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BSI Standards Publication

Energy management systems — Measuring energy performance using energy baselines (EnB) and energy performance indicators (EnPI) — General principles and guidance

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National foreword

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Energy management systems — Measuring energy performance using energy baselines (EnB) and energy performance indicators (EnPI) — General principles and guidance

Systèmes de management de l'énergie — Mesurage de la performance énergétique à l'aide des performances énergétiques de référence (PER) et d'indicateurs de performance énergétique (IPÉ) — Principes généraux et lignes directrices

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Foreword

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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 Technical Committee ISO/TC 242, *Energy management*.

Introduction

This International Standard provides organizations with practical guidance on how to meet the requirements of ISO 50001 related to the establishment, use and maintenance of energy performance indicators (EnPIs) and energy baselines (EnBs) in measuring energy performance and energy performance changes. EnPIs and EnBs are two key interrelated elements of ISO 50001 that enable the measurement, and therefore management of energy performance in an organization. Energy performance is a broad concept which is related to energy consumption, energy use and energy efficiency.

In order to effectively manage the energy performance of their facilities, systems, processes and equipment, organizations need to know how energy is used and how much is consumed over time. An EnPI is a value or measure that quantifies results related to energy efficiency, use and consumption in facilities, systems, processes and equipment. Organizations use EnPIs as a measure of their energy performance.

The EnB is a reference that characterizes and quantifies an organization's energy performance during a specified time period. The EnB enables an organization to assess changes in energy performance between selected periods. The EnB is also used for calculation of energy savings, as a reference before and after implementation of energy performance improvement actions.

Organizations define targets for energy performance as part of the energy planning process in their energy management systems (EnMS). The organization needs to consider the specific energy performance targets while identifying and designing EnPIs and EnBs. The relationship between energy performance, EnPIs, EnBs and energy targets is illustrated in Figure 1.

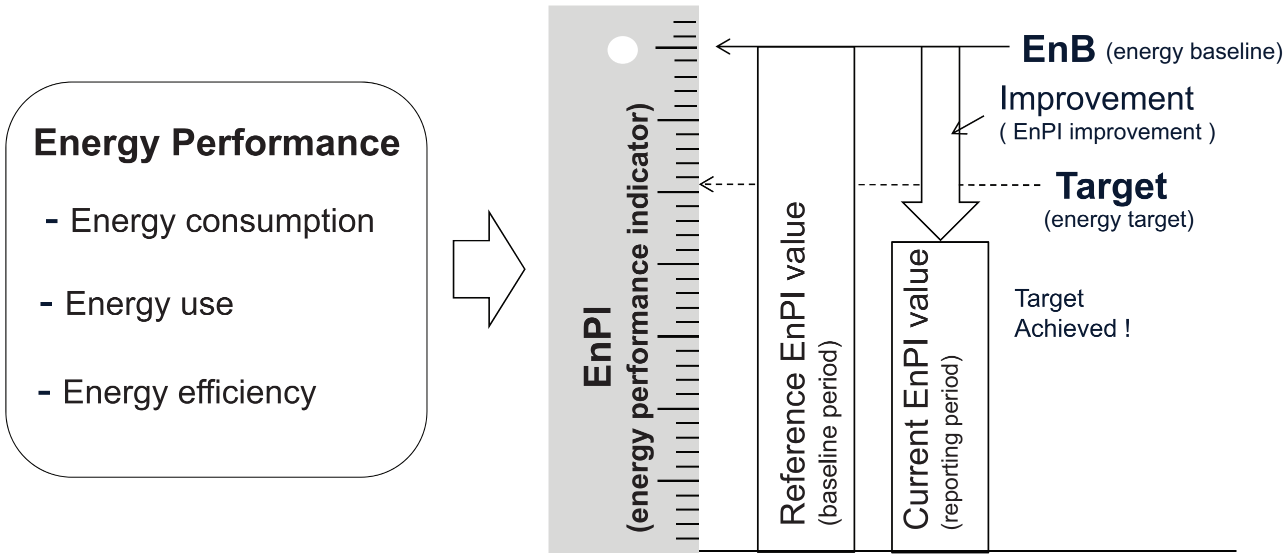


Figure 1 — Relationship between energy performance, EnPIs, EnBs and energy targets

This International Standard includes practical help boxes designed to provide the user with ideas, examples and strategies for measuring energy performance using EnPIs and EnBs.

The concepts and methods in this International Standard can also be used by organizations that do not have an existing EnMS. For example, EnPIs and EnBs can also be used at the facility, system, process or equipment level, or for the evaluation of individual energy performance improvement actions.

Ongoing commitment and engagement by top management is essential to the effective implementation, maintenance and improvement of the EnMS in order to achieve the benefits in energy performance improvement. Top management demonstrates its commitment through leadership actions and active involvement in the EnMS, ensuring ongoing allocation of resources including people to implement and sustain the EnMS over time.

Energy management systems — Measuring energy performance using energy baselines (EnB) and energy performance indicators (EnPI) — General principles and guidance

1 Scope

This International Standard provides guidance to organizations on how to establish, use and maintain energy performance indicators (EnPIs) and energy baselines (EnBs) as part of the process of measuring energy performance.

The guidance in this International Standard is applicable to any organization, regardless of its size, type, location or level of maturity in the field of energy management.

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.

ISO 50001:2011, *Energy management systems — Requirements with guidance for use*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 50001 and the following apply.

3.1
adjustment
process of modifying the energy baseline in order to enable energy performance comparison under equivalent conditions between the reporting period and the baseline period

Note 1 to entry: ISO 50001 requires adjustments to the EnB when EnPIs no longer reflect organizational energy use and consumption, or when there have been major changes to the process, operational patterns, or energy systems, or according to a predetermined method.

Note 2 to entry: Typically adjustments are made to account for changes in static factors.

Note 3 to entry: Predetermined methods typically reset the EnB at defined intervals.

3.2
baseline period
defined period of time used to compare energy performance with the reporting period

3.3
boundaries
physical or site limits and/or organizational limits as defined by the organization

EXAMPLE A process; a group of processes; a site; an entire organization; multiple sites under the control of an organization.

[SOURCE: ISO 50001:2011, 3.1]

3.4
energy
electricity, fuels, steam, heat, compressed air, and other like media

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

Note 2 to entry: Energy can be defined as the capacity of a system to produce external activity or perform work.

[SOURCE: ISO 50001:2011, 3.5]

3.5
energy baseline
EnB
quantitative reference(s) providing a basis for comparison of energy performance

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 and/or consumption, e.g. production level, degree days (outdoor temperature), etc.

Note 3 to entry: The energy baseline is also used for calculation of energy savings, as a reference before and after implementation of energy performance improvement actions.

[SOURCE: ISO 50001:2011, 3.6, modified — Abbreviated term has been added.]

3.6
energy consumption
quantity of energy applied

Note 1 to entry: Energy consumption can be represented in volume and mass flow or weight units (fuel) or converted into units that are multiples of joules or watt-hours (e.g. GJ, kWh).

Note 2 to entry: Energy consumption is typically measured using permanent or temporary meters. The values can be measured directly or can be calculated over a specific period of time.

[SOURCE: ISO 50001:2011, 3.7, modified —Notes 1 and 2 to entry have been added.]

3.7
energy efficiency
ratio or other quantitative relationship between an output of performance, service, goods or energy, 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 50001:2011, 3.8]

3.8
energy performance
measurable results related to energy efficiency, energy use and energy consumption

Note 1 to entry: In the context of energy management systems, results can be measured against the organization's energy policy, objectives, targets and other energy performance requirements.

Note 2 to entry: Energy performance is one component of the performance of the energy management system.

[SOURCE: ISO 50001:2011, 3.12]

3.9
energy performance indicator
EnPI
quantitative value or measure of energy performance, as defined by the organization

Note 1 to entry: EnPIs could be expressed as a simple metric, ratio or a more complex model.

[SOURCE: ISO 50001:2011, 3.13]

3.10
energy target
detailed and quantifiable energy performance requirement, applicable to the organization or parts thereof, that arises from the energy objectives and that needs to be set and met in order to achieve this objective

[SOURCE: ISO 50001:2011, 3.17]

3.11
energy use
manner or kind of application of energy

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

[SOURCE: ISO 50001:2011, 3.18]

3.12
facility
single installation, set of installation or production processes (stationary or mobile), which can be defined within a single geographical boundary, organization unit or production process

[SOURCE: ISO 14064-3:2006, 2.22]

3.13
normalization
process of routinely modifying energy data in order to account for changes in relevant variables to compare energy performance under equivalent conditions

Note 1 to entry: EnPIs and corresponding EnBs can be normalized.

3.14
relevant variable
quantifiable factor that impacts energy performance and routinely changes

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

3.15
reporting period
defined period of time selected for calculation and reporting of energy performance

EXAMPLE The period for which an organization wants to assess changes in EnPIs relative to the EnB period.

3.16
significant energy use
SEU
energy use accounting for substantial energy consumption and/or offering considerable potential for energy performance improvement

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

[SOURCE: ISO 50001:2011, 3.27, modified — Abbreviated term has been added.]

3.17
static factor
identified factor that impacts energy performance 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 (e.g. office workers); range of products.

EXAMPLE 2 A change of a static factor could be a change in a manufacturing process raw material, from aluminium to plastic.

[SOURCE: ISO 50015:2014, 3.22, modified — Examples have been modified.]

4 Measurement of energy performance

4.1 General overview

4.1.1 General

In order to effectively measure and quantify its energy performance, an organization establishes EnPIs and EnBs. EnPIs are used to quantify the energy performance of the whole organization or its various parts. EnBs are quantitative references used to compare EnPI values over time and to quantify changes in energy performance.

Energy performance results can be expressed in units of consumption (e.g. GJ, kWh), specific energy consumption (SEC) (e.g. kWh/unit), peak power (e.g. kW), percent change in efficiency or dimensionless ratios, etc. The general relationship between energy performance, EnPIs, EnBs and energy targets is illustrated in Figure 1 in the introduction.

Energy performance can be affected by a number of relevant variables and static factors. These can be linked to changing business conditions such as market demand, sales and profitability.

An overview of the process to develop, use and update EnPIs and EnBs is illustrated in Figure 2 and described in detail in 4.2 to 4.6. This process helps the organization to continually improve the measurement of its energy performance.

4.1.2 Energy consumption

Quantifying energy consumption is essential for measuring energy performance and energy performance improvements.

When multiple forms of energy are used, it is useful to convert all forms to a common unit of measure of energy. Care should be taken to perform the conversion in a manner that appropriately represents total energy consumed including losses in the energy conversion process.

4.1.3 Energy use

Identifying energy uses such as energy systems (e.g. compressed air, steam, chilled water, etc.), processes and equipment helps to categorize energy consumption and to focus energy performance on uses that are important to an organization.

4.1.4 Energy efficiency

Energy efficiency is a frequently used metric for measuring energy performance and may be used as an EnPI.

Energy efficiency can be expressed in a number of ways, such as energy output/energy input (conversion efficiency); energy required/energy consumed (where energy required may be derived from a theoretical model or some other relationship); production output/energy input (for example the tons of production per unit energy consumed).

NOTE Energy input/production output is sometimes used as an EnPI and is referred to as energy intensity.

