of the EnPIs which were previously identified are not measurable due to data limitations or other barriers. In such cases, the organization should assess and consequently revise the EnPIs or introduce additional meters, measurement, or modelling methods.

If the expenditure towards installation of new meters, sub-meters and/or sensors to collect data on the required variables is justified by the improvement in its energy performance, the organization should specify such metering in its data collection plans.

In cases where more detailed energy consumption data are not available, energy bills can be used.

Consideration should be given to variation in the billing period between bills.

Table 4 describes examples of challenges in gathering data.

Table 4 — Energy data collection challenges

Scenarios	Description and examples
Lack of detailed measured data from energy suppliers	When an organization does not have detailed measured data from energy suppliers, they may consider additional options for measurements provided by themselves or through their energy supplier.
Lack of data on relevant variables	When an organization does not have data for certain facilities, equipment, systems or energy using processes, they may add measuring instruments to acquire these data, or use external sources such as official weather data. A proxy variable can be used for relevant variables for which data are not directly available (e.g. electricity consumption representing elevator usage as a proxy for building occupancy).

5.6.2 Data quality

The quality, precision and accuracy of the data collected to calculate EnPIs needs to be considered if the calculated results are to be meaningful. Prior to calculating EnPIs and their corresponding EnBs, the organization should review the set of measured energy consumption and relevant variables to determine the data quality.

Ensuring that data used are of appropriate quality and completeness can help increase the robustness of the determined EnPI value and ensure that they meet the needs of the organization. Factors to consider in determining the appropriate quality of data may include the following:

— the method of collection, i.e. manual or automatic;

— the source of data, e.g. third-party weather station data;

— the frequency of data collection, i.e. covering all shifts, hourly, daily, monthly, working hours and seasons;

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— the accuracy of meters and measuring equipment;

— precision (measurement uncertainty regarding bias, linearity, resolution, etc.);

— repeatability of data from the data source;

— validation of the data.

5.6.3 Measurement

Measurements can be taken continuously (e.g. using data from a supervisory control and data acquisition system or a data acquisition and handling system), on a temporary basis (e.g. using data loggers) or on a spot basis (e.g. using mobile/portable meters). If continuous measurement is not possible, the organization should ensure that spot or temporary measurements are made during periods that are representative of typical operating conditions (see 5.6.2).

Energy consumption may be measured by using permanent or temporary, meters or sub-meters, or may be estimated by other means such as engineering calculations or modelling. Wherever possible, permanent meters should be installed for measurement. Temporary meters may be used during energy audit or where continuous measurements are not required. The organization should be aware of the accuracy and repeatability of the measuring equipment and should consider the relative importance of the decisions being made as a result of the data collected from these measurement instruments.

In many cases, the quantity of energy consumed can only be measured indirectly. This can require measuring a flow, volume or mass of fuel supplied, and can vary with factors such as composition, outdoor temperature, pressure and other factors. Multipliers or factors are commonly applied to the actual measured flow of gas or liquid fuel to calculate the quantity of energy contained in the fuel. These should be based on verifiable sources.

5.6.4 Data collection frequency

The data collection period and frequency should be sufficient to capture a range of operating conditions and provide an adequate number of data points for analysis. The organization should select an appropriate data collection frequency (e.g. hourly, daily, weekly) for the energy consumption and relevant variables included in each EnPI and the corresponding EnB.

NOTE Data collection frequency is typically based on available data (e.g. monthly energy bills).

The data collection frequency may be much higher than the frequency of reporting in order to measure and understand the impact of relevant variables on energy performance. For example, hourly, daily or weekly data collection can be needed at the operational level to address significant deviations. Such energy consumption and relevant variables should be aggregated for periodic review (e.g. monthly reviews at the organizational level).

For statistical analysis, it is necessary that energy consumption and associated relevant variable data have the same time intervals.

Even if the data collection period is the same (e.g. monthly), the data periods for energy and the relevant variables can be different. In such cases, the data periods should be adjusted so that the data period for energy and relevant variable data are aligned.

EXAMPLE Energy consumption is metered on the 20th day of each month and provided as an energy bill. The relevant variable (production) is measured at the end of each month. The organization decides to unify the timing of metering to the 20th day of every month and to estimate the data of production.

5.6.5 Identifying and analysing outliers

Faulty metering, faulty data capture or unusual operating conditions can produce significant outliers. Before excluding an outlier, investigations should be carried out to determine if there is a legitimate

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reason for the outlier. If some outliers are excluded, care should be taken to ensure that this does not introduce bias into the EnPI value or its corresponding EnB.

EXAMPLE An annual plant shutdown can result in a significant variation in energy consumption.

Outliers may be identified by appropriate methods (e.g. scatter diagram, trend line). Data points more than a pre-determined number of standard deviations from the expected value of the trend line or function may be outliers.

6 Determining energy performance indicators

6.1 General

While selecting appropriate EnPIs, the effects of relevant variables and the needs of users of the information are key factors to be considered.

If appropriate, organizations should determine EnPIs including at least one EnPI for each SEU.

