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ISO 50006:
The new ISO standard for
energy baselines and performance indicators

BSI 英國標準協會 台灣分公司

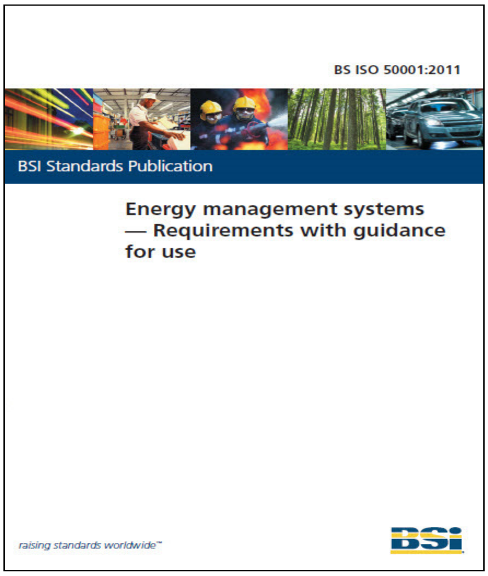
感謝大家參與

By : Kevin Lin 林信作

ISO 50001- Energy management systems 能源管理系統
組織建立所需的系統與過程以改善能源績效的標準

The future ISO 50001 will:

- Establish a framework for industrial plants, commercial facilities or entire organizations to manage energy
- Have broad applicability across national economic sectors, potentially influence up to 60 % of the world's energy use.



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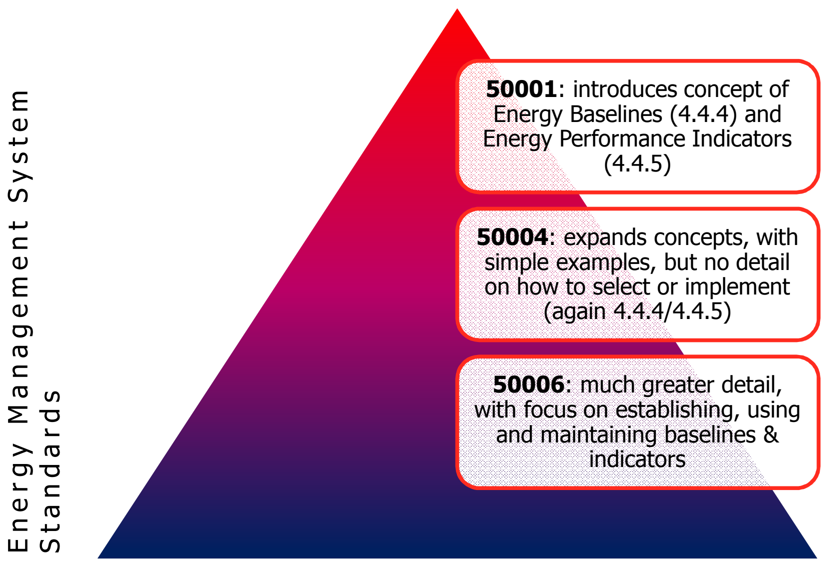
ISO 50001 was incomplete...

- **ISO 50001 is a Management Systems standard**
- **As such it focuses on process, including how to develop a PDCA cycle, but in some ways lacks specificity to energy**
- **The relevant ISO committee recognised this, so is drawing up supporting standards**
- So far:
  - 50002 – Energy audits - Requirements with guidance for use
  - 50003 – Requirements for bodies providing audit and certification of energy management systems
  - 50004 – Guidance for the implementation, maintenance and improvement of an energy management system
  - **50006 – Energy Baselines and Energy Performance Indicators**
  - 50015 – Measurement and verification of energy performance of organizations - General principles and guidance

So where does it fit in?



So what does ISO 50001 say?

4.4.4 Energy Baselines

- The organization shall establish an energy baseline(s) using the information in the initial energy review, considering a data period suitable to the organization's energy use and consumption. Changes in energy performance shall be measured against the energy baseline(s).
- Adjustments to the baseline(s) shall be made in the case of one or more of the following:
  - EnPIs no longer reflect organizational energy use and consumption, or
  - there have been major changes to the process, operational patterns, or energy systems, or
  - according to a predetermined method.
- The energy baseline(s) shall be maintained and recorded.

- *Note "shall" imposes a requirement*
- *Determination follows energy review & may be adjusted*

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So what does ISO 50001 say?

4.4.5 Energy Performance Indicators

- The organization shall identify EnPIs appropriate for monitoring and measuring its energy performance. The methodology for determining and updating the EnPIs shall be recorded and regularly reviewed.
- EnPIs shall be reviewed and compared
  to the energy baseline as appropriate.

- *Again "shall"; linked to baseline, but otherwise little guidance on what or how.*

ISO 50004 expands both sections to around half a page, and gives examples of types of indicators:

- energy consumption (in total or broken down by energy use)
  (e.g. kWh, GJ);
- simple ratio such as energy consumption per unit of output
  (e.g. kWh per tonne, kWh per man hour worked);
- statistical model
  (e.g. linear and nonlinear regression);
- engineering based model
  (e.g. simulation).

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So we need more guidance in 50006

- Like ISO 50004, a guidance standard (no requirements)
  - Designed to be practical; ISO 50001 *is* normative
  - Use of Help Boxes dispersed within text
- Focus on establishing, using and maintaining baselines & indicators
- Starts with a general overview
- Suggests how to use the Energy Review to obtain relevant energy performance information
- Then identifies suitable energy performance indicators...
- ...and establishes matching baselines
- Considers how to use them...
- ...and how to maintain and adjust them as circumstances change

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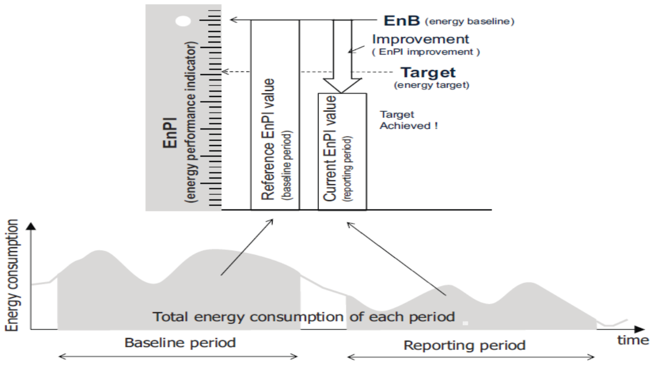
General Overview

- Reminds users of distinction between energy consumption and use, and the various meanings of energy efficiency
- Shows how measuring energy performance fits into a PDCA cycle
- Introduces Energy Performance Indicators (EnPIs) and Energy Baselines
- Places these into the context of quantifying energy performance



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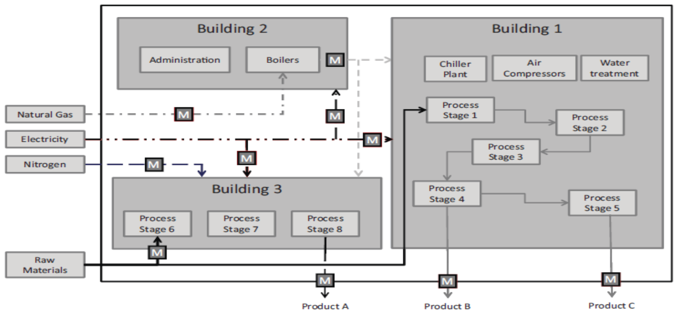
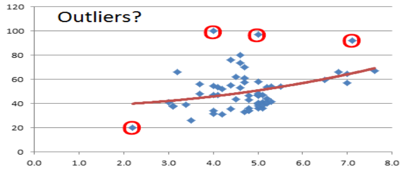
Obtaining information from Energy Review

- Start by defining EnPI boundaries
  - Individual facility/process
  - System
  - Organization
- Fence diagrams & energy flows
- Define & quantify relevant variables and static factors
- Collect the data
  - Measurement & metering
  - Frequency
  - Quality
  - Outliers





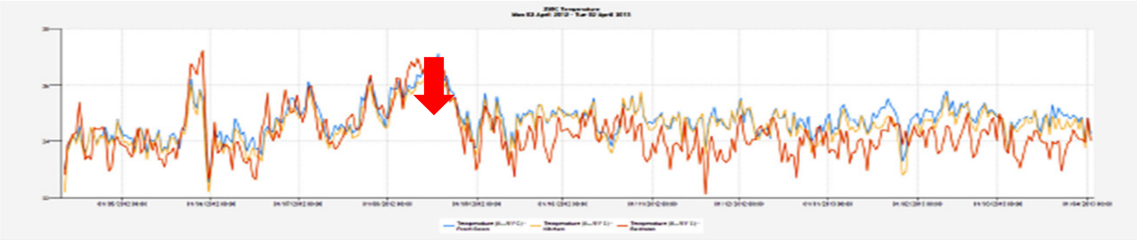
Identify Energy Performance Indicators

- Links to Energy Management System & Objectives
- Ensure appropriate to users (may need multiple indicators)
- Four broad types of EnPIs:

EnPI Type	Examples
Measured Energy Value	kWh, GJ, peak demand (kW)
Ratio of measured values	MWh/tonne, GJ/unit, kWh/m^2, litres/passenger-km
Statistical Model	Base load; multiple variables
Engineering model	Simulations; whole building models

Establish Energy Baselines

- The value of the EnPI during the Baseline period
- Identify the purpose for which it will be used
- Determine a suitable data period
  - One year most common, effects of weather periodicity or seasonal demand
  - Can average over several years
- Collect data and determine and test the EnB



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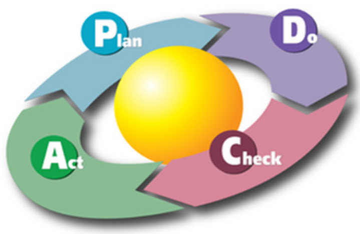
Using Energy Performance Indicators

- Normalisation
- Calculating energy performance improvements
  - EnPI difference
  - Percentage change
  - Current ratio (reporting period value/baseline)
- Communicating changes in energy performance
- Maintaining EnPIs and baselines
  - Tests for continuing validity
  - Necessary adjustments to baselines
  - Changes due to static factors, improved data availability, revised EnPI targets, regular (rolling) baselines, management review



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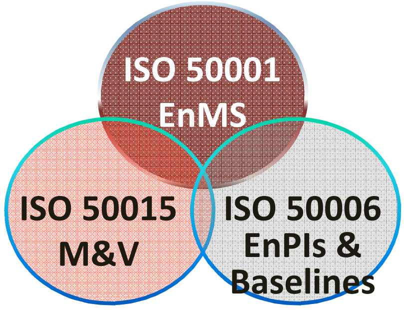
Relationship to other standards

- In addition to 50001 & 50004, ISO 50006 links to other standards:
- ISO 50015 – Measurement and verification of energy performance of organizations
- ISO 14064-3 – Greenhouse gases — Part 3: Specification with guidance for the validation and verification of greenhouse gas assertions

also

- ISO 17747 (in preparation) – Determination of energy savings in organizations
- EN 16231 – Energy Efficiency Benchmarking



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課 程 內 容

ISO 50006:2014

(使用能源基線與能源績效指標量測能源績效之一班原則與指引)

1. 名詞與觀念
2. 能源績效指標(EnPI)之類型與應用
3. 能源基線(EnB)之建立與類型

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Contents

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Introduction(1/3)

- The purpose of ISO 50001 Energy Management System (EnMS) is to enable organizations to establish the system and processes necessary to improve energy performance.
- It requires organizations to quantify energy performance and monitor, measure and analyze key characteristics of its operations.
- It defines operational features as the key characteristics that affect organizational energy performance. Examples of key characteristics include significant energy uses (SEUs), relevant variables related to SEUs, energy baseline (EnB), energy performance indicators (EnPIs), effectiveness of action plans, etc.

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Introduction(2/3)

- **An EnB quantifies energy performance during a specified time period to be used as a base reference for comparing energy performance.**
- The EnB enables comparisons of energy performance between selected periods thereby enabling the organization to assess changes in energy performance between the periods.
- The EnB is a reference that characterizes and quantifies an organization's energy performance prior to the introduction of energy performance improvement actions.
- The EnB is also used for calculation of energy savings, as a reference before and after implementation of energy performance improvements.

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Introduction(3/3)

- 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 there energy performance**.

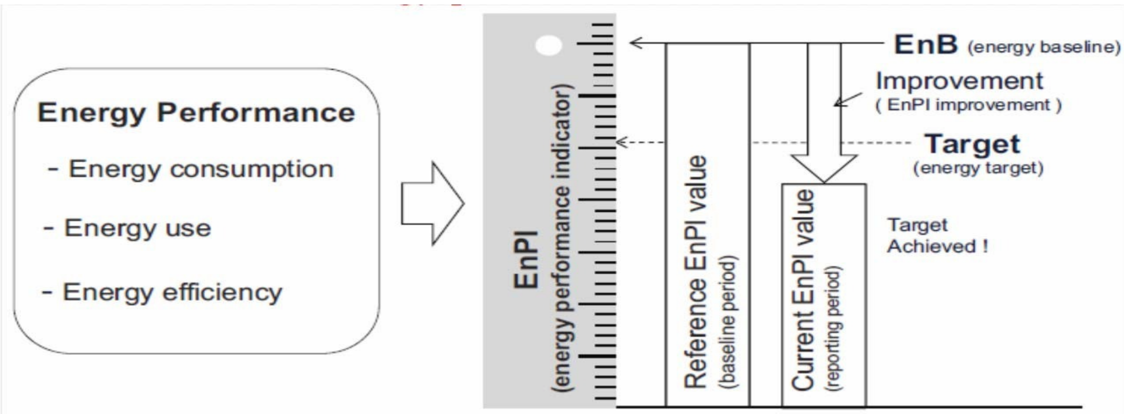

Figure 1– Relationship between EnPIs, EnBs and energy targets

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Terms and definitions (1/17)

Adjustment 調整

- 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.

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Terms and definitions (2/17)

Baseline period 基準期

- Defined period of time used to compare energy performance with the reporting period.

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Terms and definitions (3/17)

Boundaries 範圍

- 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.

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Terms and definitions (4/17)

Energy 能源

- Electricity, fuel, steam, heat, compressed air, and other like media.
  - **NOTE 1:** 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:** Energy can be defined as the capacity of a system to produce external activity or perform work.

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Terms and definitions (5/17)

Energy baseline, EnB 能源基線

- Quantitative reference(s) providing a basis for comparison of energy performance

  提供作為能源績效比較的基準之量化參考

  - **NOTE 1** ： An energy baseline reflects a specified period of time.
  - **NOTE 2**：An energy baseline can be normalized using variables which affect energy use and/or consumption,
  - production level, degree days (outdoor temperature), etc.
  - **NOTE 3**：The energy baseline is also used for calculation of energy savings, as a reference before and after implementation of energy performance improvement actions.

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Terms and definitions (6/17)

Energy consumption 能源消耗

- Quantity of energy applied
  - **Note 1**: 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**: 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.

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Terms and definitions (7/17)

Energy efficiency 能源效率

- 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**: Both input and output need to be clearly specified in quantity and quality, and be measurable.

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Terms and definitions (8/17)

Energy performance 能源績效

- Measurable results related to energy efficiency, energy use and energy consumption
  - **NOTE 1**：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**：Energy performance is one component of
  - the performance of the energy management system.

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Terms and definitions (9/17)

Energy performance indicator(EnPI) 能源績效指標

- **Quantitative value or measure of energy performance, as defined by the organization.**
  量化的值或者如組織所定義的能源績效的量測值

- **NOTE** EnPIs could be expressed as a simple metric, ratio or a more complex model. [SOURCE: ISO 50001:2011, 3.13]

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Terms and definitions (10/17)

Energy target 能源標的

- 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

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Terms and definitions (11/17)

Energy use 能源使用

- Manner or kind of application of energy.

- **EXAMPLE**: Ventilation; lighting; heating; cooling; transportation; processes; production lines.

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Terms and definitions (12/17)

Facility 設施

- 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.

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Terms and definitions (13/17)

Normalization 標準化

- Process of routinely modifying energy data in order to account for changes in relevant variables to compare energy performance **under equivalent conditions**.

- **Note 1**: EnPIs and corresponding EnBs can be normalized.

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Terms and definitions (14/17)

Relevant variable 相關變數

- 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).

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Terms and definitions (15/17)

Reporting period 報告週期

- 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.

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Terms and definitions (16/17)

Significant energy use, SEU 重大能源使用

- Energy use accounting for substantial energy consumption and/or offering considerable potential for energy performance improvement.

- **Note 1**: Significance criteria are determined by the organization.

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Terms and definitions (17/17)

Static factors 靜態因子

- 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 aluminum to plastic.

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4 Measurement of energy performance(1/3)

- 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.
- The general relationship between EnPIs, EnBs, and energy targets is illustrated in **Figure 1**.