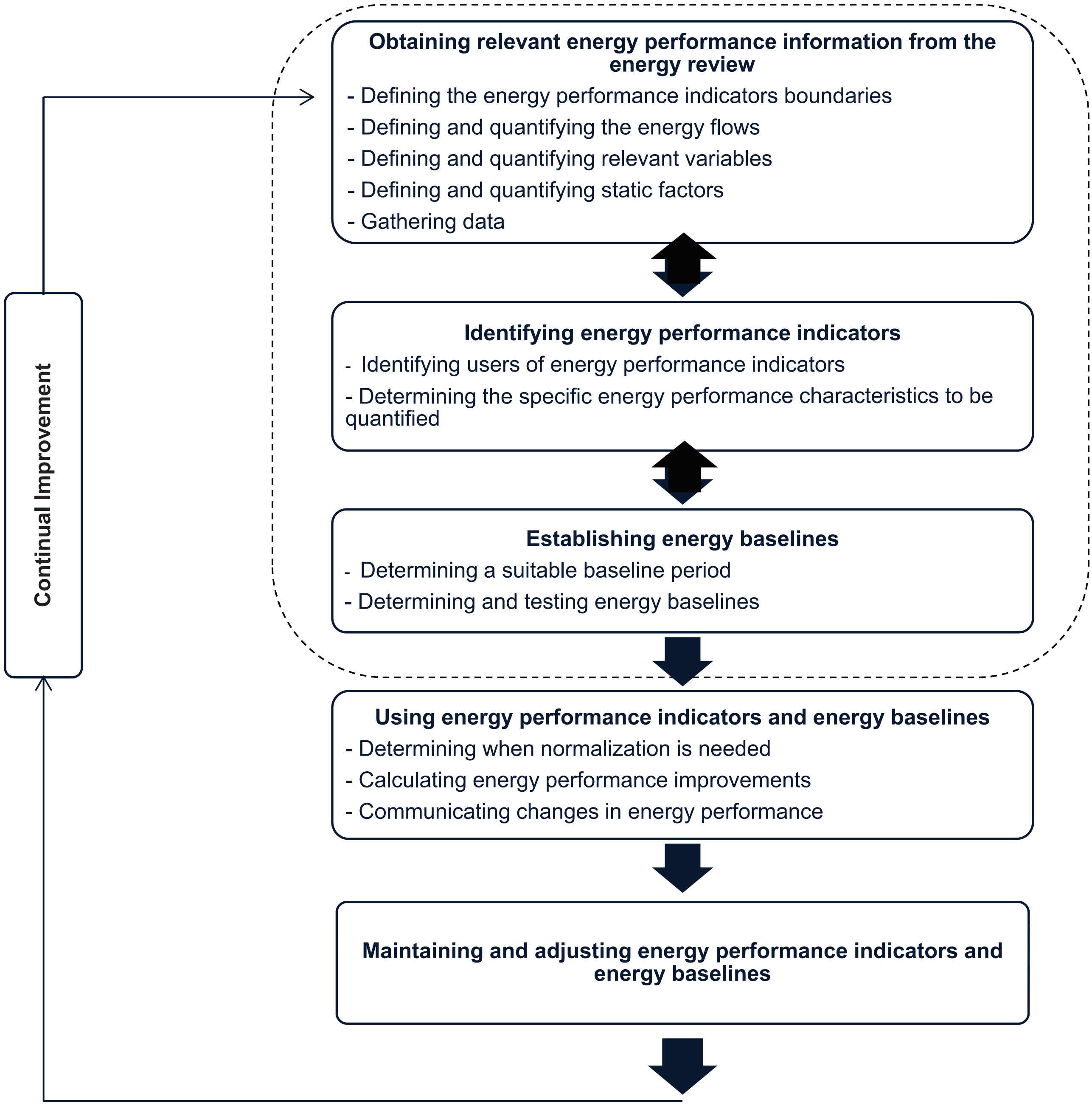


Figure 2 — Overview of energy performance measurement

4.1.5 Energy performance indicators (EnPIs)

EnPIs should provide relevant energy performance information to enable various users within an organization to understand its energy performance and take actions to improve it.

The EnPIs can be applied at facility, system, process or equipment levels to provide various levels of focus.

An organization should set an energy target and an energy baseline for each EnPI.

4.1.6 Energy baselines (EnBs)

An organization should compare energy performance changes between the baseline period and the reporting period. The EnB is simply used to determine the EnPI values for the baseline period. The type of information needed to establish an energy baseline is determined by the specific purpose of the EnPI.

4.1.7 Quantifying energy performance

Energy performance changes can be calculated using EnPIs and EnBs for facilities, systems, processes or equipment.

Comparing energy performance between the baseline period and the reporting period involves calculating the difference in the value of the EnPI between the two periods. Figure 3 illustrates the simple case where direct measurement of energy consumption is used as the EnPI and energy performance is compared between the baseline period and the reporting period.

In cases where the organization has determined that relevant variables such as weather, production, building operating hours etc. affect energy performance, the organization should normalize the EnPI and its corresponding EnB to compare energy performance under equivalent conditions.

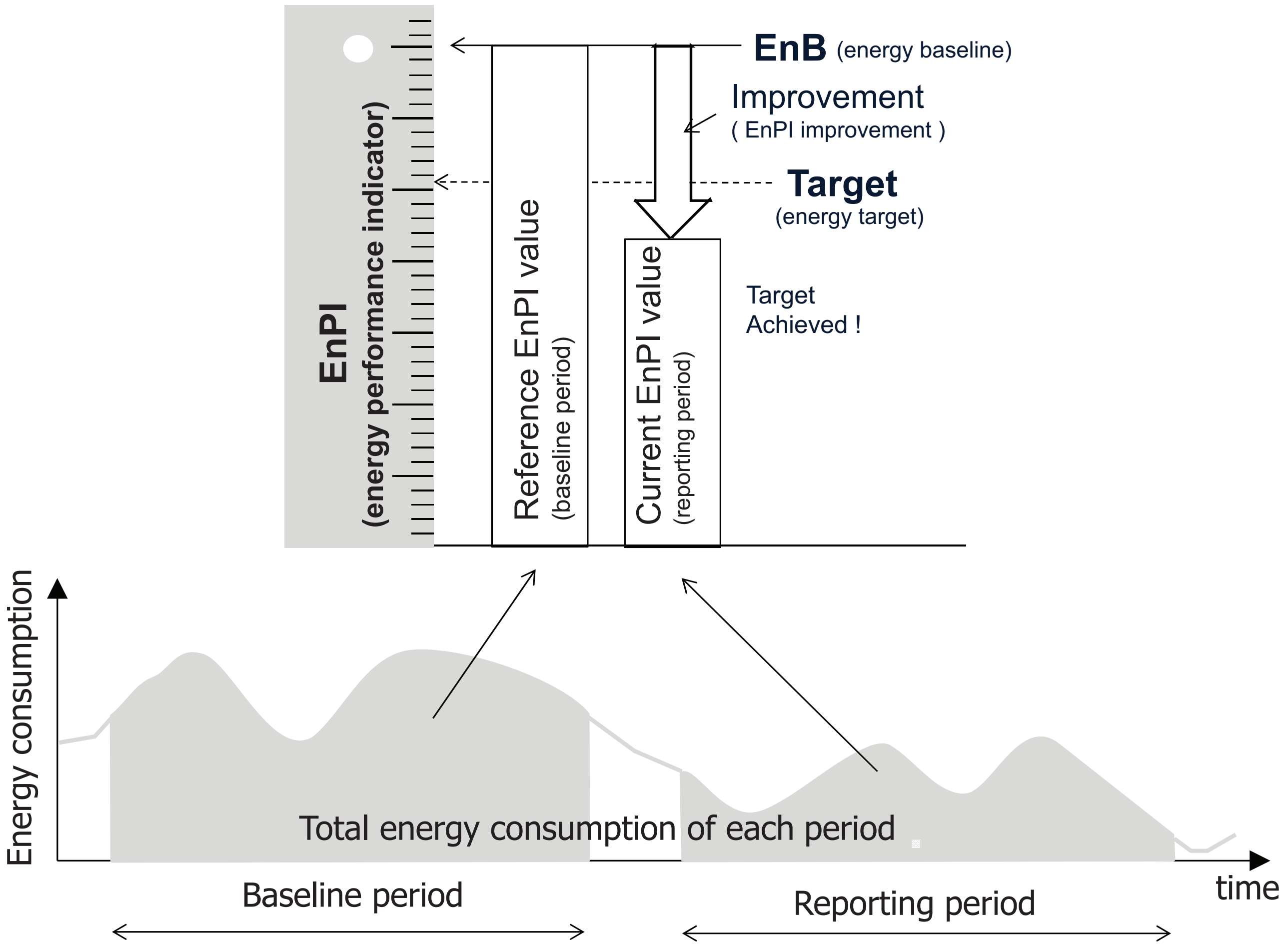


Figure 3 — Concept of baseline period and reporting period for an EnPI

4.2 Obtaining relevant energy performance information from the energy review

4.2.1 General

The energy review provides useful energy performance information for developing EnPIs and EnBs. Annex A illustrates the relationship between the energy review and information needed to identify EnPIs and establish EnBs. The establishment of appropriate EnPIs and corresponding EnBs requires access to available organizational energy data, analysis of the data, and processing of energy information.

4.2.2 Defining the energy performance indicator boundaries

The EnMS scope and boundary comprise the area or the activities within which an organization manages energy performance.

To measure energy performance, suitable measurement boundaries for each EnPI should be defined. These are termed EnPI boundaries and they may overlap.

NOTE The users of EnPI and their needs are identified first (see 4.3.2), and then the corresponding EnPI boundary is defined.

When defining an EnPI boundary, consideration should be given to:

— organizational responsibilities in relation with energy management;

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

— the EnMS boundary;

— the significant energy use (SEU) or group of SEUs the organization designates as a priority to control and improve;

— specific equipment, processes and sub-processes that the organization wishes to isolate and manage.

The three primary EnPI boundary levels are individual, system and organizational as described in Table 1.

Table 1 — The three EnPI boundary levels

EnPI boundary levels	Description and examples
Individual facility/equipment/process	The EnPI boundary can be defined around the physical perimeter of one facility/equipment/ process the organization wants to control and improve Example: The steam production equipment
System	The EnPI boundary can be defined around the physical perimeter of a group of facilities/ processes/equipment interacting with each other that the organization wants to control and improve Example: The steam production and the steam use equipment, such as a dryer
Organizational	The EnPI boundary can be defined around the physical perimeter of facilities/processes/ equipment also taking into account the responsibility in energy management of individuals, teams, groups or business units designated by the organization Example: Steam purchased for a factory/factories, or department of the organization