There are many other types of indicators that are used to monitor other parts of the EnMS as defined by the organization (e.g. control of SEUs, increase employee awareness of energy, benchmarking equipment or processes). Care should be taken in using these indicators as EnPIs as they do not always appropriately monitor energy performance or appropriately represent measures of energy performance improvement.

While choosing EnPIs, the organization should consider its existing measurement and monitoring capabilities, related to energy consumption and relevant variables.

Annex C provides additional information on the selection of EnPIs.

When the organization's objectives include reduction of greenhouse gas emissions, it should consider using additional indicators with CO_2 emission factors. See Annex G for additional information.

EnPIs can be used for a variety of purposes such as:

— understanding the energy performance of facilities, equipment, systems or energy-using processes;

— communicating information and engaging the organization in issues related to energy performance;

— tracking progress towards energy targets;

— managing and controlling SEUs;

— monitoring and measurement of energy performance;

— evaluating and demonstrating continual energy performance improvement.

EnPI values may be available from measurements or calculations.

6.2 Expressing energy performance indicators

6.2.1 Statistical model

6.2.1.1 General

The organization should normalize (see Clause 8) its energy consumption or energy efficiency using an appropriate energy model. An energy model can be used to calculate the expected energy consumption or the expected energy efficiency.

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6.2.1.2 One relevant variable

6.2.1.2.1 General

In cases where there is only one relevant variable, a simple linear regression or a nonlinear regression energy model for energy consumption or energy efficiency can be used.

A simple linear regression energy model for energy consumption can be expressed by Formula (1):

$$Y = mx + C \tag{1}$$

where

Y is the energy consumption;

m is the energy consumption per unit of the relevant variable;

x is the value of the relevant variable;

C is the base load energy consumption, not related to the relevant variable.

Special cases of the linear regression energy model are described in 6.2.1.2.2 and 6.2.1.2.3.

6.2.1.2.2 Simple metric

In the specific case where $m = 0$, the energy model can be expressed by Formula (2):

$$Y = c_E \tag{2}$$

where

Y is the energy consumption;

c_E is the constant energy consumption.

A simple metric can be used as an EnPI where there are no relevant variables affecting energy consumption. Whether a simple metric is appropriate or not can be established by observing a trend of energy consumption over time. This means that the daily, weekly or monthly energy consumption varies within an acceptable range as established by the organization. If Y is not constant, or within an acceptable range established by the organization, then this indicates that there can be relevant variables and normalization is required.

6.2.1.2.3 Ratio

In the specific case where $c = 0$, the energy model can be expressed by Formula (3):

$$Y = mx \tag{3}$$

where

Y is the energy consumption;

m is the energy consumption per unit of the relevant variable;

x is the value of the relevant variable.

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In this specific case where the base load is zero, ratio of energy consumption per unit of the relevant variable (m) gives an appropriate energy model. This is usually known as specific energy consumption (SEC).

A ratio can be used as an EnPI when there is one relevant variable affecting energy consumption and there is no base load energy consumption.

6.2.1.3 Multiple relevant variables

In cases where there is more than one relevant variable, a multiple linear regression or a multivariable regression energy model can be used. A multiple linear regression energy model for energy consumption can be expressed by Formula (4):

$$Y = m_1x_1 + m_2x_2 + \ldots + m_nx_n + c \quad (4)$$

where

Y is the energy consumption;

$m_1, m_2, \ldots m_n$ are the energy consumption per unit of relevant variables;

$x_1, x_2, \ldots x_n$ are the relevant variables;

c is the constant value.

In practice, an energy model with multiple relevant variables is most common.

6.2.2 Aggregated models

An aggregated energy model can be calculated by combining different energy models.

Condition-based models are also aggregated models. In this case, different energy models are applied on either side of a threshold value (N) of a relevant variable. A condition-based model can be expressed by Formulae (5) and (6):

$$Y = f(x_1, x_2, \ldots x_n) \text{ -- if } x_i > N \quad (5)$$

$$Y = g(x_1, x_2, \ldots x_n) \text{ -- if } x_i <= N \quad (6)$$

where

Y is the energy consumption;

f is the energy model considering the relevant variables, when the relevant variable x_i is above the threshold value (N);

g is the energy model considering the relevant variables, when the relevant variable x_i is below or at the threshold value (N);

$x_1, x_2, \ldots x_n$ are the relevant variables.

EXAMPLE The state of a plant includes not only “in operation” but also “part-load” and “standby”. A condition-based model can be used if it cannot be treated as an outlier.

6.2.3 Engineering model

Engineering models are often described by physical or empirical laws (e.g. equation relating fluid resistance and flow velocity to pump power consumption).

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Engineering models can be used for calibrated simulation to assess the energy performance of simple and complex facilities, equipment, systems or energy-using processes.

NOTE Calibrated simulation is a simulation that adjusts parameters of the energy model so that the actual energy consumption and the simulation result (expected energy consumption) are equivalent.

The organization can use existing engineering models (e.g. for buildings). However, creating an engineering model can require particular expertise.