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4 Measurement of energy performance(2/3)

- Energy performance can be affected by a number of factors or variables such as occupancy level, production rate or weather. These factors can be linked to business objectives such as product quality or system reliability.
- An overview of the overall process to develop, use and update EnPIs and EnBs is illustrated in Figure 2 and described in detail in Section 4.2 to 4.6.

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4 Measurement of energy performance(3/3)

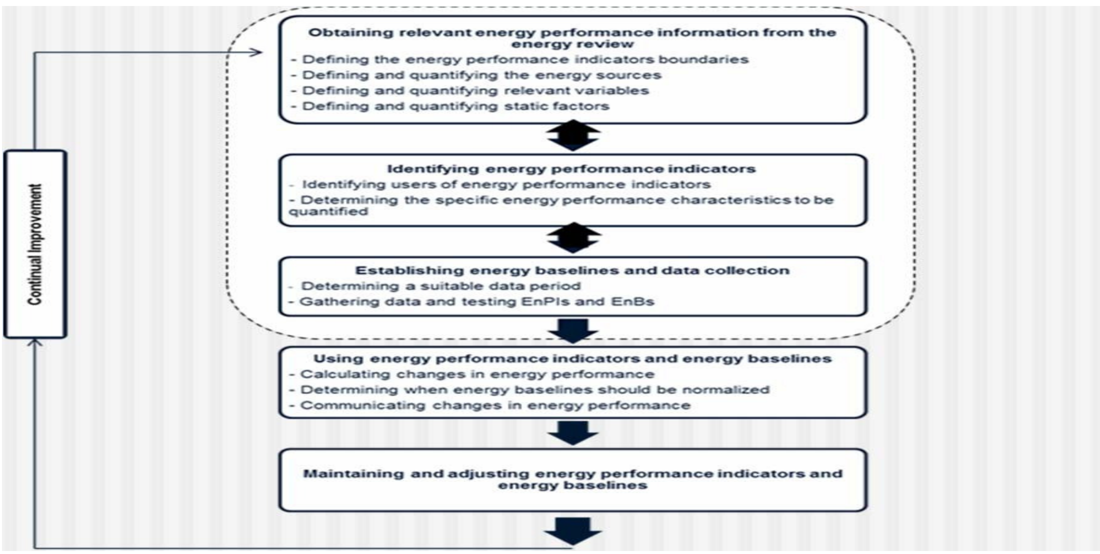

Figure 2— Overview of energy performance measurement

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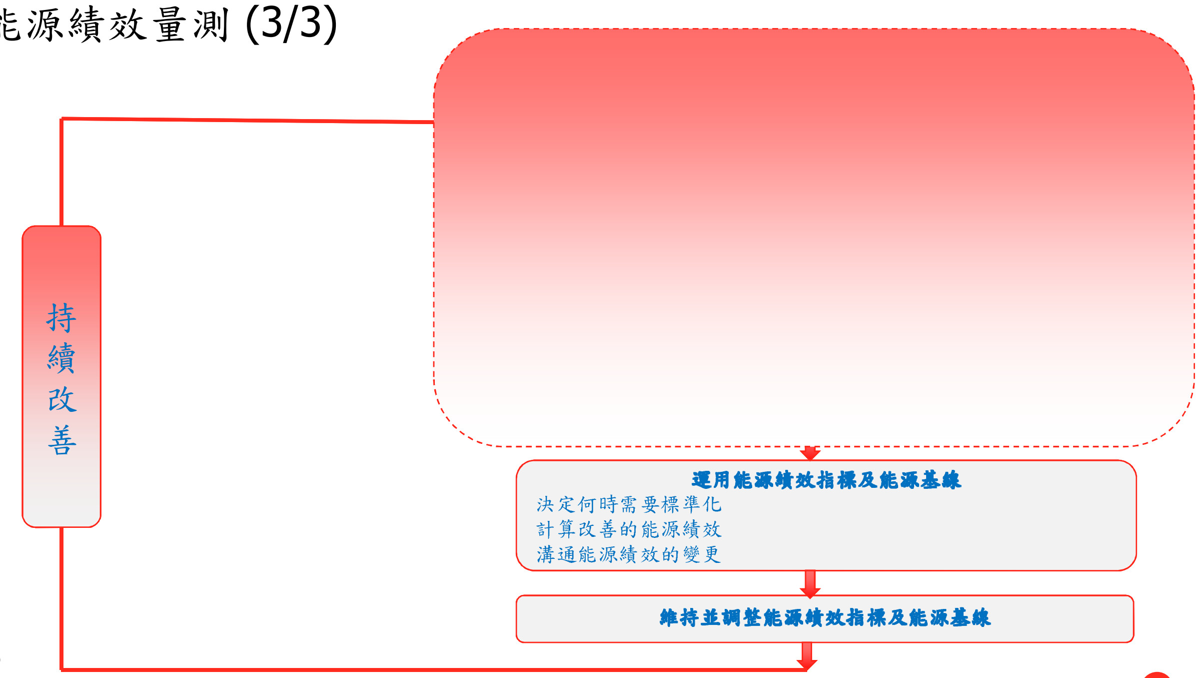
4 能源績效量測 (3/3)



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4.1.2 Energy consumption

- **When multiple forms of energy are used, it is useful to convert all forms to a common unit of measure.**
- Care should be taken however to perform the conversion in a manner that most accurately represents total energy consumed including losses in conversion process within an organization.

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Energy consumption

- Conversion of all forms of energy into equivalent units of source energy is a well established and practical method to represent total energy. (e.g. converting natural gas energy into electrical energy or steam energy).

- Energy consumption should be measured over a specific period of time (e.g. a day, a week, month, or year)

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4.1.5 Energy performance indicators (EnPIs)(1/2)

- **There are many types of EnPIs, including measured values, ratios, statistical models or engineering models.**
- **EnPIs should provide relevant energy performance information to enable various groups 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.

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Energy performance indicators (EnPIs)(2/2)

- For example: within one organization, an executive may require a facility-wide EnPI and an operations manager may require an EnPI for a product line or area of facility.
  - ✓ **Therefore, energy performance is often represented by more than one EnPI**.
- To compare under equivalent condition, EnPIs may **need to be normalized** with respect to **relevant variables or changes** in static factors.
- EnPIs should **be selected and developed** in order to measure the energy performance improvement that results from the implementation of the EnMS.

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4.1.6 Energy baselines (EnBs)

- **Once the EnPIs are selected, EnBs are established to serve as a comparative reference against each corresponding EnPIs**.
- An EnB should be developed using data collected over a suitable period of time known as the baseline period.
- An organization should compare energy performance changes from the period for which the EnB has been constructed (baseline period) and the period being evaluated by the EnPI (reporting period).

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Energy baselines (EnBs)

- The type of information needed to establish an energy baseline is determined by the specific purpose of the EnPI.

NOTE: Where there is no operating history such as in the case of a new facility, it may be necessary to simulate, estimate or calculate the expected energy consumption for the new facility to serve as the EnB against which energy performance will be compared using the EnPI once the facility is operating.

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4.1.7 Quantifying energy performance(1/2)

Figure 3 illustrates the simple case where direct measurement of energy consumption is used as the EnPI and is compared between the baseline and the reporting period.