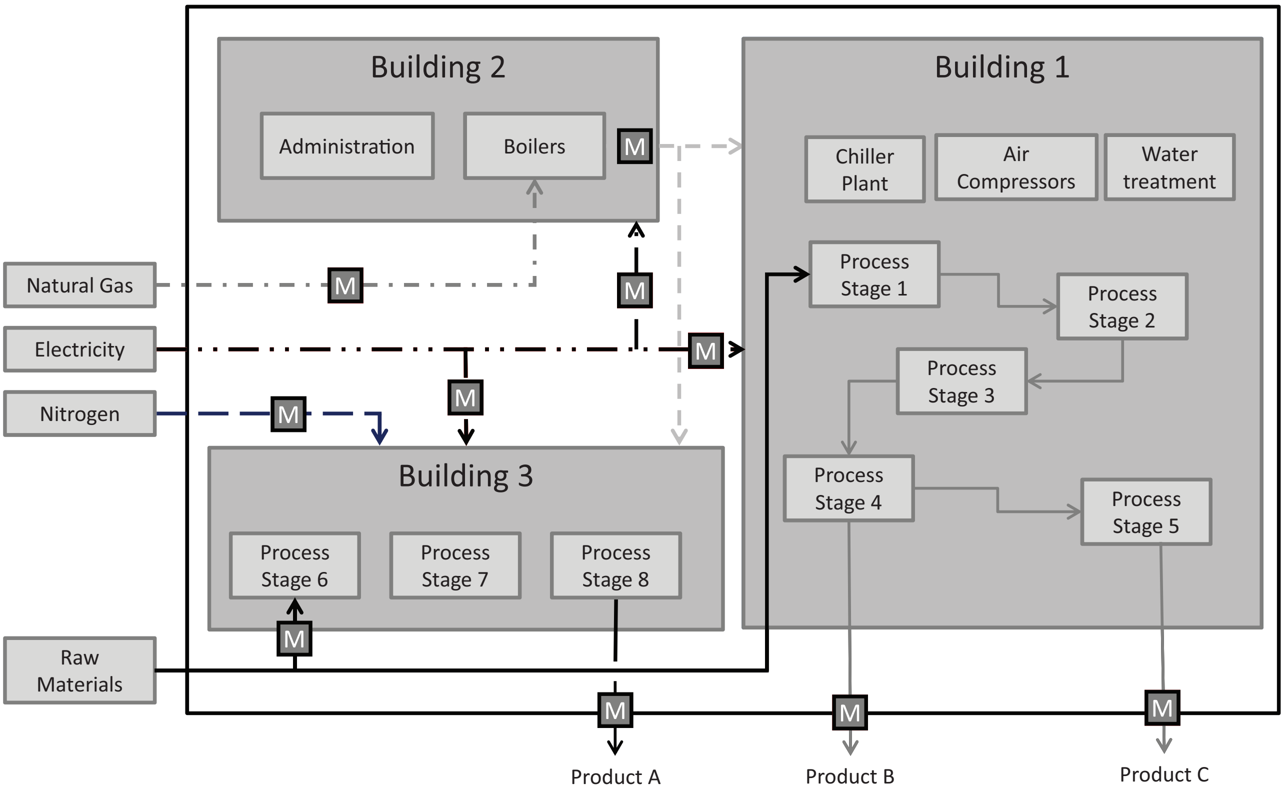
Supplemental information on EnPI boundaries in the production process can be found in Annex B.

4.2.3 Defining and quantifying energy flows

Once an EnPI boundary is defined, the organization should identify energy flowing across the boundary. The organization can use a diagram like the one in Figure 4 to determine the energy information required to establish EnPIs. These fence diagrams or energy maps visually show flow of energy within and across the EnPI boundary. They can also include additional information, such as metering points and product flow which are important for energy analysis and establishment of EnPIs.

The organization should measure energy flows across the EnPI boundary, changes in stock levels of fuels, as well as the quantity of any stored energy.

EnPIs and EnBs for SEUs require well-defined boundaries in order to quantify energy flows. An important consideration for each SEU is appropriate metering for measuring energy consumption that crosses the SEU boundary as well as availability of data on relevant variables.



Key

M Measurement

Figure 4 — Fence diagram

4.2.4 Defining and quantifying relevant variables

Depending on the needs of the organization and its EnMS, relevant variables that are likely to have an impact on energy performance should be defined and quantified at each EnPI boundary. It is important to isolate those variables which are significant in terms of energy performance from the variables which have little or no influence. Data analysis is often required to determine the significance of relevant variables.

Some variables are more relevant to energy consumption than others. For example, where energy consumption per unit of production is being measured, counting the number of final products may provide a misleading result if there are intermediate outputs produced, and whether these intermediate outputs are waste, value added, or recycled.

Once the relevant variables have been isolated, further modelling techniques can be used to determine the precise nature of the relationship.

Practical Help Box 1: Defining and quantifying relevant variables
Organizations are often challenged to understand the magnitude of the relationship between variables and energy consumption. The following describes a method to assess whether a variable significantly affects energy consumption. First, it can be helpful to understand any trends in energy consumption and in potentially relevant variables. These can be plotted over time in a trend chart. This will enable the organization to see evidence of seasonality or evidence of variables changing at similar times as energy consumption. For example, if energy consumption is due to heating, the consumption will increase during the cooler winter months. If the load is related to cooling, consumption will increase during the summer months, as shown in Figure 5. After visibly assessing trends in energy consumption and variables, the organization can assess the significance of the relationship. To do this, the organization can plot a variable against energy consumption using a simple X-Y diagram. If the variable is relevant, one expects to see evidence of a relationship in the scatter of points. If the points appear to be scattered around a mathematical function, shown as a trend line then this is indicative of the presence of relevant variables (see Figure 6 a) and b)).If the points appear as a random cloud with no evident relationship, the variable is likely not relevant (see Figure 6 c)). In many cases, a simple linear relationship is adequate for determining relevance. Certain variables may show nonlinear relationships and the organization will need to decide how to include those variables in the EnPI calculation. When a single relevant variable does not appear to significantly relate to energy consumption, the organization may use a model-based EnPI, with two or more relevant variables (see 4.3.3). Alternatively, the EnPI boundary could be divided to isolate energy consumption that is significantly related to only one variable (see Annex B). Certain relevant variables may exhibit co-linearity, where two or more independent variables consistently change together. To determine this situation, the organization can plot the variables using an X-Y diagram. If the organization determines that co-linearity exists, the organization should use the variable that has a greater impact on energy consumption and should keep the other variable as constant. Where operating patterns and the values of relevant variables fluctuate significantly, it is important to ensure that the data being analysed for correlations are at the correct frequency to enable the effects of each variable to be accurately observed.

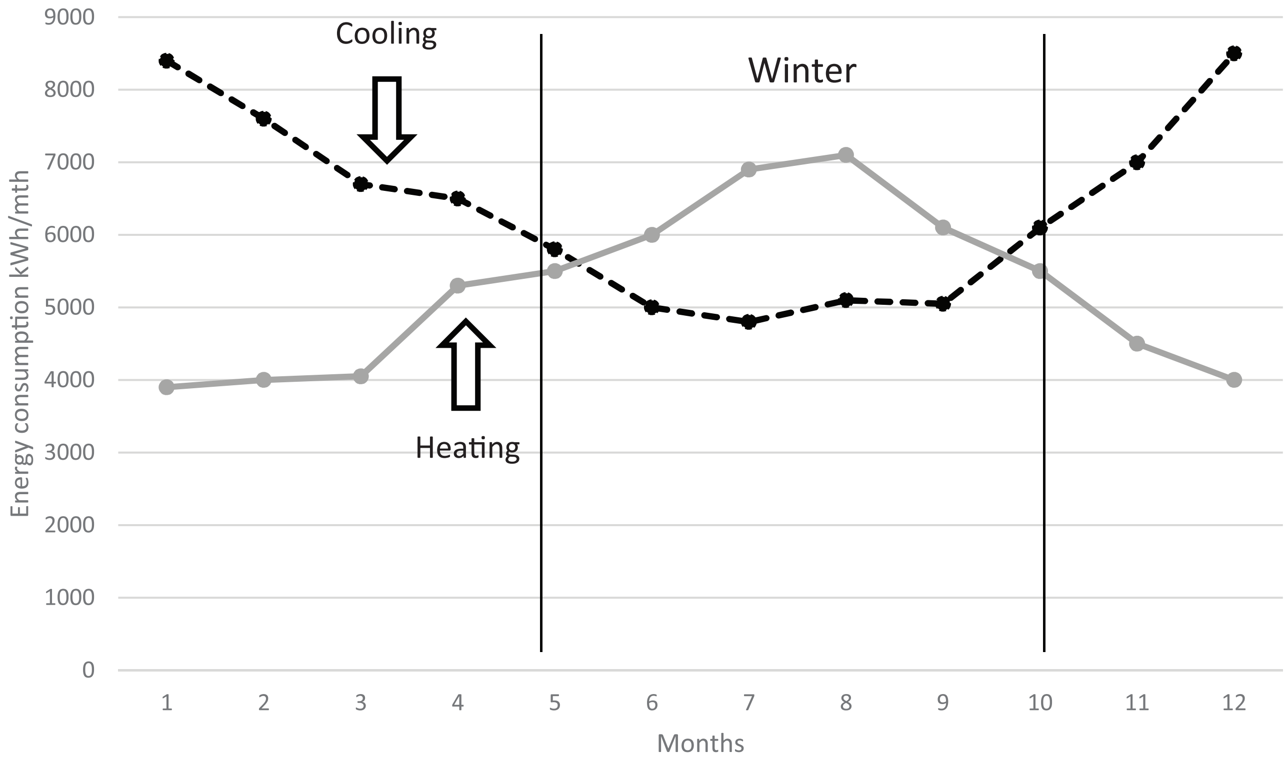
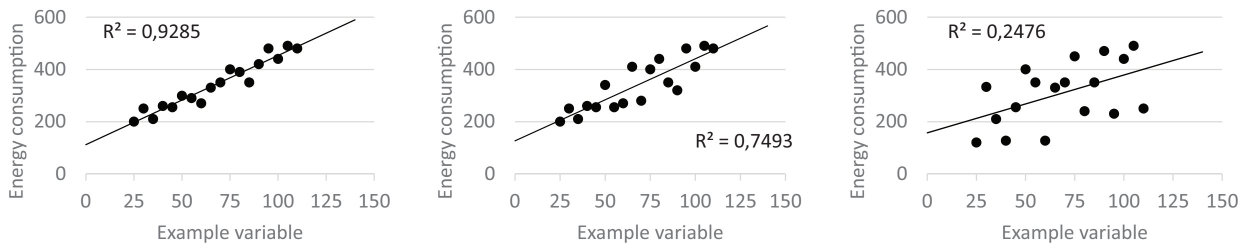


Figure 5 — Trend chart showing seasonality



a) Significant variable **b) Less significant variable** **c) Not significant variable**

Figure 6 — Variables with differing levels of significance

4.2.5 Defining and quantifying static factors

Factors affecting energy performance often change in value. Factors should be analysed to see if they are best considered as a relevant variable or as a static factor. For example, a manufacturing plant may have a routinely changing production level that is a relevant variable and non-routinely changing product mix that is a static factor.

It is important to record the condition of these static factors at the time when EnPIs and EnBs are being established. The organization should review these static factors over time, to ensure that the EnPIs and EnBs remain appropriate and to record any major changes that could affect energy performance.

Although static factors do not vary substantially between the reporting period and the baseline period, if conditions change the static factors could change and the organization should maintain related EnPIs or EnBs (see 4.6).

Practical Help Box 2: Static factor changes that require maintenance to related EnPIs or EnBs
It can be difficult to understand when static factors require maintenance to related EnPIs or EnBs. The following describes a few helpful scenarios. - Change in product type – A plant may have a consistent set of products that it produces. Product type would then be a static factor. If they introduce a new product, maintenance may be required for the new product type. - Change in shifts per day – A plant has a fixed number of production shifts per day. If the number of shifts increases or decreases, this may 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 may require maintenance. - Change in floor area – A building has a fixed size floor area. If the organization significantly expands the building, then this may require maintenance.

4.2.6 Gathering data

4.2.6.1 Data collection

An organization should specify the data to be collected for each EnPI and its corresponding EnB. Data collection can happen at any point during the process. The source of energy should be specified together with relevant variables. It is important to gather all data including static factors that will be used to develop EnPIs and the corresponding EnBs.

Practical Help Box 3: Energy data collection challenges
Organizations can experience several data collection challenges. The following scenarios describe potential solutions to some of these challenges. - Lack of detailed metered data from energy suppliers – when an organization does not have detailed metered data from energy suppliers, they may investigate additional metering options provided on their own or through their energy supplier. - Lack of data on relevant variables – when an organization does not have data for a specific energy intensive production process, they may add sensors to acquire this data. - Incompatible data forms – when an organization's energy data are in a different measurement frequency than the data for their other factors, they may aggregate or disaggregate data to align them. - Lack of data for specific energy uses – when an organization's energy data does not provide visibility to specific energy uses, they may acquire sub-meters for those uses.