7 Establishing energy baselines

7.1 Concept of EnB

The EnB is used for the comparison of energy performance. Comparison is made for monitoring energy performance and demonstrating energy performance improvement.

The following steps should be taken to establish an EnB:

— determine the specific purpose for which the EnB will be used;

— determine a suitable data period;

— collect the data;

— analyse the data to develop a method of normalization (if applicable);

— determine and evaluate the EnB.

7.2 Determining baseline period

When establishing the EnBs the organization should determine a suitable period considering its energy goals and targets along with the nature of its operations. The baseline period should be long enough to ensure that the variability in operating patterns is accounted for by the EnPI and EnB (seasonality in production, weather patterns, etc.).

The frequency with which an organization acquires data can be a consideration in determining a suitable baseline period.

Table 5 presents typical baseline periods to be considered.

If an organization wishes to monitor EnPIs every day, even where a baseline period is one year, daily data are required for the EnB. In this case, the EnB is set for one year of daily data.

Table 5 — Typical baseline periods to be considered

Typical periods	Description and examples
One year	The most common baseline period is one year. It can capture a full range of weather conditions or business operating cycles.
Less than one year	A shorter period may be used where energy consumption is seasonal (e.g. a vegetable canning factory, ski resort). Short EnB durations can also be necessary for situations in which there is an insufficient quantity of reliable, appropriate or available historical data.
More than one year	Seasonality and business trends can combine to make a multi-year EnB optimal (e.g. a winery wants to track energy performance only during the crushing and fermentation period of each year; however, over multiple years).

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8 Normalization

8.1 Concept of normalization

During the operation of any facility, equipment, system or energy-using process the relevant variables routinely change. As a result, the energy performance, energy consumption and energy efficiency appear to fluctuate. Normalization is used to calculate the EnB to account for changes in the relevant variables.

The organization should establish an EnB for each EnPI using values of energy consumption and relevant variables during the baseline period. The EnB should be normalized if the organization has data indicating that certain variables significantly affect energy performance.

The organization should measure its actual energy consumption during the reporting period and compare it versus the expected energy consumption. An example of how to monitor and measure energy performance is shown in Figure 1.

Energy performance improvement is evaluated by the organization by comparing the EnPI value against the corresponding EnB.

A stepwise procedure is presented in Annex D as a guidance to carry out normalization.

A numerical example of the application of this procedure is given in Annexes E and F.

8.2 Uncertainty of model

When developing EnPIs and EnBs organizations should consider the uncertainty of measurements and of the energy model. Additional resources should be considered for higher accuracy.

Organizations should select an energy model that will result in EnPI values with the appropriate uncertainty for each comparison purpose. In the operation of facilities, equipment, systems or energy-using processes, EnPI value is compared with the operation criteria (e.g. upper and lower limits) and the energy target.

9 Maintaining energy performance indicators and energy baselines

9.1 General

When changes to facilities, equipment, systems or energy-using processes occur, energy efficiency, energy consumption and associated relevant variables can be impacted. The organization should ensure that the current EnPIs, the corresponding boundaries and EnBs are still appropriate and effective in measuring energy performance. If they are no longer appropriate, the organization should review or develop new EnPIs and corresponding EnBs.

There are several tests for determining whether the EnPI and EnB are still appropriate or valid including:

a) the relevant variables used to determine the expected energy consumption from the energy model should fall within one of the following:

   1) within the range of relevant variables used in the model;

   2) not exceeding a pre-determined number of standard deviations from the mean of the relevant variable data;

b) identifying major changes in static factors which can invalidate the determination of energy performance under equivalent conditions.

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The baseline period can be revised (e.g. shifted to a different time period), or energy performance can be calculated without changing the baseline period.

Table 6 illustrates circumstances that can require organizations to revise EnPIs and corresponding EnBs.

Table 6 — Examples of circumstances that may require revision of EnBs and EnPIs

Common changes	Description and examples
Static factors	If a static factor (see 9.2) changes, the related EnB may be revised. In some cases, it can be necessary to develop a new EnPI and EnB. Statistical tests may establish whether an organization should develop a new EnB or EnPI. For example, these can include major production processes added or stopped and or changes to the number of production shifts or substantial modifications to the building structure and building equipment.
Relevant variables	When the relevant variable significantly changes and operates significantly outside of the range upon which the baseline was established, a new EnB and associated EnPI should be established.
Energy type	When an organization changes the types of energy it is using, it may need to modify what is tracked (EnPIs) and how those factors are weighted in its EnB.
Data availability	Improvements to the facility's metering and data collection system can result in better quality data becoming available or new relevant variables coming to light. It can be necessary to revise EnPIs and EnBs.
Data frequency	If data are collected at more regular intervals or at a higher frequency, this can enable more effective management with a new EnPI and EnB.
Baseline period	Organizations may wish to update the baseline period to lock in accomplishments to date and focus on improving against the current energy performance instead of a past period. A strategic decision of such a nature can necessitate the updating of the baseline period to a more recent period (such as the last year) to serve as the new reference point.
According to a predetermined method	The organization can find it useful to identify conditions in advance that can require a revision of EnPIs and corresponding EnBs. For example, many organizations update their EnBs annually.