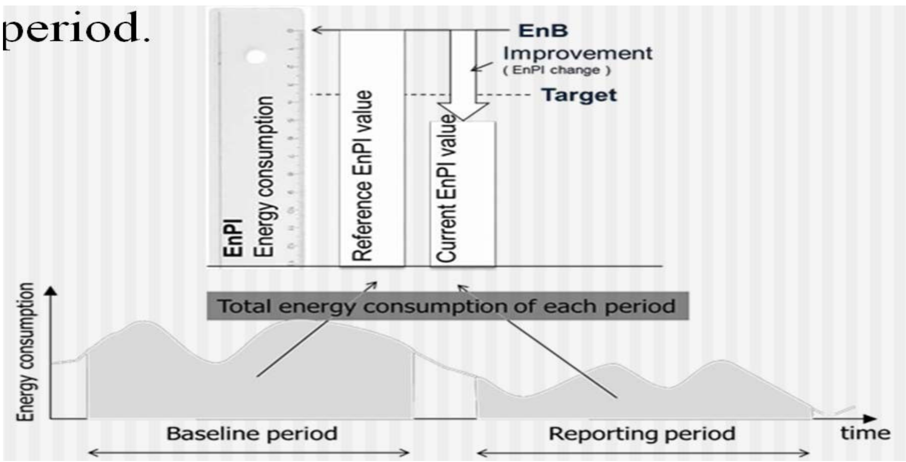

Figure 3- Concept of Baseline period and Reporting period for EnPI

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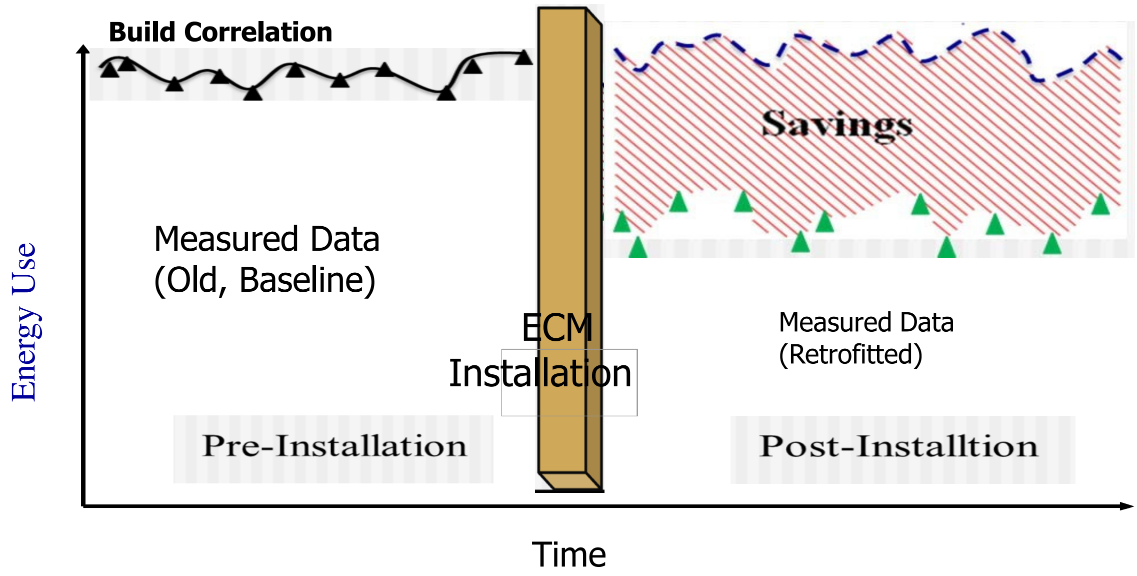
M&V 概念



Keep Independent Variable(s) Fixed

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IPMVP 基本公式

IPMVP 節能量基本公式

節能量(報告的任何期間)=
(基準耗能量+/- 調整量) – 改善期報告耗能量

參考文獻: IPMVP Volume Ⅰ, 2010, Chapter 4.1

From: 柯明村 教授

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Quantifying energy performance

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

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4.2.2 Defining the energy performance indicator boundaries(1/7)

- The EnMS scope and boundary comprise the area or the activities within which an organization manages energy performance.
- **Suitable EnPI boundaries should be defined:**
  - ✓ 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.

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Defining the energy performance indicator boundaries(2/7)

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

Table 1 — The three EnPI boundary levels

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Defining the energy performance indicator boundaries(3/7)

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

Defining the energy performance indicator boundaries(4/7)

Evolving business requirements:

- Evolving business requirements should be considered when defining EnPI boundaries.
- Physical changes or business events can occur that change the initially defined EnPI boundaries.
  - ✓ For example, a facility expansion or partial shut-down could warrant a change in the EnPI boundaries in which energy is managed and data are collected.

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Defining the energy performance indicator boundaries(5/7)

EnPIs at different levels:

- The organization may find it valuable to monitor energy at several different levels, each of which defines one (or more) EnPIs.
  - ✓ Senior business managers may prefer EnPIs from broader-level boundaries, while operations manager or process engineers may prefer EnPIs based on narrower EnPI boundaries.
  - ✓ Energy managers may find use for EnPIs at both levels.

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Defining the energy performance indicator boundaries(6/7)

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

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Defining the energy performance indicator boundaries(7/7)

Reviewing EnPI boundaries:

- It may be necessary to revisit EnPI boundaries and revise them based on downstream requirements, such as the availability of appropriate data for certain production lines.
- Supplemental information on EnPI boundaries in the production process can be found in Annex B.

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4.2.3 Defining and quantifying the energy flows(1/2)

- Once an EnPI boundary is defined, the energy flowing across the boundary should be identified.
- A diagram like the one in Figure 4 can be useful in the energy information required to establish EnPIs.
- Such diagrams are referred to as **Fence Diagrams or Energy Maps.**
- These diagrams visually show flow or energy sources alongside the various energy consuming processes or systems.
- Such a diagram can also include additional information, such as metering points and product flow which are important for energy analysis and establishment of EnPIs.

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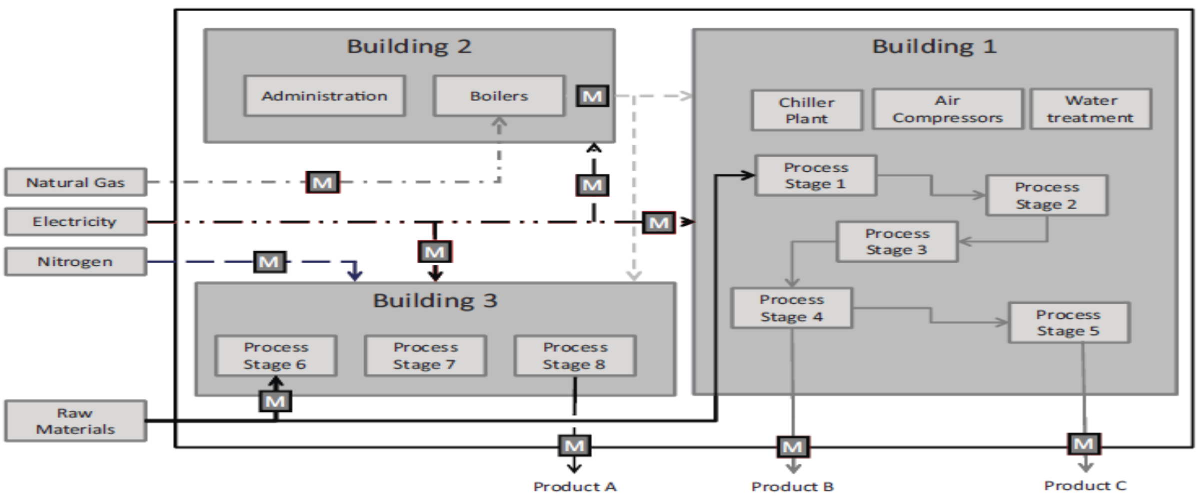
4.2.3 Defining and quantifying the energy sources(2/2)



NOTE: M=measurement

Figure 4 — Fence Diagram

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4.2.4 Defining and quantifying relevant variables(1/4)

- 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 as energy consumption. For example,
  - ✓If the load 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 showed in Figure 5.

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Defining and quantifying relevant variables(2/4)

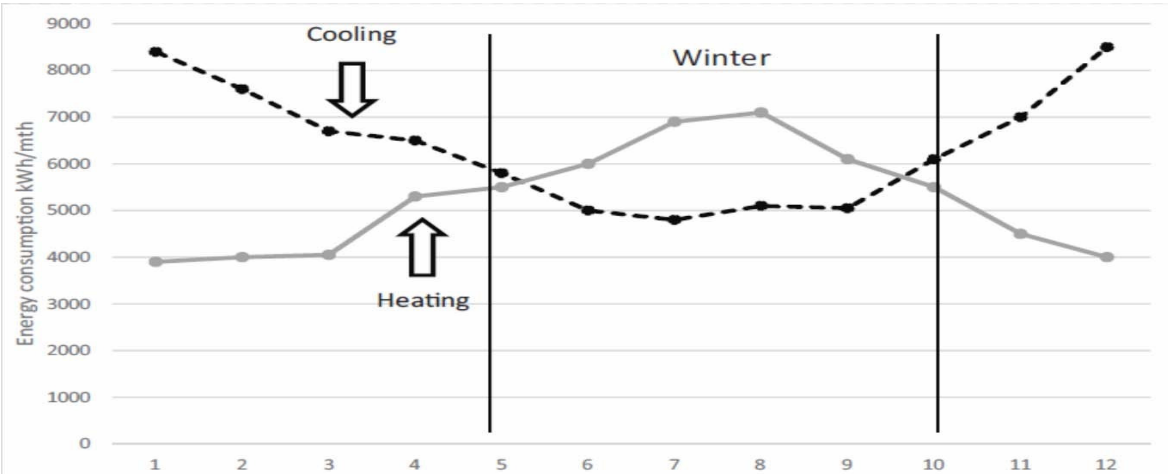

Figure 5 — Trend chart showing seasonality

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Defining and quantifying relevant variables(3/4)

- 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 (see Figure 6a).
  - ✓ If the points appear to be scattered around a mathematical function then this is indicative of the presence of relevant variables (see Figure 6b).
  - ✓ If the points appear as a random cloud with no evident relationship, the variable is likely not relevant (see Figure 6c).