The organization may determine that the significance of the energy use in an EnPI boundary or the opportunity for improvement is sufficiently high to justify the expense of new meters, sub-meters, and/or sensors to measure other relevant variables. In such cases, the organization will specify such metering in its monitoring, measurement, and analysis plan.

When organizations use estimated values to calculate EnPIs and the corresponding EnBs, they should document their assumptions and methods.

An organization may discover that some of the EnPIs that were identified previously as significant may not be measurable due to data limitations or other barriers. In this case, the organization will need to assess, and consequently refine the EnPIs or introduce additional meters or measurement methods.

4.2.6.2 Measurement

Energy consumption is typically measured using permanent meters or sub-meters or with temporary metering. Energy consumption should be measured and calculated by using data over a specific period of time.

When choosing EnPIs, the organization should consider its existing measurement and monitoring capabilities. The organization should take measurements for each energy value and relevant variable necessary to calculate the selected EnPIs and the corresponding EnBs.

NOTE In many cases, the quantity of energy consumed needs to 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.

Measurements can be taken on a spot basis (e.g. using mobile/portable meters), on a temporary basis (e.g. using data loggers), or continuously (e.g. using data from a supervisory control and data acquisition (SCADA) system or a data acquisition and handling system (DAHS)). Energy consumption and relevant variables used to calculate each EnPI should be measured at the same time and frequency. If continuous measurement is not possible, the organization should ensure that spot or temporary measurements are made during periods that are representative of the typical pattern of operation.

All measurements should be accurate and repeatable and the corresponding meters calibrated. All measured values should be validated.

4.2.6.3 Selecting data collection frequency

The data collection period can be longer than the baseline period and reporting period. Data collection is performed periodically (e.g. hourly, daily, weekly). This is called data collection frequency.

The organization should select an adequate data collection frequency for each energy consumption and relevant variable included in the EnPI and the corresponding EnB. The data collection period and frequency should be sufficient to capture operating conditions and provide an adequate number of data points for analysis.

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 may be needed at the operational level to address significant deviations. Such energy values and relevant variables may then be aggregated for monthly reviews at the organizational level.

If new measurement systems are to be installed, the organization should consider the frequency of data needed to meet its energy performance monitoring needs.

4.2.6.4 Ensuring data quality

Prior to calculating EnPIs and corresponding EnBs, the organization should review the set of measured energy values and relevant variables to determine the quality of the data. Faulty metering, faulty data capture, or atypical operating conditions may produce significant outliers which may need to be examined.

Practical Help Box 4: Identifying and analysing outliers
It can be challenging to identify and analyse outliers. Typically, outliers can be identified from looking at a scatter diagram. This may be by reference to a trend line or function of the relevant variables, with the mean, standard deviation and standard error of the data being calculated. Data points in excess of a pre-determined number of standard deviations from expected value of the trend line or function may be considered to be outliers. For example, an annual plant shutdown results in a significant variation in energy consumption that appears as an outlier in a particular week of operation. Before excluding an outlier, investigations should be carried out to determine if there is a legitimate reason for the outlier, and if excluding, reasons for this should be documented.

If some outlying measurements are excluded, care should be taken that this does not introduce bias into the EnPI or corresponding EnB.

Inaccuracies in measuring devices can undermine the validity of the data collected. The organization should consider calibrating equipment periodically according to the manufacturer’s recommendation to reduce the risk of inaccurate data.

Measurement accuracy and the level of uncertainty should be taken into account when interpreting and reporting on EnPIs.

4.3 Identifying energy performance indicators

4.3.1 General

When identifying an EnPI, the organization should understand its energy consumption characteristics such as base load (i.e. fixed energy consumption) as well as variable loads due to production, occupancy, weather, or other factors.

Organizations define targets for energy performance as part of the energy planning process in their EnMS. Energy performance targets should be characterized by EnPI values.

EnPIs should, when compared over time, allow an organization to determine if the energy performance has changed and whether it is meeting its targets.

When selecting appropriate EnPIs, key factors to consider are the users of the information and their needs.

The main types of EnPIs are:

— measured energy value: consumption of an entire site or one or more energy uses measured by a meter;

— ratio of measured values: expression of the energy efficiency;

— statistical model: relationship between energy consumption and relevant variables using linear or nonlinear regressions;

— engineering based model: relationship between energy consumption and relevant variables using engineering simulations.

4.3.2 Identifying users of energy performance indicators

EnPIs should be easily understandable by their users. The type and complexity of the EnPI should be adapted to the different end users' needs. Multiple EnPIs may be required.

EnPIs can be developed for internal or external users. Internal users typically use EnPIs to manage improvements in energy performance. External users typically use EnPIs to meet information requirements derived from legal and other requirements.

Practical Help Box 5: EnPI users
It may be difficult to know who may gain value in an organization's EnPIs. The following outline describes some common users.
- Top management - Responsibilities include to ensure that EnPIs are appropriate to the organization, to consider energy performance in long term planning, to ensure that all legal and other external requirements are met and to ensure that results are measured and reported at determined intervals. Top management may use one or more EnPI(s) representing the whole organization.
- Management representative - Works with an energy management team and is responsible for delivering measurable results within the EnMS to the top management. Management representative may use all of the EnPIs the organization uses.
- Plant or facility manager - Typically controls resources within the plant or facility and is accountable for results. The plant or facility manager should understand both planned energy performance and any deviation from desired performance both in terms of energy performance and in financial terms. Plant or facility managers may use all of the EnPIs in their plant or facility including the EnPI regarding its SEU.
- Operation and maintenance personnel - Responsible for using EnPIs to control and ensure efficient operation by taking corrective actions for deviations in energy performance, eliminating waste and undertaking preventive maintenance to reduce energy performance degradation. Operation and maintenance personnel may use the EnPIs relevant to the process or equipment which they have responsibility for.
- Process engineer – Plan, execute and evaluate an energy performance improvement action using suitable EnPI for the action and its evaluation method. Process engineer may use complex EnPIs such as engineering models.
- External users – May include regulatory bodies, professional and sector associations, EnMS auditors, customers, or other organizations.

EnPIs can be established at various levels of the organization or facility.

4.3.3 Determining the specific energy performance characteristics to be quantified

The organization should choose the type of EnPI to meet the user needs and the complexity of the application. Table 2 outlines the various EnPI types as well as when an organization should choose each type.

Table 2 — Types and applications of EnPIs

EnPI type	Useful for	Examples	Observation
Measured energy value	- Measuring reductions in absolute use or consumption of energy - Meeting regulatory requirements based on absolute savings - Monitoring and control of energy stocks and costs - Understanding trends in energy consumption - Obtained when measurement of energy consumption is given by a meter, with or without a conversion factor	- Energy consumption (kWh) for lighting - Fuel consumption (GJ) of boilers - Electricity consumption (kWh) during peak hours - Peak demand (kW) in month - Total energy savings (GJ) from energy efficiency related programmes	- Does not take into account the effects of relevant variables, giving misleading results for most applications - Does not measure energy efficiency

Table 2 *(continued)*

EnPI type	Useful for	Examples	Observation
Ratio of measured values	- Monitoring energy efficiency of systems that have only one relevant variable - Monitoring systems where there is little or no base load - Standardizing comparisons across multiple facilities or organizations (benchmarking) - Meeting regulatory requirements based on energy efficiency - Understanding energy efficiency trends - Can express the energy efficiency of a piece of equipment or a system	- kWh/tonne of production - GJ/unit of product - kWh/m^2 of floor space - GJ/man-day - litres of fuel per passenger kilometre - Conversion efficiency of a boiler (%) - Input energy/output energy (for instance, "heat rate" in power generation facilities) - kWh/MJ for cooling systems - kW/Nm^3 for compressed air systems - L/100km - kWh/value-added in unit of currency - kWh/unit of sales	- Does not account for base load and nonlinear energy use effects; will be misleading for facilities with a large base load
Statistical model	- System with several relevant variables - System with base load energy consumption - Where comparison requires normalization - Modelling complex systems where the relationship between energy performance and the relevant variables can be quantified; - Organizational level energy performance with several relevant variables - Illustrates the relationship between energy consumption and relevant variables	- Energy performance of a production facility with two or more product types - Energy performance of a facility having a base load - Energy performance of a hotel with variable occupancy rate and outside temperature - Relationship between the energy consumption of a pump/fan and the flow rate	- For models with multiple variables relationships can be difficult to determine and models can take time to create and can be difficult to ensure accuracy - May not be clear if any residual error is due to modelling error or lack of control over energy consumption - May be inaccurate if not confirmed by statistical tests - Requires a detailed system understanding to define the correct functional form of relationship expected when data are not linear - Models should be maintained to ensure valid results
Engineering model	- Evaluating energy performance from operational changes where variables are numerous. - Transient processes and/or systems involving dynamic feedback loops - For systems with interdependent relevant variables (such as temperature and pressure) - Estimating energy performance at a design stage	- Industrial or power generation systems where engineering calculations or simulations enable accounting for changes in relevant variables and their interactions - Model of the electricity consumption of a chiller using the demand for cooling, the outside temperature (condensing temperature) and inside temperature(evaporating temperature) - Whole building models that account for hours of operation, centralized versus distributed HVAC systems, and varying tenant needs	- Models should be maintained to ensure valid results
NOTE 1 The type of EnPIs would also apply to the corresponding EnBs. NOTE 2 In the building environment, kWh/m^2 of floor space is commonly used, but it is sub-optimal because floor space is rarely a relevant variable for appliances and/or lighting. A better building EnPI for appliances and/or lighting would be kWh/occupant-hour. NOTE 3 In some cases, an organization might need to combine EnPIs into a single EnPI. For example, a factory with multiple activities might need to submit a single EnPI value to meet a government programme requirement. NOTE 4 In some cases, an organization can present the performance of the statistical model EnPI type as a single EnPI. For example, an organization would use an EnPI that shows the percentage performance between their expected consumption and actual consumption of their entire operation. This single EnPI would enable the output of a statistical model to be consolidated into a single number that is understandable by the organization. NOTE 5 Statistical and engineering models enable energy performance comparisons under equivalent conditions, even if there are changes or relevant variables. Models generally describe the relationship between energy values and relevant variables in the baseline period. Models are explained in more detail in Annex C.			

Annex C provides supplemental information about selecting EnPIs.

Annex D provides information about normalization of EnPIs and corresponding EnBs.

4.4 Establishing energy baselines

4.4.1 General

The EnB is characterized by the value of the EnPI during the baseline period. A comparison between the EnB and reporting period EnPIs can be used to illustrate progress towards meeting energy objectives and energy targets and demonstrate improvements in energy performance.

The following steps should be taken to establish an EnB:

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

— determine a suitable data period;

— data collection;

— determine and test the EnB.

4.4.2 Determining a suitable baseline period

When establishing the EnBs the organization should determine a suitable data period in consideration of the nature of its operations. The baseline period and reporting period should be long enough to ensure that the variability in operating patterns are accounted for by the EnB and EnPI. Typically these periods are 12 months long to account for seasonality in energy consumption and relevant variables.

The frequency with which an organization acquires data is an important factor in determining a suitable baseline period. The baseline period should be of sufficient duration to capture variations in relevant variables, such as seasonality in production, weather patterns, etc.