9.2 Static factor changes

Static factors need to be considered if they change, and if that change affects the relationship between energy consumption and relevant variables.

Table 7 describes examples when changes in static factors require revising the EnPIs or EnBs.

Table 7 — Static factor changes that require revision of EnPIs or EnBs

Scenarios	Description and examples
Change in product type	A plant produces a consistent set of products. The introduction of a new product that changes the set of products should be considered as a static factor.
Change in shifts per day	A plant has a fixed number of production shifts per day. If the number of shifts increases or decreases, then this should require maintenance.
Change in building occupancy	A building has a relatively stable number of occupants. If the number of occupants significantly increases or decreases due to new leases, then this should require maintenance.
Change in floor area	A building has a fixed floor area. If the organization significantly expands the building, or sells or rents out part of it, then this should require maintenance.

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10 Monitoring and reporting of energy performance and demonstrating energy performance improvement

10.1 General

Energy performance can be monitored using EnBs and EnPIs for the following purposes:

— to ensure that operational control of processes is effective;

— to demonstrate energy performance improvement;

— to monitor progress towards achievement of energy targets.

Energy performance should be presented to users based on their needs and roles.

10.2 Monitoring and reporting

Energy performance can be monitored by comparing the actual energy consumption (EnPI value) against the expected energy consumption (EnB) on an hourly, daily, weekly or monthly basis. Monthly comparison can be adequate in the initial stages of developing these concepts.

Several tools and techniques are used to monitor and report energy performance, based on the energy model, including:

— monitoring the difference between the actual and the expected energy consumption using a trend chart of EnPIs (and relevant variables);

— monitoring the cumulative sum (CUSUM) of the difference between the actual and the expected energy consumption using a trend diagram;

— comparing the difference between the actual and the expected energy consumption with an energy target (energy target can be calculated as a targeted percentage reduction from the expected energy consumption);

— monitoring the energy consumption and the production by using a scatter diagram.

In each case, the information can be represented graphically or in tables.

The process of monitoring energy performance using EnPIs is routine. If an unexpected result is observed, the cause should be investigated by:

— investigating operational control of the equipment/systems to establish the cause of the deviation;

— if the deviation is causing excessive energy consumption, taking corrective action to prevent the deviation from occurring again;

— if the deviation is a result on unexpectedly low consumption, establishing the cause and trying to embed this action into normal operations;

— ensuring that the data are accurate;

— considering if a static factor has changed.

The results of EnPI monitoring can also be reported in summary or in detail.

10.3 Demonstrating energy performance improvement

Organizations can need to demonstrate energy performance improvement.

Improvement in energy performance should be evaluated by comparing EnPI values against the corresponding EnB(s).

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This can be done at facility level, SEU level, process level, etc.

Table 8 illustrates some common approaches to monitor and report on energy performance improvement.

Table 8 — Monitoring, reporting and demonstrating energy performance improvement

Method	Description and examples	Formula
Difference	Difference between the reporting period EnPI value (R) and the EnB (B). The cumulative sum of $R - B$ is a useful technique for monitoring and for demonstrating improvement.	$R - B$
Per cent change	Difference between the reporting period EnPI value (R) and the EnB (B), expressed as a percentage of the EnB.	$[(R - B)/B] \times 100$
Ratio	Ratio of the reporting period EnPI value (R) and the EnB (B).	(R/B)
Index	Ratio of the reporting period EnPI value (R) and the EnB (B), expressed as a percentage.	$(R/B) \times 100$
Key B is the EnB. R is the reporting period EnPI value.		

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Annex A
(informative)