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Defining and quantifying relevant variables(4/4)

- In many cases, a simple linear relationship is adequate for determining relevance.
- Certain variables may show nonlinear relationships and the organization will have to decide how to include those variables in the EnPI calculation.

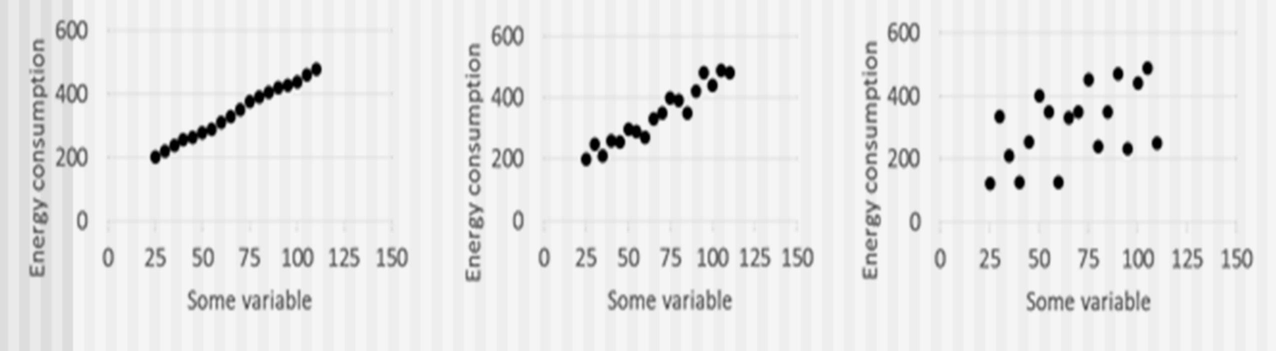

Figure 6 — Variables with differing levels of significance

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4.2.5 Defining and quantifying static factors

- Examples of potential static factors and changes that could turn them into relevant variables are shown in Table 2.

Table 2 — Examples of potential static factors

Static factor	Description	Conditions which change a static factor into a relevant variable.
Product type	Specific products produced by the plant	A plant introduces a new product and/or product mix changes.
Shifts per day	Plant currently runs a set number of shifts per day	A change to more or less shifts would significantly impact energy consumption.
Building occupancy	The occupancy pattern of a building is determined by the current tenants.	A change in tenants might result in a significant change in occupancy pattern resulting in changes in energy use and consumption.
Floor area	The size of the building that is the focus of the EnMS	The building is expanded which impacts energy use and consumption.

4.2.6 Gathering data(1/6)

Data collection

- Energy and relevant variables data are typically collected using meters and sub-meters either on a permanently installed, temporary or spot measurement basis.
- Challenges to energy data collection include:
  - ✓a lack of detailed metered data from energy suppliers,
  - ✓a lack of data on relevant variables,
  - ✓data in a form that is incompatible with the energy data, for example where energy data comes from monthly supplier invoices but production data is captured weekly.

bsi.

4.2.6 Gathering data(2/6)

Measurement

- Energy values 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.

bsi.

4.2.6 Gathering data(3/6)

- The organization should analyze what relevant variables need to be measured.
  - ✓ For example, **where energy use 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.**
- 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.

bsi.

4.2.6 Gathering data(4/6)

- Organizations should also collect data more frequently when they desire higher statistical accuracy.
  - ✓ The higher the data acquisition frequency, the more flexibility there will be to analyze data in different ways.
- If new measurement systems are to be installed, the organization should consider the frequency of data needed to meet its energy monitoring needs.

bsi.

4.2.6 Gathering data(5/6)

Ensuring data quality

- Prior to calculating EnPIs and corresponding EnBs, it is recommended that the set of measured energy values and relevant variables is reviewed to determine the quality of the data.
- Significant outliers, which are typically a result of faulty metering or data capture or atypical operating conditions need to be examined.
  - ✓ Practical help box 3 describes one way to identify and analyze outliers.

bsi.

Practical help box 3: Identifying and analyzing outliers

- Typically, outliers will 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 (standard deviation of the mean) of the data 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.

bsi.

Practical help box 3: Identifying and analyzing outliers

- Outliers may exist as a result of faulty measurement, data handling errors or simply extreme values resulting from atypical operations.
  - ✓ For example, an annual plant shutdown will result in a significant variation in energy consumption that will appear as an outlier in any analysis.
- 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.

bsi.

4.2.6 Gathering data(6/6)

- If some outlying measurements are excluded, **care should be taken that this does not introduce bias into the EnPI model or corresponding EnB.**
- Inaccuracies in the measuring devices used can undermine the validity of the data collected.
- The organization should consider calibrating the equipment periodically according to the manufacturer's recommendation to reduce the risk of inaccurate data.

bsi.

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4.3 Identifying energy performance indicators(1/2)

- Organizations define targets for energy performance as part of the energy planning process in their EnMS.
- The targets may be a single improvement value at the site level or may be composed of a number of sub- targets.
- The sub-targets may be designed to roll up into a single value.
- **EnPIs should, when compared over time, allow an organization to determine if the energy performance has changed.**

bsi.

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4.3 Identifying energy performance indicators(2/2)

The main types of EnPIs are:

- ✓ measured energy value(in total or broken down by energy use);
- ✓ ratio derived from measured values, such as energy efficiency;
- ✓ statistical model: linear and non-linear regressions;
- ✓ engineering based model: simulation.

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4.3.2 Identifying users of energy performance indicators (1/3)

- EnPIs need to take into account the needs of users.
- EnPIs should be clear so as to inform continuous improvement efforts and enable the user to make decisions and take actions.
- Where complex statistical or engineering model- based EnPIs are used the EnPI values may be presented to users in simplified forms, such as with charts.
- Therefore, **multiple EnPI types may be needed to support the energy management efforts of different end users.**

bsi.

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4.3.2 Identifying users of energy performance indicators (2/3)

– **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.

– **These users may include regulatory bodies,**

- professional and sector associations, EnMS auditors, other organizations and customers.

– **Table 3 outlines some common internal users of EnPIs.**

bsi.

4.3.2 Identifying users of energy performance indicators (3/3)

Internal EnPI Users	Usage/application of EnPIs
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.
Management representative (energy manager)	Working with an energy management team, has the responsibility for delivering measurable results within the EnMS to the top management.
Plant or facility manager	Typically controls resources within the plant or facility and is accountable for results. Oversees supervisors who typically hold operational responsibility for a significant energy use and monitor energy performance over time. The plant or facility manager should understand both planned energy performance and any deviation from desired performance both in terms of energy consumption and/or energy efficiency and in financial terms.
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.

4.3.3 Determining the specific energy performance characteristics to be quantified(1/2)

EnPI type	Useful for	Examples	Disadvantages
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
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/m2 of floor space - GJ/man-day - liters of fuel per passenger kilometer - Conversion efficiency of a boiler (%) - Input energy/output energy (for instance, "heat rate" in power generation facilities) - kWh/MJ for cooling systems - kW/Nm3 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

4.3.3 Determining the specific energy performance characteristics to be quantified(2/2)

EnPI type	Useful for	Examples	Disadvantages
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 under- standing 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 tempera- ture 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

4.4 Establishing energy baselines(1/2)

- **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 and corresponding EnPIs for which the EnB will be used;
  - ✓ determine a suitable data period;
  - ✓ data collection;
  - ✓ calculate and test the EnB.

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4.4 Establishing energy baselines(2/2)

- When establishing an EnB, the organization should understand its energy consumption characteristics such as base load as well as variable loads due to production, occupancy, weather, or other variables.
  - ✓ This understanding may lead to the opportunity for improvement
- The EnB serves as the reference point against which to measure an organization's energy performance improvement efforts resulting from the EnMS action plans.

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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. 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.
- 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.

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Help Box 6: Typical baseline period to be considered

- 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)

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Help Box 6: Typical baseline period to be considered

- 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.

bsi.