Practical Help Box 6: Typical baseline period to be considered
Typical periods to be considered are: - One year – The most common EnB duration is one year, likely due to alignment with energy management and business objectives, such as reducing energy consumption from a previous year. One year also includes the full range of seasons and hence can capture the impact of relevant variables such as weather on energy use and consumption. It can also capture a full range of business operating cycles where production may vary during the year due to annual market demand patterns. - Less than one year – EnB duration of less than one year can be suitable in cases where there is no seasonality in energy consumption or when shorter operating periods capture a reasonable range of operating patterns. Short EnB durations may also be necessary for situations in which there is an insufficient quantity of reliable, appropriate or available historical data (e.g. when changes to the organization, policies or processes make only current data available). - More than one year – Seasonality and business trends can combine to make a multi-year EnB optimal. Specifically, custom multi-year EnB periods are useful for extremely short annual production cycles where a business manufactures products for a few months each year and is relatively dormant for the remainder of the year (e.g. a winery might want to track energy performance only during the crushing and fermentation period of each year, however over multiple years). It is necessary to prepare the data set of the EnB which should be compared to the EnPI within the reporting period. 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.

Some organizations will develop a baseline using standard operating conditions, based on multi-year data. For example, a commercial building may use average weather data for the past 40 years to characterize typical operating conditions and apply this data to create an EnB.

NOTE In some cases, such as when a new facility is being constructed and there is no appropriate operating history, it can be necessary to simulate, estimate or calculate the expected energy consumption for the new facility to serve as the EnB.

4.4.3 Determining and testing energy baselines

To determine the EnB, the corresponding EnPI should be measured or calculated using the energy consumption and relevant variable data from the baseline period. If appropriate, the EnB should be tested for validity to ensure that it is an appropriate reference for comparison. When models are used, the validly of the EnB can be determined using statistical tests such as the P-Value, F-Test or the coefficient of determination to determine if the statistical model has been best fitted from the data. If a model is determined not to be valid, the organization should consider adjusting the EnB or determine a new model, corresponding EnPI and EnB. The testing results should be recorded.

4.5 Using energy performance indicators and energy baselines

4.5.1 Determining when normalization is needed

Direct comparison of energy consumption (non-normalized method) between the baseline period and the reporting period can only be accomplished if there are no significant changes to the relevant variables.

In order to compare energy performance between two periods under equivalent conditions, the EnPI and corresponding EnB should be normalized using relevant variables as follows:

— in case of a single significant relevant variable and small base load, a simple ratio of energy consumption divided by the relevant variable can be used (e.g. a specific energy consumption);

— in case of multiple relevant variables or a large base load, a model describing the relationship between the energy consumption and relevant variables is used.

Annex D provides information about normalizing EnPIs and EnBs using relevant variables.

Practical Help Box 7: Evaluating comparative measures
Example: Electricity consumption at the site fell by 200 000 kWh/year between 2008 and 2012. Without additional information about changes that occurred between 2008 and 2012, it would be difficult to determine whether progress has been made towards meeting the organization's goals and targets. For example, if market demand required a change in the mix of products produced during 2011 and 2012, the drop in consumption cited above might or might not be related to improvements in energy performance. If the organization established improvement targets based on efficiency or intensity or total consumption, excluding effects attributed to changes in product mix, then the direct comparison of results showing improvement might be misleading.

4.5.2 Calculating energy performance improvements

To assess changes in energy performance, organizations should quantify EnPIs during the reporting period and compare these values to the corresponding EnBs. The organization also should compare the quantified energy performance to its energy targets and take action.

There are many approaches and techniques for organizations to calculate and express energy performance.

Practical Help Box 8: Calculating energy performance improvements
It can be difficult for organizations to choose from the large number of approaches to measure energy performance improvement. The following approaches are common. - EnPI difference: This is the difference between the baseline period EnPI value and the reporting period EnPI values. This could be illustrated in the following equation, where the baseline EnPI value is B, the reporting value is R: Difference = $R - B$ - Percent change: This is the change in values from the baseline period to the reporting period, expressed as a percentage of the EnB value. This could be illustrated in the following equation. Percent change = $[(R - B) / B] \times 100$ - Current ratio: This is a ratio of the reporting period value divided by the baseline period value. Current ratio = (R/B) These three common approaches can be used for all types of EnPIs and EnBs.

4.5.3 Communicating changes in energy performance

Energy performance should be presented based on the needs of the users. It should typically be shown or reported with the EnPIs, EnB and an energy target value.

For information on ways to monitor and report energy performance, see Annex E.

4.6 Maintaining and adjusting energy performance indicators and energy baselines

When changes to facilities, systems or processes occur, energy use, consumption, efficiency and associated relevant variables may be impacted. The organization should ensure 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 change or develop new EnPIs or make adjustments to the EnB.

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

a) comparing the baseline values of relevant variables to reporting period conditions to see if they are within a valid statistical range (used with statistical models);

b) identifying any major changes in static factors which could invalidate the calculation of energy performance under equivalent conditions including major production processes added or deleted and major production changes like changes to the number of production shifts.

If the EnB values are no longer valid, then adjustments for calculating energy performance will need to be made. The baseline period can be adjusted (e.g. shifted to a different time period) or energy performance can be calculated without changing the baseline period, using several methods, including:

— using energy data from the reporting period to develop a statistical model, and then calculating performance using the actual baseline data; one this approach is sometimes called backcasting;

— using energy data based on standard conditions to develop a statistical model and then calculating performance with the actual energy and relevant variable data from the baseline and reporting period.

Combinations of these approaches can also be used. These methods are important to allow organizations undergoing a significant amount of change to keep from constantly adjusting their baseline period.

Practical Help Box 9: Examples of EnPI and EnB changes
The following are relatively common changes an organization may anticipate.
- Static factor changes – If a static factor (see 4.2.5) changes, the related EnB may require adjustment. In some cases, it may be necessary to develop a new EnPI and EnB. Statistical tests may prove whether an organization chooses to develop a new EnB or EnPI.
- Energy use change - When an organization makes a fundamental change to the forms 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 may result in better quality data becoming available or new relevant variables coming to light. Changes to EnPIs and EnBs may then be desirable.
- Data frequency – If data are collected at more regular intervals or at a higher frequency, this could enable more effective management with a new EnPI and EnB.
- Target changes - Organizations may wish to update the EnB period in order 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 would necessitate the updating of the EnB to a recent period (such as the last year) to serve as the new reference point.
- Using a predetermined method - The organization may find it useful to identify conditions in advance that may require a change to the EnPIs or an adjustment to EnBs. The organization should also predetermine the rules and methods that will be used (see 3.1, Note 3 to entry).
- Management review - One of the inputs to management review is the review of EnPIs. Therefore, an output of the review could be a change to EnPIs.

The organization should record and regularly review the method for determining and updating the EnPIs and corresponding EnBs.

Annex A
(informative)

Information generated through the energy review to identify EnPIs and establish EnBs

ISO 50001 requires an energy review to be undertaken. Table A.1 presents further details on activities resulting from the energy review.

Table A.1 — Examples of energy review activities

Energy review		**Typical activities resulting from the energy review**
a) analyse energy use, efficiency and consumption based on measurement and other data	a1) identify current energy sources	- Create a list: energy sources and energy values (consumption, peak power, etc.)
	a2) evaluate past and present energy use and consumption	- Create energy value trend charts by use (purpose) - Create energy value trend charts by source of energy
b) based on the analysis of energy use, efficiency and consumption, identify the areas of SEU	b1) identify the facilities, equipment, systems, processes and personnel working for, or on behalf of, the organization that significantly affect energy use and consumption	- Create a list: facilities, equipment, systems, processes - Add personnel information to this list - Add energy value to this list - Add SEU candidate information to this list
	b2) identify other relevant variables affecting SEUs	- Identify relevant variables affecting energy value (see 4.2.3, define and quantify relevant variables)
	b3) determine the current energy performance of facilities, equipment, systems and processes related to identified SEUs	- Create a list: management purpose in each management level and prioritize (see 4.3.1) - Set EnPI boundaries (see 4.2.2) - Identify EnPIs in each EnPI boundaries (see 4.3) - Establish EnBs corresponding EnPIs (see 4.4)
	b4) estimate future energy use and consumption	- Estimate energy value using the trend chart - Estimate energy value using EnB model in case of using model-based EnPI (see Annex C)
c) identify, prioritize and record opportunities for improvement in energy performance		- Examine energy performance improvement actions (EPIA) and create a list - Add target EnPI value (or measure) to this list - Estimate investment roughly - Prioritize opportunities based on investment return - Develop an implementation plan and maintain records

Annex B
(informative)

EnPI boundaries in an example production process

In the process of energy performance improvement, it is important to find the most inefficient portion in the production system. An EnPI boundary can be used effectively to focus on this portion by narrowing the boundary. As a first step, the EnPI boundary is the entire factory. For the entire factory, the data points appear as a random cloud, as in X-Y diagram in Figure 6. In such cases, the target boundary should be divided into several EnPI boundaries. As next steps, the EnPI boundaries should be narrowed on the SEU of the production system to find a specific area for the energy efficiency improvement. Figure B.1 shows the EnPI boundary division process.

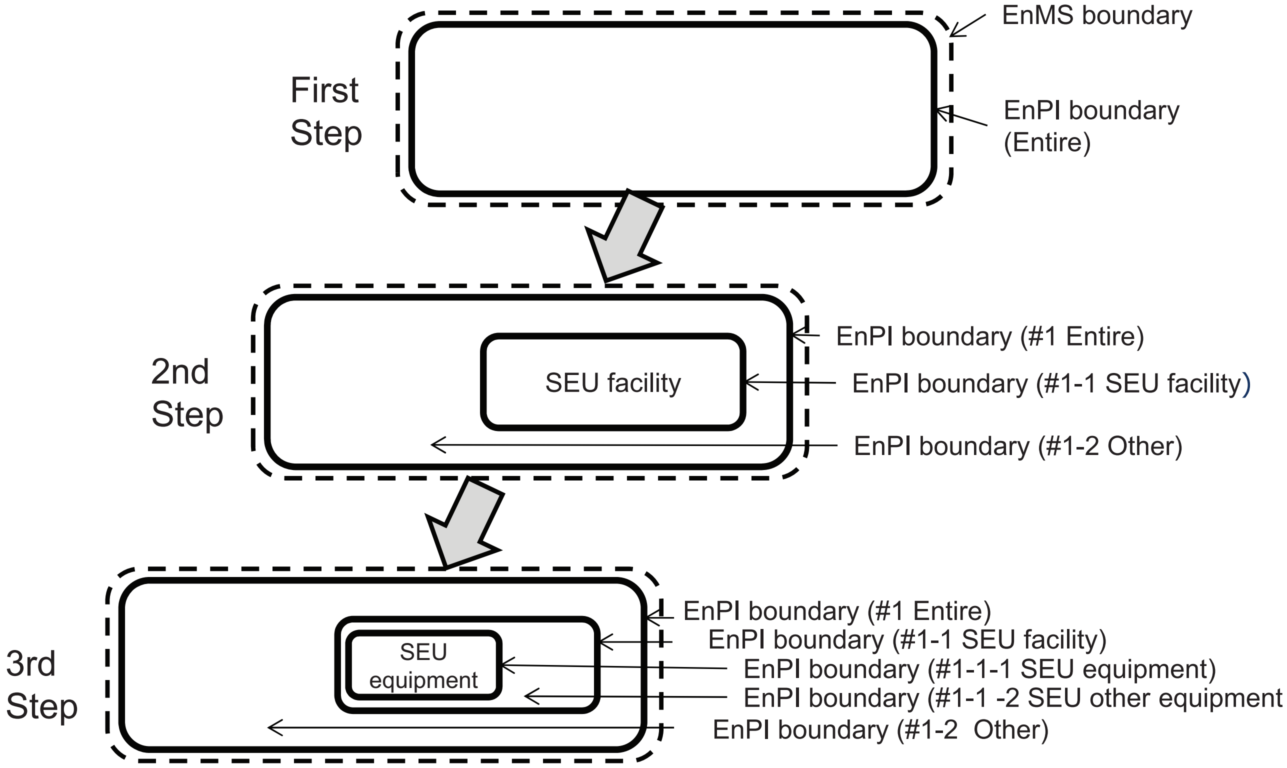


Figure B.1 — EnPI boundaries division process

EnPI boundaries division could be performed as follows:

a) the number of divisions should be minimized;

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

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

d) the facility should be divided into some parts (e.g. facilities for product X, facilities for product Y, utility facilities);

e) the EnBs should 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.