EnPI and EnB planning process

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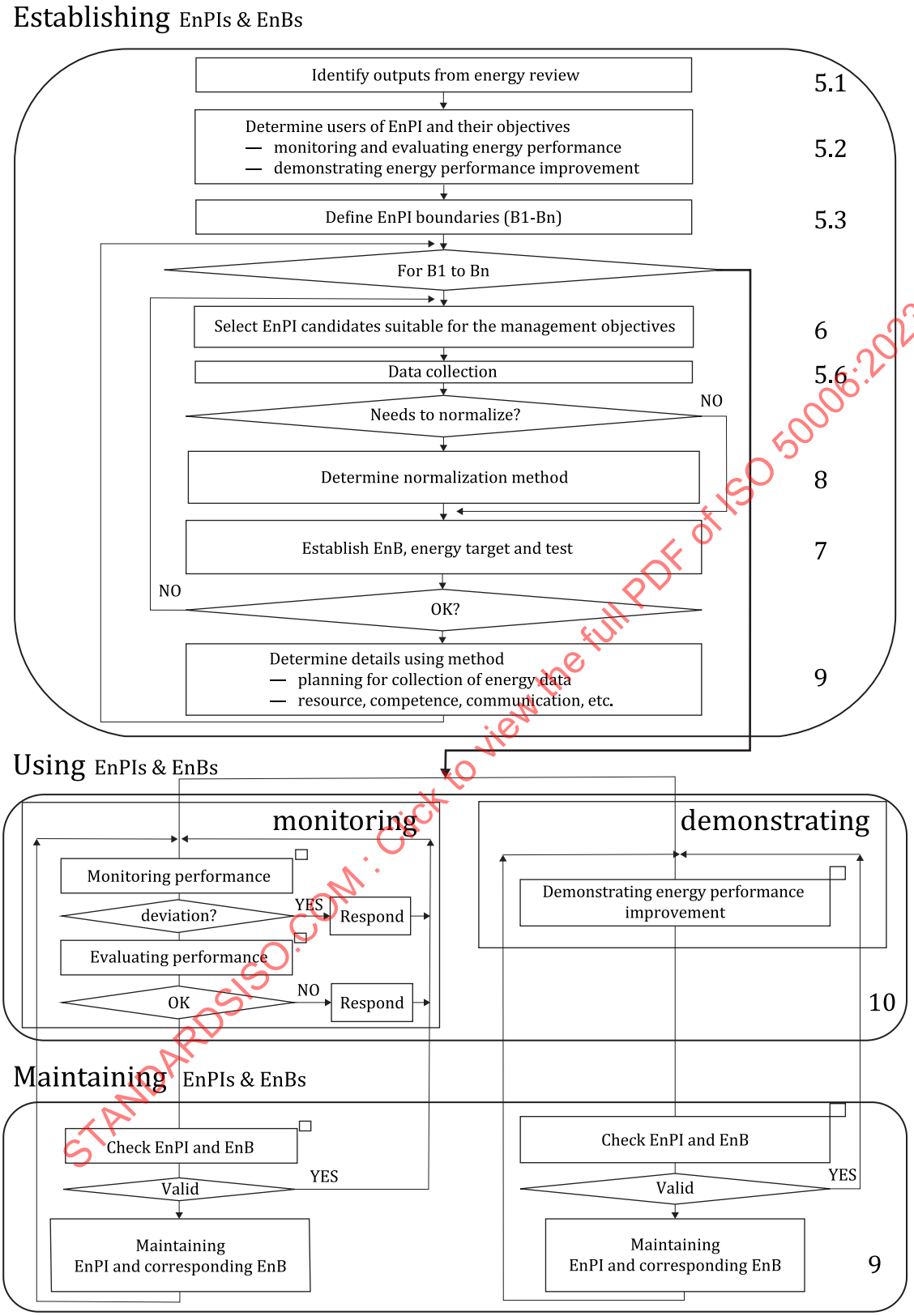

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Figure A.1 — EnPI and EnB planning process

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Annex B
(informative)

Examples of EnPI boundaries

During the process of measuring, monitoring, analysing and evaluating energy performance, and demonstrating energy performance improvement, it is important to find the most inefficient part of the production system. An EnPI boundary can be used effectively to focus on this part by narrowing the boundary. As a first step, the EnPI boundary is the entire organization. In such cases, the target boundary should be divided into several EnPI boundaries. As next steps, the EnPI boundaries should be narrowed down to the SEU level for identifying areas in which energy performance can be improved. Figure B.1 shows the EnPI boundary division process.

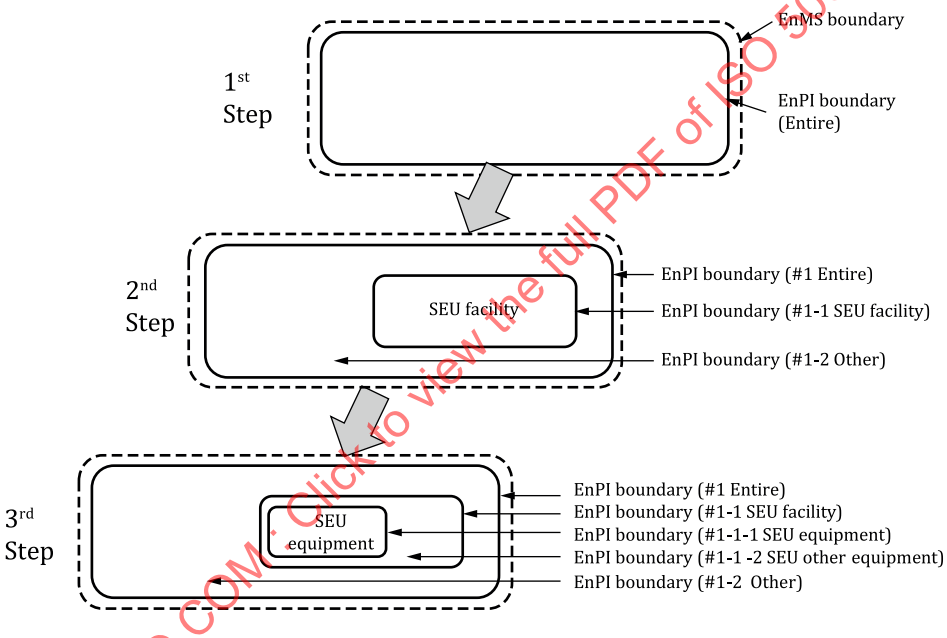

Figure B.1 — EnPI boundaries division process

When dividing the EnPI boundaries, organizations should consider that:

a) the number of divisions should be minimized;

b) it is recommended that the boundary is first divided into two parts such as SEU and other;

c) facilities that work in the same way should be categorized together;

d) the facility can be divided on the basis of process (e.g. process for product X, process for product Y and utilities);

e) the EnBs can be established for each operational status of the EnPI boundary.