4.5 Using energy performance indicators and energy baselines (1/11)

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**.
- Cases where organizations may wish to normalize their EnBs using variables in order to obtain useful information related to energy performance may include situations where variables impact energy consumption.

bsi.

4.5 Using energy performance indicators and energy baselines (2/11)

Direct measures of EnPIs give their value at, or over, a specific period of time. For example:

- energy consumption for a site in 2010 was 1,200,000 kWh;
- energy consumed for lighting during a month was 24 MWh.

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4.5 Using energy performance indicators and energy baselines (3/11)

Calculating energy performance improvements

- There are **three common approaches for measuring energy performance improvement** are shown below.
- Defining baseline EnPI value as "B" and the reporting EnPI value as "R", these approaches are:

a) Energy difference: this is the difference between the baseline period EnPI value and the reporting period EnPI values.

Example: Difference = R – B

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4.5 Using energy performance indicators and energy baselines (4/11)

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.

Example-- Percent Change = [(R – B) / B] x 100

c) Current ratio: This is a ratio of the reporting period value divided by the baseline period value.

Example-- Current Ratio = (R/B)

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4.5 Using energy performance indicators and energy baselines (5/11)

- A potential issue with EnPIs is that **unless** the user has some prior knowledge of the EnPI, and of the goals of the organization, **a direct value can have limited utility**.
- Direct measures can be trended over time, and it is **the trend value of the EnPI** that is informative rather than the number at a specific point in time.
- Comparative measures go some way to addressing the limitations of direct measures. Comparative measures **look at performance over a period of time**.

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4.5 Using energy performance indicators and energy baselines (6/11)

- ✓ **Practical help box 7: Evaluating comparative measures.**
- ✓ **Example**: Energy Consumption at the site level electricity consumption 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 organizations goals and targets.*

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4.5 Using energy performance indicators and energy baselines (7/11)

- ✓ 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, in fact, 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, and not on gross reductions from all causes or actions, then the direct comparison results showing improvement might be misleading.

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4.5 Using energy performance indicators and energy baselines (8/11)

Communicating changes in energy performance

- **EnPIs should be shown to fit its purpose and users.**
- **It should be shown with an EnB and a target value. These should be visualized or reported.**
- **Examples of visualization include the following:**
  - ✓ printed trend charts and pie charts on notice boards;
  - ✓ trend chart of EnPIs displayed on large-screen;
  - ✓ inter-section competition of common EnPI;
  - ✓ led signs;
  - ✓ company intranet;
  - ✓ text messages to mobile phones;
  - ✓ specific analytical report.
- For information on ways to monitor and report energy performance, see Annex E.

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4.5 Using energy performance indicators and energy baselines (9/11)

- **Maintaining and adjusting energy performance indicators and energy baselines**
- If the current EnPIs and the corresponding boundaries and EnBs are no longer appropriate, the organization should change or develop new EnPIs or adjust the EnB.

  Examples of such changes are presented in Table 5.

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4.5 Using energy performance indicators and energy baselines (10/11)

Practical Help Box 9: Examples of EnPI and EnB changes: The following are relatively common changes an organization may anticipate.

Energy use change	Changes required
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.
Operational changes	When an organization makes significant operational changes it is possible that EnPIs and EnBs may be impacted. For example, if an organization introduces a new process the organization may consider creating a new EnB following that change.
Data availability	- Improvements to the facility's metering and data collection system may result in better quality data becoming avail- able or new relevant variables coming to light. Changes to EnPIs and EnBs may then be desirable.
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.

4.5 Using energy performance indicators and energy baselines (11/11)

Energy use change	Changes required
Static factor changes	– If static factors that were identified during the EnB establishment activity change and become relevant variables that impact energy consumption, then to the extent data are available for the static factors, the EnB can be adjusted. If such data do not exist, then the EnB may need to be updated to reflect a period which includes the relevant variables. An example would be moving from a 3 shift per day to a 1 shift per day operation or changing from a 7-day week to a 5-day week. When the hours of operation of a facility change, this may require an adjustment to the EnB.
Using a predetermined method	The organization may find it useful to identify conditions in advance that would require a change to the EnPIs or an adjustment to EnBs. The organization can also predetermine the rules and methods that will be used in making adjustments. An example might be for EnPIs and EnBs that are established to comply with legal or other requirements (e.g. to external organizations). Rules and methods should be established on when and how EnPIs and EnBs will be set and adjusted to meet those requirements.
Management Review	One of the inputs to Management Review is the review of EnPIs. Therefore, a corollary output is potential changes to EnPIs.

Annex C (1/7)

- **Further guidance on energy performance indicators and energy baselines**
  - **Practical guide to EnPIs and EnBs**
    - ✓ **Measured energy value**
    - ✓ **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.
- **EXAMPLE:** Quantity of energy used per unit product.

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Annex C (2/7)

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.
- Model-base EnPIs are useful also for examination and evaluation of an energy performance improvement action.
- **Examples:**
  - ✓ influence of external temperature on energy consumption;
  - ✓ impact of regular maintenance on efficiency of production processes;
  - ✓ impact of changes in consumption of one energy source on the consumption of other energy types.

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Annex C (3/7)

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.

Annex C (3/7): 能源績效指標(EnPI)的類型

項 目	所量測能源值	所量測值的比率	統計模式	工程模式
公司型態	紙漿和造紙公司	鋼鐵公司	飯店	大學校園
過程	-蒸汽發電	-電弧爐	- 燃油鍋爐加熱	- 加熱和冷卻
意圖	-消除油耗用以降低成本	-成為世界一流的SEC以及持續經營	- 降低公用事業費用	- 實現永續發展標的
改善行動	-提高鍋爐能源效率	-很多改善行動	- 鍋爐操作員訓練	- 控制和絕緣
EnB 及 EnPI	- 耗油量（KL/月）	- SEC (kWh/ton)	- 能源效率（L /度日）	kW/人
標的	- EnPI = 0 (kl/month)	- 每年減少SEC 2%, 4年內成為世界一流。	- 提高能源利用效率5%	- 模式的標的是減少20%，調整後，每月進行分析。
備註	- 該公司不關心室外溫度及生產變化		- 這家飯店的剛開始設定能源成本EnPI。然而，能源績效改善行動計畫的效果都沒有得到驗證。因為石油價格上漲，且在基準期的平均溫度高。因此，該公司決定使用能源效率EnPI。	- 模式適用於被納入所有相關的措施的變數。

Annex C (4/7)

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%;

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Annex C (5/7)

- ✓ the output of each production line is measured independently in kilograms;
- ✓ SEC (energy consumption per kilograms) of line B is 10 times higher than that of line A and production volume of each line is almost same;
- ✓ raw material quality varies; and
- ✓ there is a project scheduled to upgrade all of the motors on production line A.
- ✓ The team establishes the following EnPIs in a hierarchy, 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, showed at Table C.2

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Annex C (6/7)

- The Energy Management Team refers to Table C.3 to guide the use and purpose of the EnPIs.

Table C.2 — Use and purpose of EnPIs-

1. Facility business level EnPIs

EnPI levels	Purpose/Need	EnPI Type	EnPI users
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

Annex C (7/7)

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

Annex D (1/8)

Normalizing energy baselines using relevant variables

- In some cases, organizations may choose to normalize their energy baselines using variables.
- Such cases typically involve situations where the values of the relevant variables in the baseline period and the performance or reporting periods are substantially different.
- **Typical examples of relevant variables** that might affect energy consumption include outdoor weather, building occupancy, facility operating hours, product mix variations, production volumes etc.

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Annex D (2/8)

- The point of normalization is to make the values of the relevant variables comparable to each other in the baseline period and the reporting period in order to neutralize the effect of the differences in the values of the relevant variables in the two periods.
- Normalization of an energy baseline is being used to describe the process of estimating the energy consumption of the baseline using the values of the variables in the EnPIs during the reporting periods.
- This is in order to calculate an adjusted EnB energy consumption value (expected energy consumption) against which the EnPI energy consumption value can be compared on a basis that renders the values for the variables in the two periods equal.