With the above procedures, the energy characteristics of the organization can be modelled easily. This method divides a boundary into sub-boundaries and models them according to their status. This method is easier than analysing all data and creating a nonlinear regression model. Results applying to well-defined sub-boundaries may also be easier to interpret.

Annex C
(informative)

Further guidance on energy performance indicators and energy baselines

C.1 Practical guide to EnPIs and EnBs

C.1.1 Measured energy value

Organizations may choose the absolute energy savings as the energy target. In such cases, EnB should be adjusted to calculate energy savings at equivalent condition. If equivalent conditions are guaranteed, direct comparison of EnB with EnPI can be performed (e.g. retrofit cooling system in a refrigerated warehouse)

C.1.2 Ratio of measured value

Organizations that operate many facilities of a similar use may use ratio to compare facility energy performance across multiple facilities and/or benchmark against competitors or industry standards.

C.1.3 Model-based EnPI

Models can be derived through linear regression, nonlinear regression (e.g. nonlinear relationships appear in fans or pumps), or can be constructed using engineering based theory. Engineering based theory can be applied where complex relationships exist between energy consumption and relevant variables that cannot be accurately captured with regression.

Model-based EnPIs are useful also for examination and evaluation of an energy performance improvement action (see EnPI level 2.1.1.1 in Table C.2 – normalized for air humidity).

C.2 Examples of EnPI types and application

Table C.1 provides descriptions about EnPI types, as well as examples of their applications.

Table C.1 — Examples of EnPI types and applications

Item	Example 1 Measured energy value	Example 2 Ratio of measured value	Example 3 Statistical model	Example 4 Engineering model
Company type	- Pulp and paper company	- Steel company	- Hotel company	- University campus
Process	- Steam generation	- Electric arc furnace	- Heating by oil boiler	- Heating and cooling
Intention	- Eliminate oil use to cut cost	- Achieve world class SEC and remain in business	- Decrease utility cost	- Achieve sustainability targets
Improvement action	- Increase energy efficiency of boiler	- Many improvement actions	- Boiler operator training	- Controls and insulation
EnPI and corresponding EnB	- Oil consumption (kl/month)	- SEC (kWh/ton)	- Energy efficiency (L/degree-day)	- kW/person - kWh/year
Target	- EnPI = 0 (kl/month)	- Reduce SEC 2 % per year and achieve world class by 4 years.	- Improve energy efficiency 5 %	- Model target is 20 % reduction, analysed monthly after adjustments.
Note	- The company does not care about outdoor temperature and production change		- This hotel set energy cost to EnPI at first. However, energy performance improvement action's effect could not be confirmed. Because unit price of oil was up and average temperature in baseline period was high. Thus this company decided to use energy efficiency as EnPI.	- Model works with all the variables related to the measures being included.

C.3 Case study

An organization produces two lines of products: A and B.

After completing a thorough energy review of its manufacturing facility, the organization's energy management team draws the following conclusions:

— the facility uses electricity, purchased from an external supplier, as the only source of energy;

— the production rate (run-rate) of each production line can be varied from zero to 100 %;

— the output of each production line is measured independently in kg;

— SEC (energy consumption per kg) of line B is 10 times higher than that of line A and production volume of each line is almost the same;

— raw material quality varies;

— there is a project scheduled to upgrade all of the motors on production line A.

The different functions within the organization include a business/marketing manager, the facilities operations manager, the accounting department, the production line A engineer and the production line B engineer, as well as the operating technicians for each line. The energy management team holds discussions with each of these functions, and based on these discussions, the team determines that, because of the multi-level nature of the organization, with each level having specific responsibility for energy performance at its own level and sphere of control, a tiered set of EnPIs should be established in order to provide the organization with the information it needs to effectively manage and improve energy performance. Each functional group will require different levels of information to meet management requirements and to respond to specific energy management questions. Since two production lines have quite different SEC, they select energy consumption per value of production (energy intensity) as the facility level EnPI.

The team then collects time-series data at the facility level and production line level for energy consumption, energy costs, raw material quality and quantity, production for each line, and weather conditions. The team uses the collected data to model the facility and two production lines. Through analysis of the data and model, the team determines that there is a correlation between changes in some of the variables and energy consumption. The team identifies the following as the relevant variables: production quantity, production rate, product mix and air humidity.

Data analysis in this case, indicates that raw material quality does not cause a significant change in energy consumption. The team establishes the EnPIs in a hierarchy presented in Table C.2, with higher level EnPIs (e.g. 1.1) geared toward higher level information requirements, with more specific EnPIs (e.g. 2.1.1.1) aimed at line engineers and technicians. The energy management team refers the Table C.2 to guide the use and purpose of the EnPIs.

Table C.2 — Use and purpose of EnPIs

EnPI levels	Purpose/Need	EnPI Type	EnPI users
1 Facility business level EnPIs			
1.1 Facility level energy consumption (kWh/day)	- Total production cost control - Budgeting	Measured energy value	- Top management - The accounting department - Business leaders - Budget managers
1.1.1 Facility level energy consumption per volume of production (kWh/US$)	- Total energy efficiency control - Evaluate the effect the improvement action	Ratio of measured values	- Facility decision makers - Marketing manager - Sales department - Manufacturing manager - Business manager - Facilities owner
2 Product line A EnPIs			
2.1 Line A energy consumption (kWh/day)	- Total production cost control of line A - Budgeting	Measured energy value EnPI	- Plant A engineer - Budgeting manager - Accounting department
2.1.1 Line A energy consumption per kg of product output (kWh/kg)	- Energy efficiency control of line A - Evaluate EPIA effect	Ratio of measured values	- Marketing manager - Sales department - Business manager - Plant A engineer - Budgeting manager - Accounting department
2.1.1.1 Line A energy consumption per kg of product output (kWh/kg) – normalized for air humidity [a]	- Evaluate air humidity effect	Ratio of measured values	- Plant A engineer - Plant A operating technicians
2.1.1.2 Line A energy consumption per kg of product output (kWh/kg) – normalized for run-rate	- Evaluate run-rate effect	Ratio of measured values	Same as 2.1.1.1
2.1.1.2.1 Line A energy consumption per kg of product output (kWh/kg) – normalized for air humidity and run-rate	- Evaluate run-rate and air humidity effect	Ratio of measured values	Same as 2.1.1.1
3 Product line B EnPIs (same as line A)			
Repeated for Line B			

[a] “Normalized for air humidity” means additional normalization by air-humidity for normalized SEC by product output. If air-humidity and SEC have proportional relation, normalized SEC can be calculated. Run-rate can be normalized in the same way (Normalized SEC = SEC x Air humidity / reference Air humidity).

Annex D
(informative)

Normalizing energy baselines using relevant variables

D.1 Concept of normalization

Normalization is a term that is used broadly and can have substantially different meanings in different fields and applications. In this context, normalization is being used to describe the process of modelling energy consumption data with respect to relevant variables in order to compare energy performance under equivalent conditions. Typically, statistical methods such as linear regression are used to normalize or model energy consumption with respect to relevant variables. The general concept of calculating energy performance using normalized EnPIs and EnBs is illustrated in Figure D.1.

The dotted line in Figure D.1 shows values of energy consumption based on a statistical model of the EnPI that normalizes consumption with respect to relevant variables. The values of the relevant variables during the baseline period are used to develop the model. The dashed line shows actual energy consumption. If the statistical model is developed properly, then the values of the EnPI during the baseline period, or EnB, will predict the actual consumption during the baseline period accurately.

NOTE The predicted and actual values of energy consumption during the baseline period will typically not lay exactly on top of each other, as shown in Figure D.1.

The model can also be used to predict future energy consumption. Using the values of relevant variables during future time periods in the model will give predicted or estimated values for energy consumption. By comparing predicted energy consumption with actual energy consumption, the energy performance improvement can be calculated. The difference between the actual energy consumption and the predicted or expected consumption will indicate whether an energy performance improvement has occurred. If an organization is actively implementing its action plans, then this difference should be evident. The predicted energy consumption shows what energy would have been consumed in the reporting period had there been no energy performance improvement opportunities or action plans implemented.

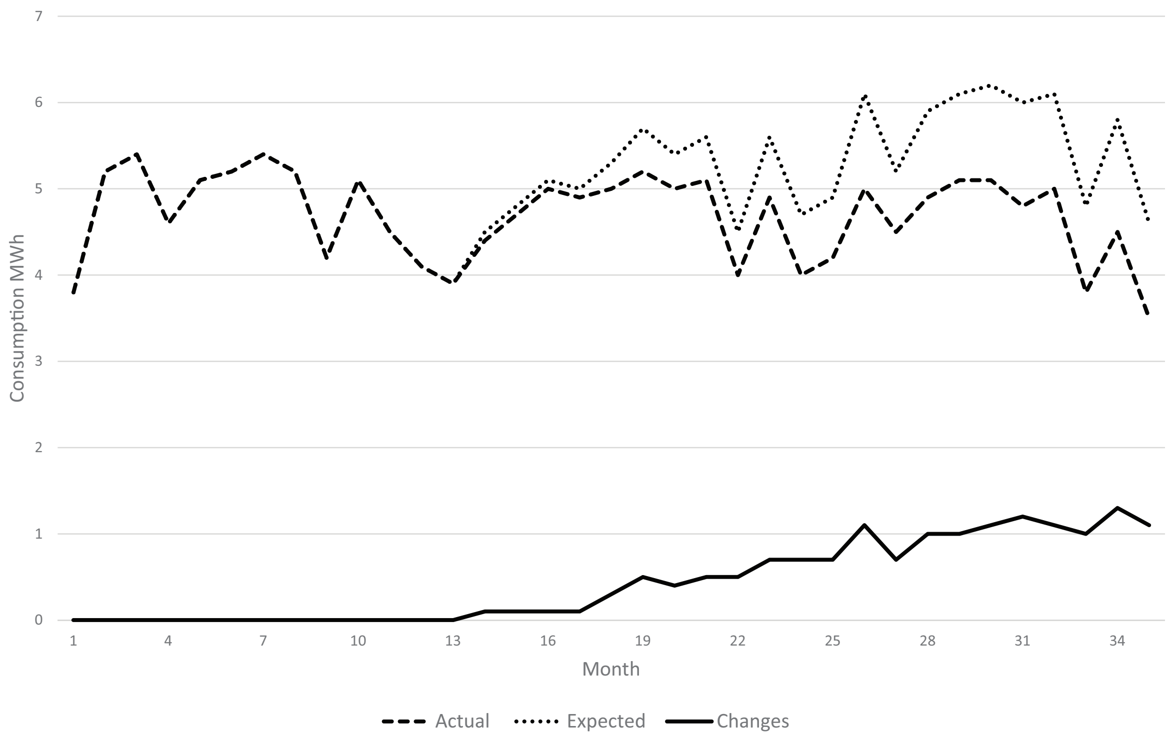


Figure D.1 — Calculating energy performance using normalization

D.2 Examples of normalization calculation

The EnPI quantifies the mathematical relationship between energy consumption and the relevant variables. Using linear regression, an example relationship may be as follows:

Energy consumption (kWh) = A + B x Product A + C x T

where

A	is a fixed energy consumption (base-load) (kWh);
B	is the energy consumption per unit of product A (kWh/unit);
Product A	is the production volume of product A (unit/month);
C	is the energy consumption per degree of monthly temperature per week (kWh/°C);
T	is the average monthly temperature (°C).