The operational status refers to production ramp-up, normal operation, production hold, production stop, etc. As a minimum, it is recommended that organizations establish at least two EnB operational status conditions: under production conditions, and under non-production conditions.

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Annex C
(informative)

Examples of energy performance indicators

Table C.1 provides descriptions about the expression of EnPIs, as well as examples of their applications. It outlines the various EnPI calculation methods as well as when an organization should choose each method. All methods should be regularly maintained to ensure valid results.

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Table C.1 — Expression of EnPIs — Applications and examples

Categories	Typical uses	Examples of EnPIs and applications	Observations
No relevant variable (simple metric, see 6.2.1.2.2)	— Measuring reduction in absolute consumption of energy. — Meeting regulatory requirements based on absolute savings. — Understanding of trends in energy consumption. — Monitoring and determining energy performance improvement in cases where there are no relevant variables which affect consumption. — Energy value as a basic EnPI to understand real energy use and calculate other EnPIs.	EnPIs: — energy consumption (kWh, GJ); — electricity consumption for lighting (kWh); — fuel consumption for a boiler (GJ).	— Does not take into account the effects of relevant variables, giving misleading results for most applications. — Can be obtained from a utility meter/bill.
One relevant variable (ratio, see 6.2.1.2.3)	— Expressing the energy efficiency of a piece of equipment or a system, particularly under standard or equivalent conditions. — Monitoring the energy efficiency of systems that have only one relevant variable and no base load. — Meeting regulatory requirements based on energy efficiency.	EnPIs and applications: — kWh/t of production; — GJ/quantity of product; — l/100 km.	— Can be appropriate where there is one relevant variable and no base load and is misleading in other cases. — Metrics of energy performance improvement SEC type EnPI value calculations should be avoided unless otherwise required for legal requirements or other requirements. Where SECs are required, it is good practice to include the underlying assumptions when reporting these values. — Statistical tests can be required to confirm that there is no base load and that other relevant variables do not exist.

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Table C.1 *(continued)*

Categories	Typical uses	Examples of EnPIs and applications	Observations
Statistical model	— System with one or more relevant variables and significant base load energy consumption. — At the system and organizational level. — Determining energy performance improvement within the relevant variable ranges during the baseline period. — Evaluation of potential energy performance improvement opportunities, e.g. by evaluating different modes of operation of equipment or processes. — Verification of energy savings from an implemented energy performance improvement opportunity.	EnPIs: — modelled energy-based unit. Applications: — model of energy performance of a production facility with one or more production types; — model of energy performance of a hotel with variable occupancy rate and outside temperature; — model of the relationship between the energy consumption of a pump/fan and the flow rate.	— Linear regression models with one or more relevant variables are commonly used and held as a best practice by many practitioners when monitoring energy performance and determining energy performance improvement for a facility. — If the boundary is complex, the boundary should be divided according to the organization, activity type, etc, before applying the statistical model. This division reduces the number of relevant variables and thus makes it easier to check and maintain the appropriateness of the model.
Engineering model	— To supplement energy flow measurements, and in some cases used to effectively infer or calculate energy flows from relevant variables. — At a design phase to conceptually optimize energy performance or estimate energy performance improvement for a specific energy performance improvement action (EPIA) before investments are made.	Applications: — Building modelling, including calibrated simulation, is another example of calculating an EnPI value from engineering models. — Model of a petroleum refinery. — Engineering models can be used even if relevant variables are not independent of each other (e.g. temperature and pressure). — Model of an electric arc furnace: in addition to the measured electrical and gas flows, carbon powder is added to the batch to adjust the chemistry of the steel. This carbon also adds combustion energy to the batch, and although the number of bags is typically tracked, the process model is often used to calculate the energy contribution.	— Sometimes referred to as simulations, engineering models can capture the energy performance of simple or complex systems and facilities. — Engineering models can encapsulate a large number of relevant variables and provide insights regarding process and/or system transient operation when properly calibrated to measured performance. — If well calibrated, engineering models can provide a normalized basis by which to determine energy performance improvement. — Engineering-based modelling can also be used to directly calculate energy losses or gains, e.g. additional waste heat recovery. — Engineering modelling accounts for changes in boundaries and static factors over time. — Details of engineering modelling are outside the scope of this document.

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Annex D
(informative)

Example of normalization stepwise process

D.1 Preparation for normalization

The organization should use spreadsheets or software with data analysis capabilities for statistical calculations and the normalization process. Specialized statistical analysis packages can also be used when available. Depending on the physical processes, the organization may choose a linear or nonlinear model.

The following items apply to the evaluation of validity of the model:

— The adjusted coefficient of determination (R^2) can be used to choose between the different models. Typically, it can be considered that a higher adjusted R^2 value represents a better model.