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Annex D (3/8)

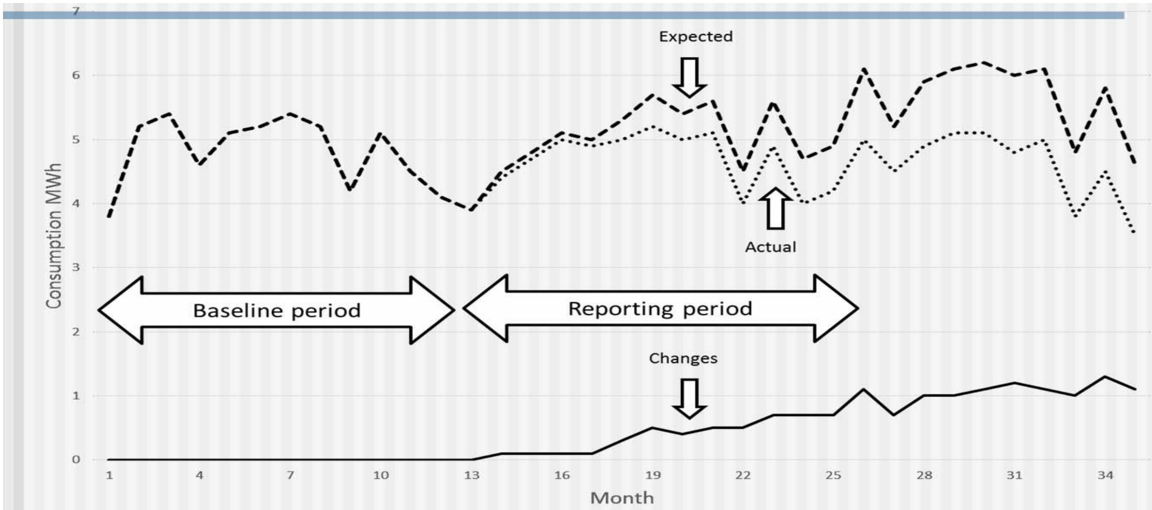

Figure D.1 – Calculating energy performance using normalization

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Annex D (4/8)

- The dashed line in the figure above shows absolute energy consumption and data on relevant variables during the performance period.
- The organization may also choose to evaluate the performance only during a specified reporting period within the reporting period in accordance with its requirements.
- The dotted line is the normalized energy consumption. The normalized energy consumption is a calculated energy consumption value (or series of values) that inputs the values for relevant variables from the reporting period into the EnB equation

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Annex D (5/8)

- This results in a calculated energy consumption value (or estimate of the energy) "that would have been consumed in the performance period, had the mathematical relationship between energy and the relevant variables been equal to that of the baseline period.
- The EnB performance equation quantifies the mathematical relationship between energy and the relevant variables for the EnB dataset.

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Annex D (6/8)

- **An example EnB equation may take the form:**
  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/℃);
- T- is the average monthly temperature (℃).

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Annex D (7/8)

- The factors A, B and C will be derived from statistical modelling methods used to develop the linear regression.
  因子A、B和C可從發展線性迴歸的統計模式方法得到。
- This relationship should also meet statistical tests. Examples of the test are coefficient of determination (R2), coefficient of variation (CV) and F-test.
  這種關係應同時滿足統計檢驗。例如檢定判定係數(R2),變動係數(CV)和F-檢定的係數。
- 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.
  此方程中使用的獨立的或相關的變數也應在解釋能耗的變化具有統計學顯著性。用於評估統計顯著性，每個變數需要滿足一定的 p-值 。

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Annex D (8/8)

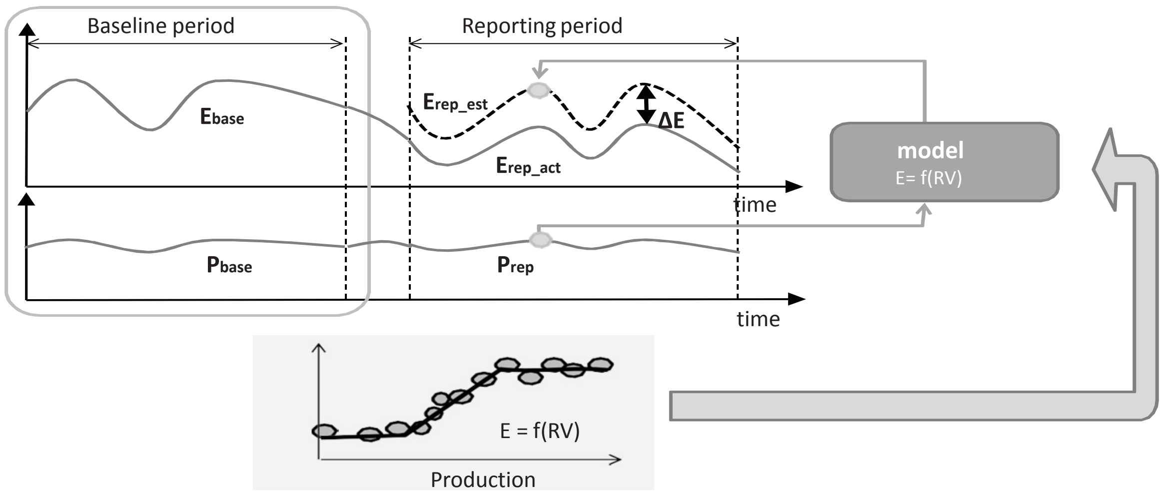

Figure D.2 – Normalization calculation process

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Annex E (1/11)

Monitoring and reporting energy performance

E.1 General

The Figure E.1 shows anoverview of the energy performance monitoring and reporting methods.

Annex E (2/11)

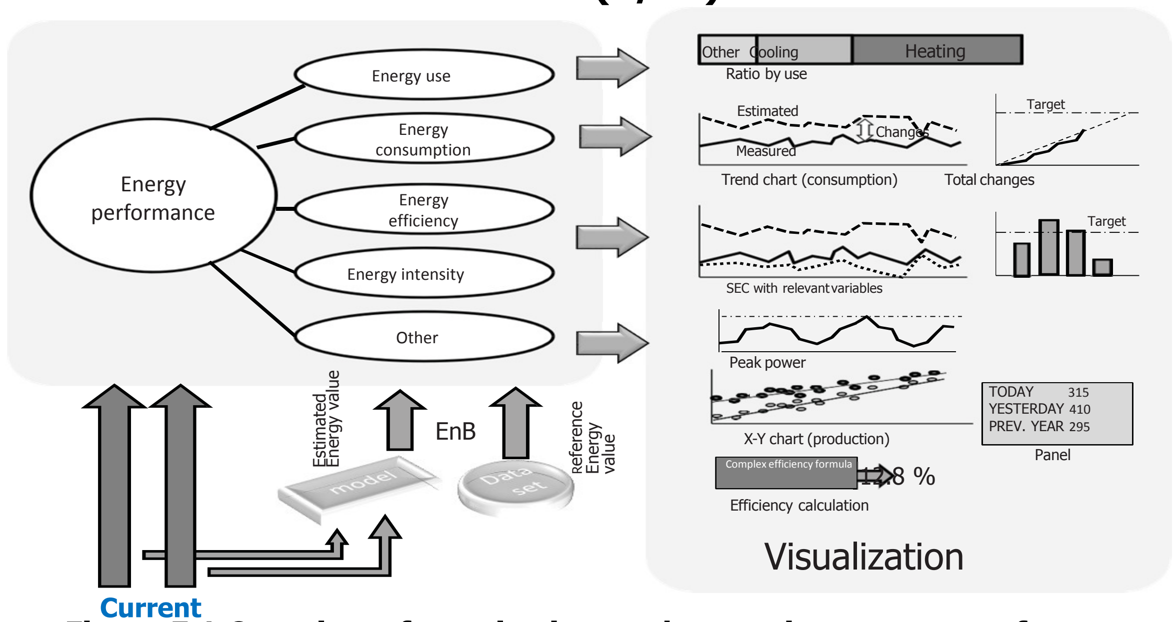

Figure E.1 Overview of monitoring and reporting energy performance

Annex E (3/11)

E.2 Types of monitoring methods and reports

- Organizations can use a variety of reports 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 valuables);
  - ✓ X-Y chart (e.g. energy consumption and production);
  - ✓ assessing variance (Variance);
  - ✓ cumulative summation chart (Cusum);

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Annex E (4/11)

- visualization using various analytical tools (e.g. Cumulative summation chart (Cusum));

  Monitoring can also be carried out using an alarm chart for detecting abnormalities in real time EnPI values.
- Multi-dimensional graphics with internal benchmarking
- In each case, the information can be represented graphically or in tables.

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E.3 Target and current EnPI comparison

- Examples ofEnPIs for the threeelementsof energy performance are shown below.
  - ✓ energy consumption (see figure 4 in 4.1.7): Energy consumption of the baseline period and reporting period are compared;
  - ✓ energy efficiency (see figure E.2a): Specific energy consumption (SEC) of the baseline period and reporting period are compared;
  - ✓ energy use (see figure E.2b): The percentage of a specific energy source in the baseline period and reporting period are compared.