The factors A, B and C will be derived from statistical modelling methods used to develop the linear regression.

This relationship should also meet statistical tests. Examples of the test are coefficient of determination (R2), coefficient of variation (CV) and F-test.

The independent or relevant variables used in the equation should also be statistically significant in explaining the variation in energy consumption. For assessing statistical significance, each variable will need to meet a certain p-value.

If the model is not statistically sound then it may need to be explored:

a) relevant variables may be missing;

b) eliminating data outliers;

c) change data aggregation period (i.e. hourly, vs, daily, vs. monthly, etc.).

Typically, the model for energy consumption would be developed using values of the relevant variables during the baseline period.

NOTE Other time periods between and including the baseline and reporting periods can be utilized to develop the regression model. This is a more advanced topic.

To calculate energy performance, the values of the relevant variables during the reporting period will be utilized in the above equation to calculate expected or predicted energy consumption and compared to the actual energy consumption, as illustrated below:

$$\text{Energy consumption}_R \text{ (kWh)} = A + B \text{ x Product } A_R + C \text{ x } T_R$$

where

Energy consumption_R	is the predicted energy consumption during the reporting period
A, B and C values	are developed from the linear regression analysis;
Product A_R	are the measured value of production volume during the reporting period;
T_R	is the measured value for average monthly temperature during the reporting period.

The concept of the above calculation process is illustrated in Figure D.2.

- Estimated energy consumption $E_{rep\_est} = f(P_{rep})$
- Energy consumption changes $\Delta E = \underbrace{E_{rep\_est}}_{Estimated} - \underbrace{E_{rep\_act}}_{Actual}$

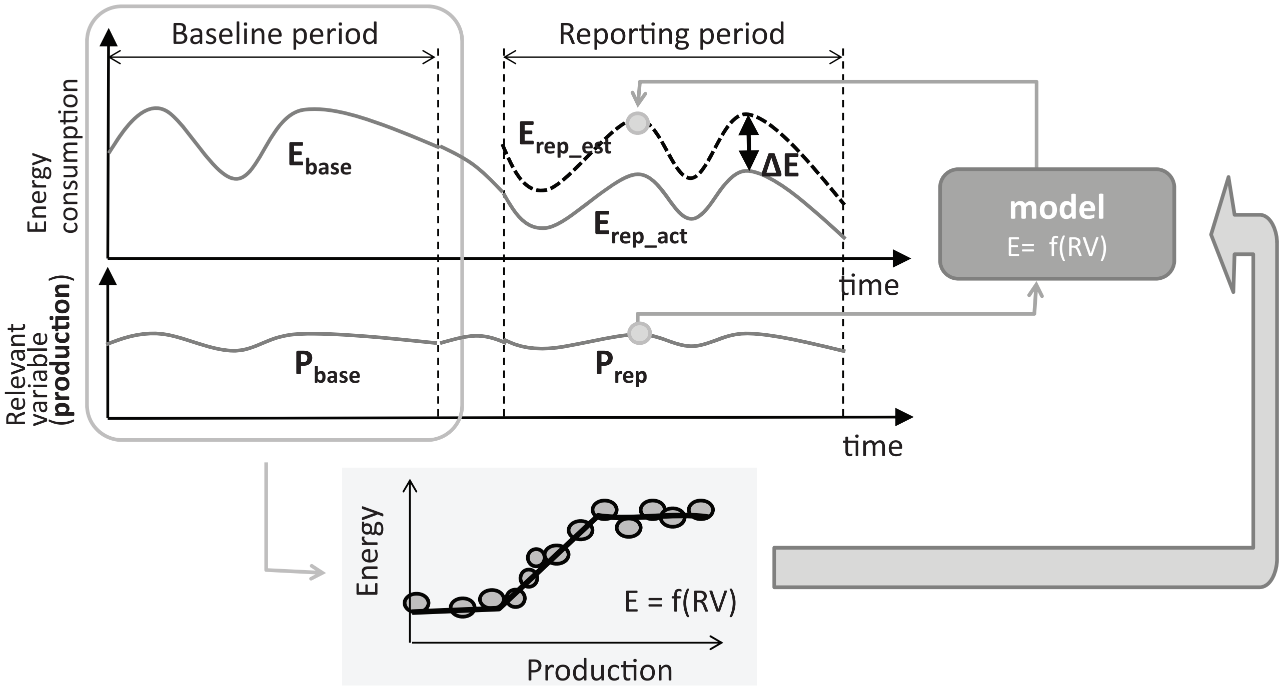


Figure D.2 — Normalization calculation process

The model of energy consumption is developed using the values for production volume during the baseline period. The model in this case only uses one relevant variable – production. The model estimates or predicts energy consumption, E_{rep_est}, based on the values for the relevant variables during the reporting period. The difference in energy consumption, ΔE, between the actual energy consumption, E_{rep_act}, and the estimated energy consumption is the calculated energy performance improvement.

Annex E
(informative)

Monitoring and reporting on energy performance

E.1 General

Figure E.1 shows the outline of the energy performance concept and its visualization method. It is required to show the measured results according to users' needs. For example, for top management may prefer the outline of the results of whole organization. Results regarding specific actions may be better suited for a plant operator. Detailed results may be better suited for the engineers in order to find opportunities for establishing energy performance improvement actions.

The current energy value and their relevant variables can be referred by these metrics as illustrated in Figure E.1. Information on the baseline period recorded to a data set are also provided. Furthermore, the estimated values by EnB models are also provided if model-based EnPI are used.

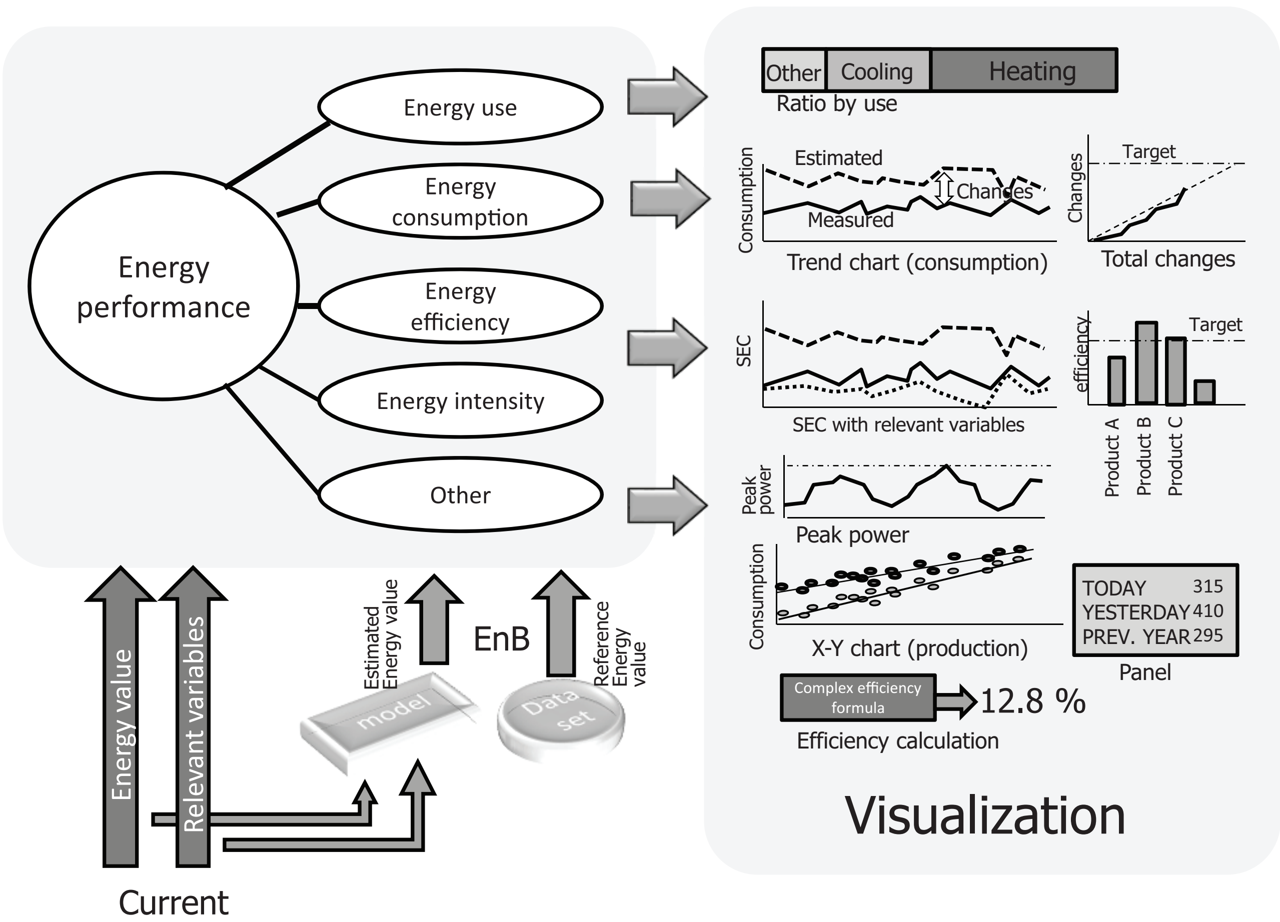


Figure E.1 — Overview of monitoring and reporting energy performance

E.2 Types of monitoring methods and reports

Organizations can use a variety of reports and various kinds of monitoring and reporting methods for energy performance, including:

— comparing current performance against target performance (comparison chart of target and current EnPI);

— trend chart of EnPIs (and relevant variables);

— X-Y chart (e.g. energy consumption and production);

— assessing variance (variance);

— cumulative summation chart (CUSUM);

— visualization using various analytical tools;

— multidimensional graphics with internal benchmarking.

Monitoring can also be carried out using alarm chart for abnormalities in real time EnPI values.

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

E.3 Target and current EnPI comparison

Examples of EnPIs comparisons for three elements of energy performance are shown below.

a) Energy consumption (see Figure 3): Energy consumptions of a baseline period and reporting period are compared.

b) Energy efficiency (see Figure E. 2 a)): SEC of a baseline period and reporting period are compared.

c) Energy use (see Figure E.2 b)): The shares of a specific energy use in a baseline period and reporting period are compared.