NOTE Standard error can also be used to determine the most suitable model. A lower standard error represents a better model.

— An F-test is used to evaluate the overall statistical significance of a regression model. The regression model is considered statistically significant when the F-test value is less than 0,1, indicating that at least one of the potentially relevant variables used in the model has a "significant" effect on energy consumption.

— The P-value criterion is typically used to determine if a variable significantly affects energy consumption. A P-value less than, for example, 0,1 or 0,05 is often used as the significance criterion. These figures indicate that there is a 90 % or 95 % chance that the variable has a systematic impact and is thus significant.

D.2 Step 1 — Collection of data for the baseline period

The potentially relevant variables are selected based on brainstorming or by considering variables related to inputs, outputs, process and environment (see 5.5).

Considering the EnPI boundary, the data are collected for energy consumption and the selected relevant variables and tabulated for further analysis.

D.3 Step 2 — Correlation test

The purpose of step 2, which is optional, is to get a preliminary analysis of the relationships between the energy data and the variables.

A correlation test on all energy types and all potentially relevant variables should be carried out in order to obtain values for the coefficient of determination R^2 for each single relation.

NOTE The correlation test is used to evaluate the association between two or more variables.

D.4 Step 3 — Regression analysis

Regression analysis is carried out to quantify the effect of each potentially relevant variable on the energy consumption. The results of the regression analysis are examined to establish which variables are relevant.

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If more than one variable does not meet the P-value criterion, the one with the highest P-value is eliminated and the regression analysis is repeated with the remaining variables. There needs to be a technical understanding of why a variable is being eliminated. It can be due to inaccurate data or poor operational control. This process continues until all variables have a P-value of less than 0,1. This is the resultant energy model and the coefficients of each relevant variable, and the intercept are used as the baseline model.

After checking the significance of the coefficients, collinearity, which can lead to distorted results of the analysis, can be checked using various tests and indicators such as the variance inflation factor (VIF).

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Annex E
(informative)

Example of normalization

E.1 General

The following example is for a heating system of a building. It outlines the basic steps taken to develop an energy model that can be used to determine and monitor energy performance and demonstrate energy performance improvement.

NOTE Gas consumption is normally measured in m^3 but also can be expressed in kWh. The conversion is made using the formula: gas consumption (kWh) = gas consumption (m^3) × calorific value × volume correction factor / unit conversion factor.

E.2 Boundary and collection of energy data

An EnPI boundary was established for the whole building including all energy uses within. Monthly gas consumption data for this EnPI boundary was collected from available sources for the baseline period. The baseline period was established to be 1 January 2020 to 31 December 2020 as this time period fully captures all operational conditions during different seasons. The data was entered into a spreadsheet (see Table E.1).

Table E.1 — Monthly as consumption of the baseline period

Year	Month	Measured gas consumption kWh
2020 (baseline period)	January	1 414
	February	916
	March	1 007
	April	921
	May	475
	June	260
	July	218
	August	252
	September	635
	October	607
	November	1 038
	December	1 267

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E.3 Preliminary analysis of the data

A graph of monthly energy consumption data versus corresponding dates of the baseline period was generated (see Figure E.1), which indicates that the amount of natural gas consumed varies seasonally over the year.

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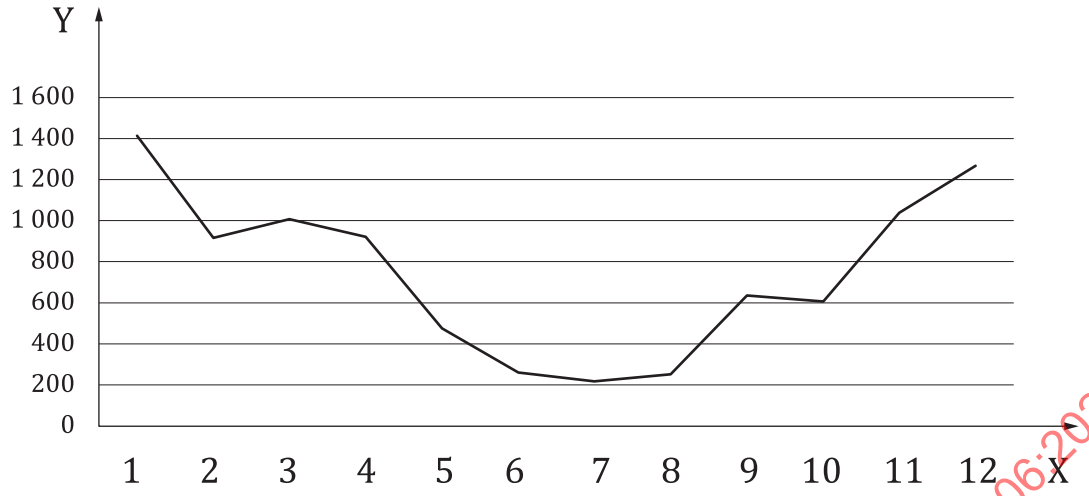

Key

X month (January to December)

Y gas consumption, in kWh

_____ measured gas consumption, in kWh

Figure E.1 — Gas consumption versus corresponding dates of the baseline period 2020

The consumption in the summer, where the heating unit is turned off, shows that there is a demand for heating energy (here for hot water, for washing hands, etc.) that is not dependent on the season (temperature) but can be seen as a base load throughout the year. These observations indicate that a simple metric and ratio are not suitable to use when determining energy performance and demonstrating energy performance improvement for the building. Accordingly, normalization is required.