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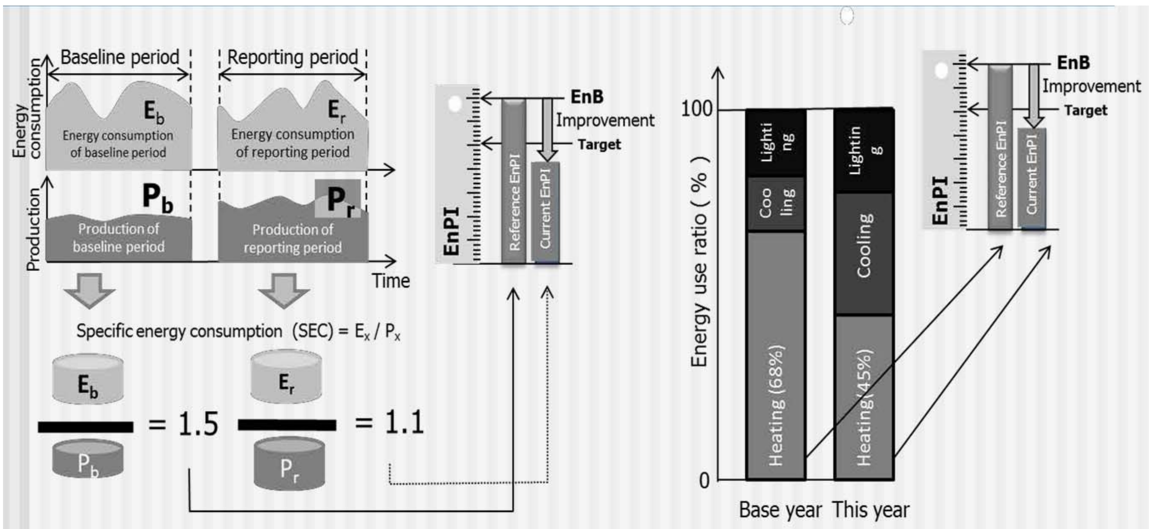

Figure E.2 Example of EnPIs comparison for energy efficiency and energy use

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An example of display of the EnB, current EnPI, and target EnPI are shown in Figure E.3. The difference between the target EnPI and the current EnPI is also displayed. A facility manager or an operator can assess the impacts of his/her work on energy performance and take actions if necessary.

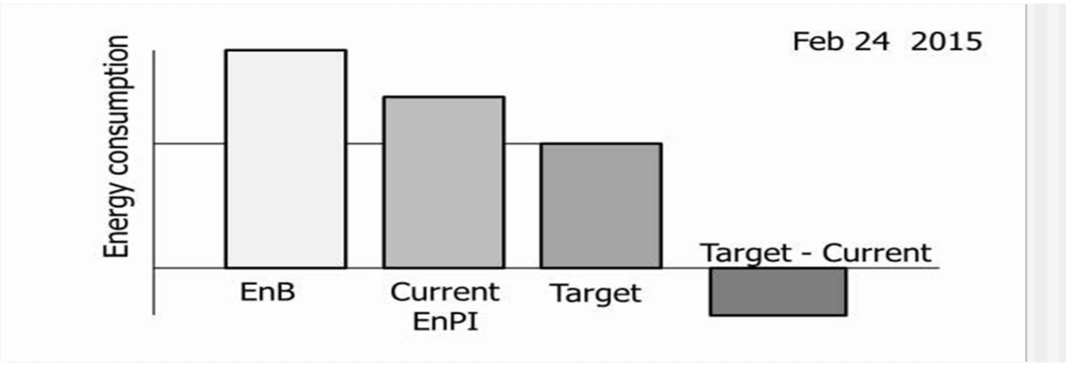

Figure E.3 EnPI and Target

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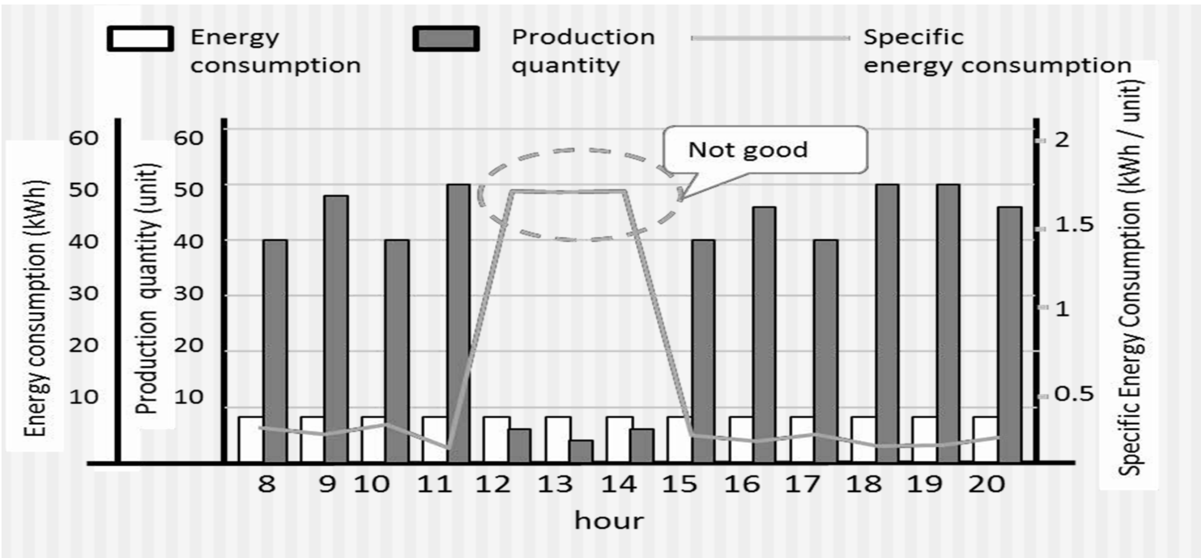

Figure E.4 — SEC trend chart

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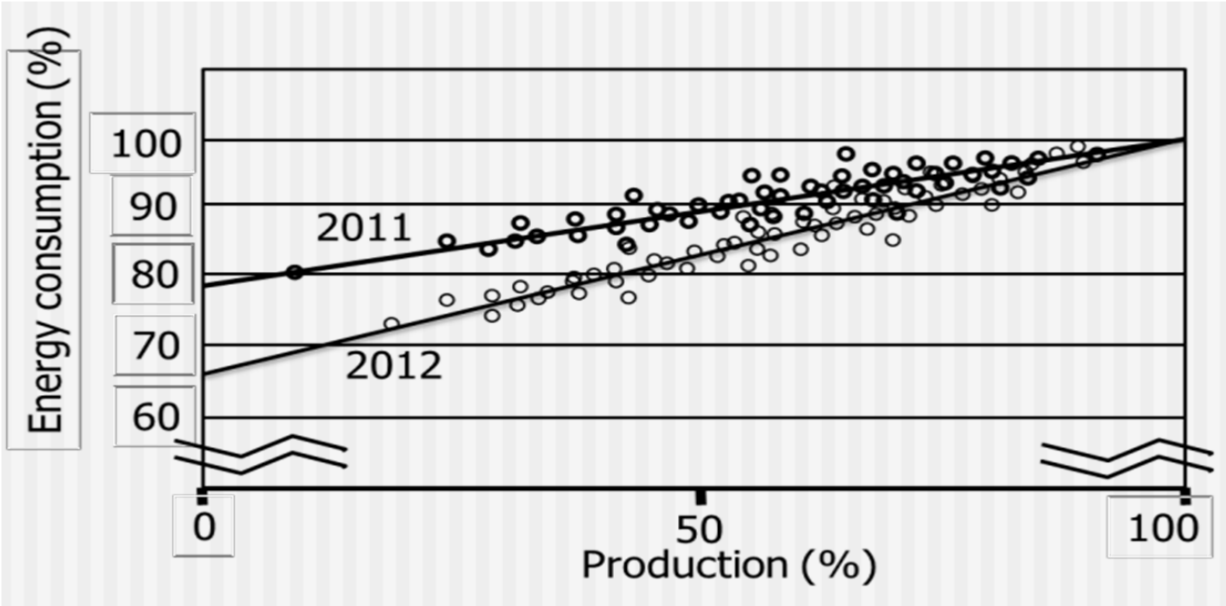

Figure E.5 X-Y chart

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Annex E (10/11)

E.6 Reporting units

- The above graphs 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.**

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- Again 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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