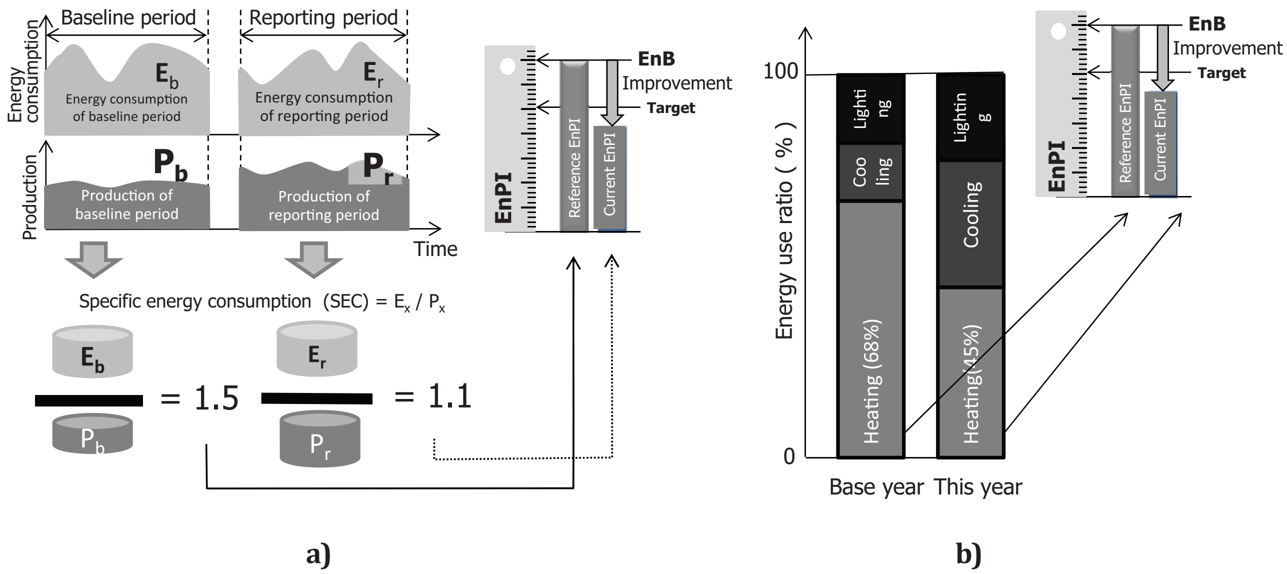


Figure E.2 — Example of EnPIs regarding energy efficiency and energy use

Figure E.3 shows how the EnB, current EnPI, and target can be displayed. The difference between target and the current EnPI is also displayed. Facility managers or operators can find the impacts of their work on energy performance and take actions if necessary.

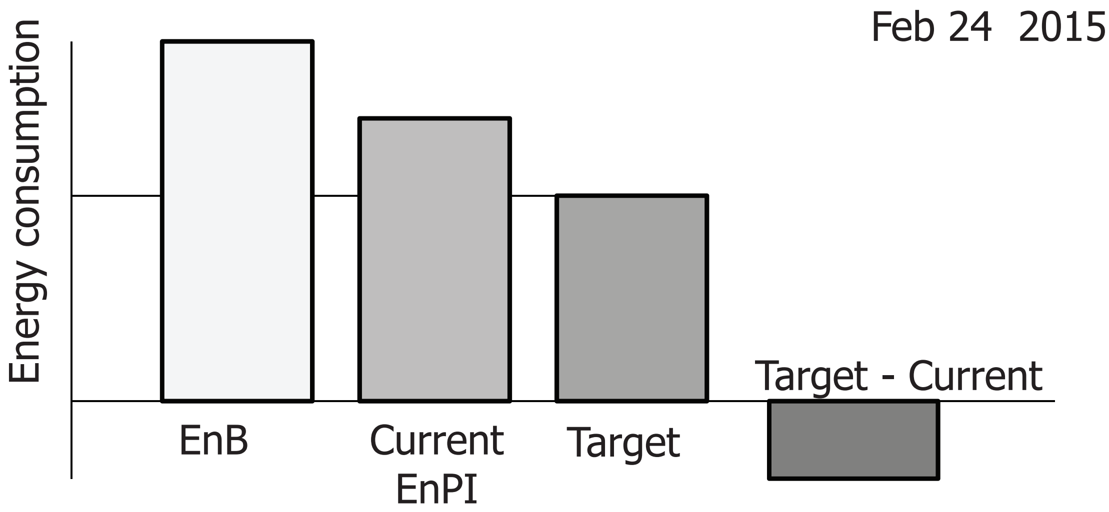


Figure E.3 — EnPI and target

E.4 Trend chart

EnPIs should be measured for individual facilities and equipment that have significant energy use. These individually-measured EnPIs can be monitored continuously and may vary over time. EnPIs and relevant variables can be displayed together as a real time trend chart. Changes in EnPI can be demonstrated.

By investigating the causes of the variation, unnecessary energy use can be identified. As shown in Figure E.4, visualization of monitoring and measurement results facilitates identification of variations of the EnPIs, or failures of equipment.

In Figure E.4, the SEC is very high at low production levels, suggesting high fixed consumption or poor part load energy performance.

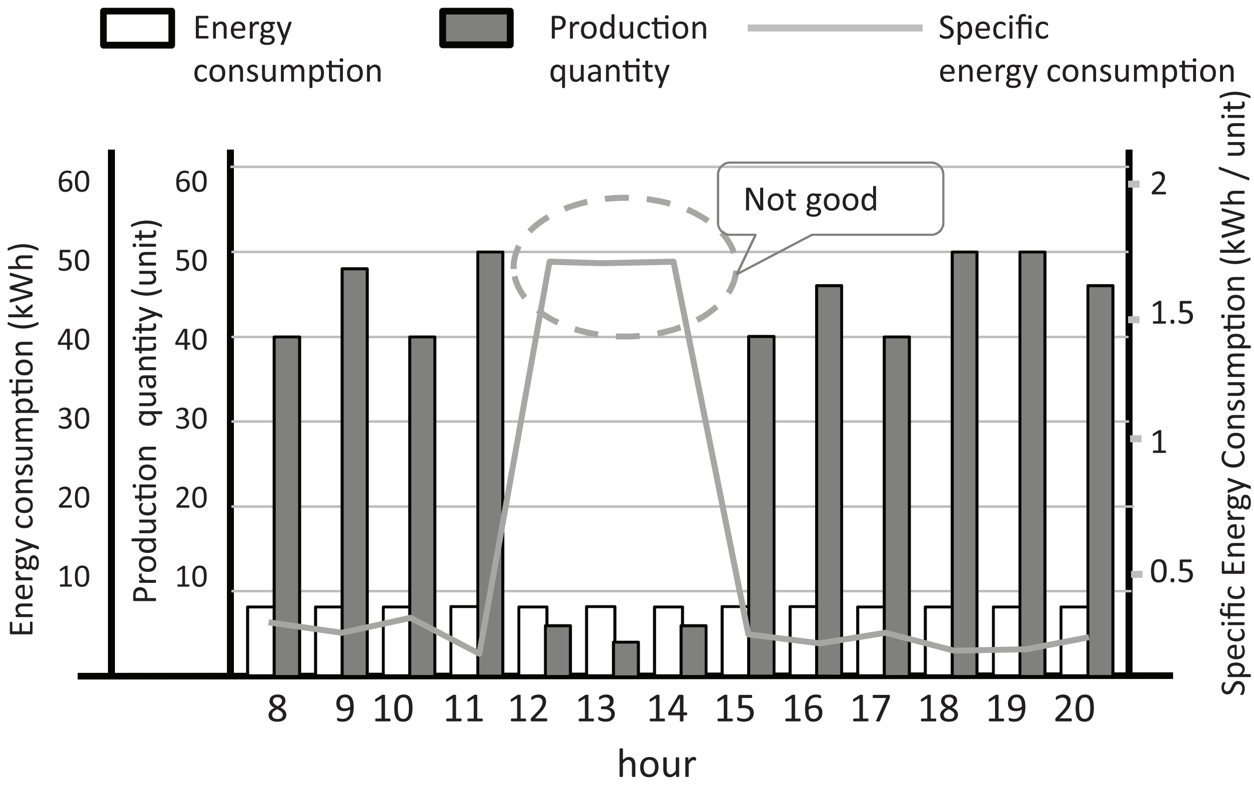


Figure E.4 — SEC trend chart

E.5 X-Y chart

The daily or weekly production quantities and their corresponding energy consumption can be shown in an X-Y chart, (Figure E.5) so that any energy performance improvement can be checked visually. For example, in 2011, a certain production facility had its equipment working at 100 % capacity. But in 2012, this production facility was retrofitted to consume energy according to the quantity of production. This is reflected as a reduction in the base load energy consumption in the X-Y chart.

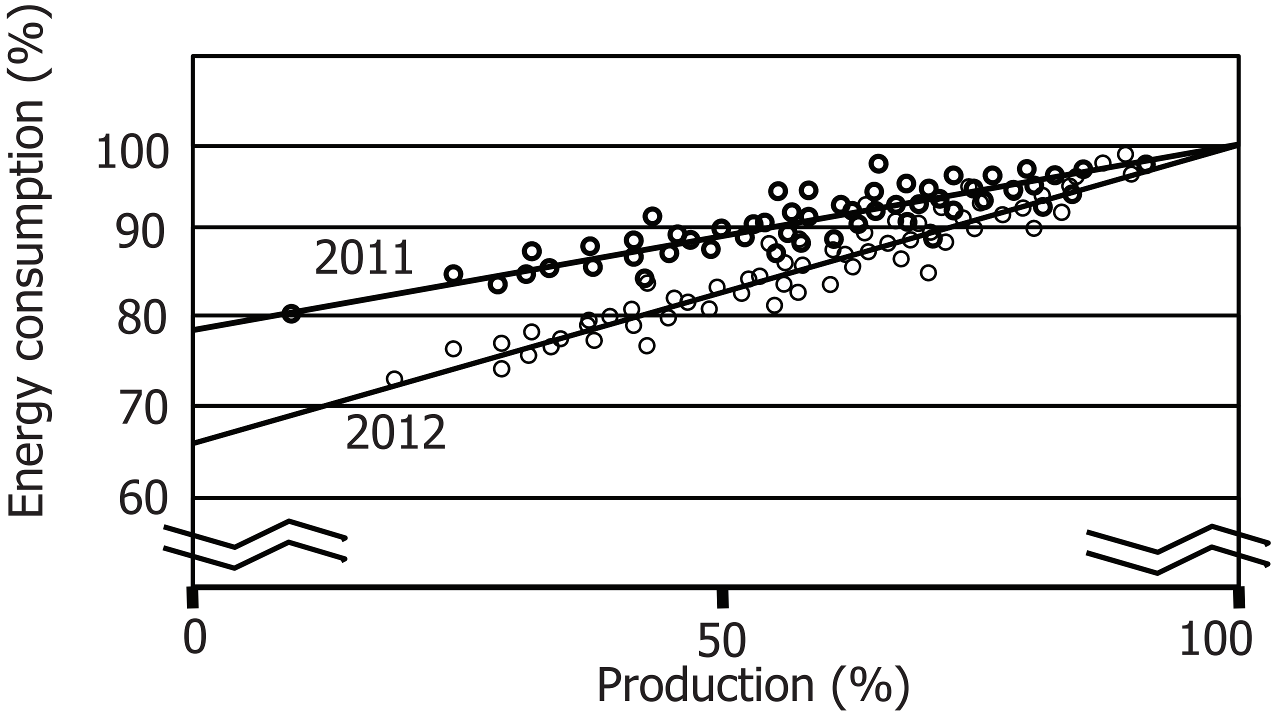


Figure E.5 — X-Y chart

E.6 Reporting units

Figures E.3, E.4 and E.5 present the energy units or percentages as reporting units. The potential problem with this approach is that, in general, people have little appreciation of the scale or value of a typical energy unit – i.e. just how much is 10 GJ worth? To overcome this barrier and to provide a sense of scale to the graphs, it is possible to convert the energy units into monetary values.

There are two possible approaches: to use a budgetary value for energy which does not change or to use actual utility purchase costs. The first approach is clearly far simpler to implement, though less accurate. In the second approach, tariff information for the utility and information on the generation and distribution efficiency is required where secondary utilities such as steam are being used.

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