Given that the natural gas consumed within the EnPI boundary is used by a heating system, heating degree days (HDD) data in kelvin days (Kd) were collected as a potentially relevant variable (see Table E.2). If the HDD are statistically significant, then it is chosen as a relevant variable.

Table E.2 — Consumption data and heating degree days

Year	Month	Measured gas consumption kWh	Heating degree days kelvin days (Kd)
2020 (baseline period)	January	1 414	598
	February	916	397
	March	1 007	325
	April	921	345
	May	475	95
	June	260	0
	July	218	0
	August	252	4
	September	635	168
	October	607	210
	November	1 038	393
	December	1 267	476

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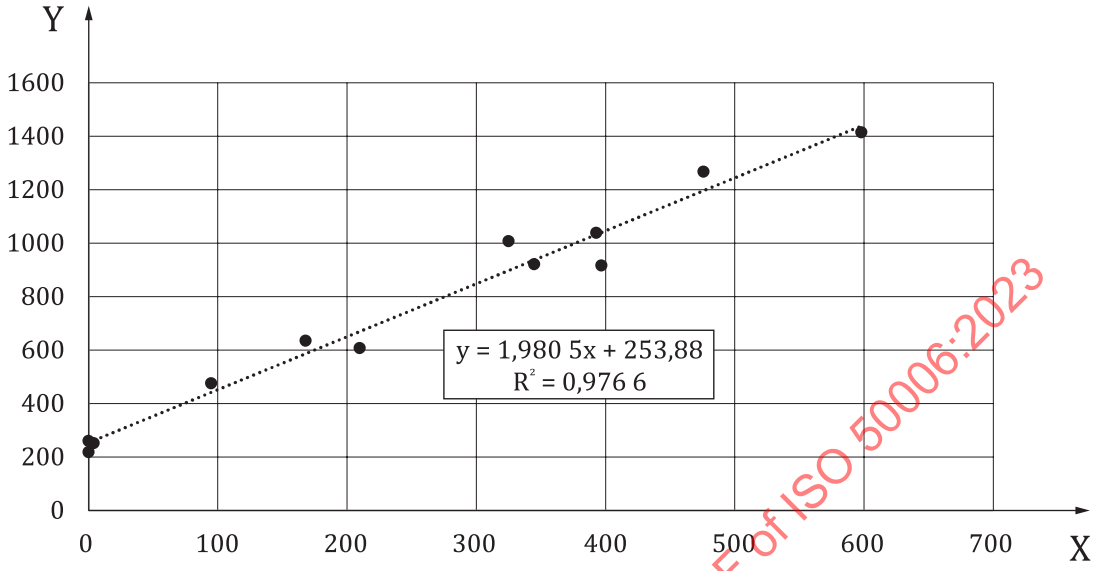
The HDD data was entered into the spreadsheet and a scatter diagram of HDD data against natural gas consumption data was developed. Visual analysis confirms a linear relationship between natural gas consumption and HDD exists (see Figure E.2).



Key

X heating degree days, in Kd

Y gas consumption, in kWh

Figure E.2 — Scatter diagram of monthly gas consumption versus heating degree days in 2020

E.4 Regression analysis

The method of linear regression was selected to create an energy model. To create the linear regression energy model, a trend line (line of best fit) was created with the energy consumption and HDD data (see Figure E.2). The resulting energy model is expressed as discussed in Formula (1) (see 6.2.1.2).

The gas consumption is function of HDD, and the baseload is represented by the constant which is typically expressed as gas consumption (kWh/month) = 1,980 5 (kWh/HDD per month × HDD per month) + 253,88 (kWh/month).

The R^2 of 97 % indicates a reasonable correlation.

NOTE Models with lower R^2 values can still be used to generate meaningful results. A general threshold for R^2 cannot be given as it is highly dependent on the variance in the analysed data.

E.5 Monitoring and reporting of energy performance and demonstrating energy performance improvement

This energy model enables calculation of expected energy consumption during a reporting period to monitor energy performance and determine energy performance improvement. For this, HDD data from January 2021 was obtained and inserted into the spreadsheet-based energy model to calculate the expected consumption for January 2021. The expected energy consumption (i.e. EnB) for January 2021 (1 1466 kWh) was then compared with the actual energy consumption for January 2021 (1 343 kWh) and the difference of –123 kWh indicates an energy performance improvement (see Table E.3).

Each individual month is monitored in the same way as with January 2021, by inserting the monthly HDD data into the energy model to calculate an expected energy consumption (i.e. EnB). The expected energy consumption is compared to the actual energy consumption and a difference is calculated. The difference can be positive or negative depending on the actual energy performance in the month.

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