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Energy savings — Determination of energy savings in organizations

National foreword

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Foreword

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

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

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

The committee responsible for this document is Technical Committee ISO/TC 301, *Energy management and energy savings*.

Introduction

This International Standard describes approaches for determining energy savings based on one of the following two approaches:

a) an organization-based approach, i.e. a change in the amount of energy consumed by the organization, as measured within the organizational boundaries;

b) an EPIA-based approach, i.e. aggregating energy savings from energy performance improvement actions (EPIAs) measured within the organizational boundaries.

Both approaches compare energy consumption for a defined period of time, the energy consumption in a baseline period and a reporting period of equivalent length. Guidance is given on reconciliation between the two approaches.

This International Standard also considers the following in the context of energy savings:

— the use of primary and delivered energy;

— methods for normalizing energy consumption;

— methods for aggregating energy savings from different types of energy.

The flowchart in Annex A shows the process for determining energy savings using this International Standard.

This International Standard is designed to be broadly consistent with the overall framework for the determination and reporting of energy savings in projects, organizations and regions set out in ISO 17743, as well as with the principles and guidelines given in ISO 50015 on the measurement and verification of energy performance of organizations.

Energy savings — Determination of energy savings in organizations

1 Scope

This International Standard describes approaches for the determination of energy savings in organizations. It can be used by all organizations, whether or not they have an energy management system, such as ISO 50001.

This International Standard addresses the following topics in the context of energy savings:

— establishing the purpose of determining energy savings;

— determining boundaries;

— energy accounting, including primary and delivered energy and the use of common energy units;

— selecting an approach for the determination of energy savings;

— establishing an energy baseline;

— normalization of energy consumption;

— determination of energy savings;

— reporting and other matters.

Specific methods for the measurement and verification of energy performance and its improvement are outside the scope of this International Standard.

NOTE ISO 50015 establishes general principles and guidelines for the process of measurement and verification of energy performance of an organization or its components.

2 Normative references

There are no normative references.

3 Terms and definitions

3.1
baseline period
defined period of time selected as the reference for the determination of energy savings

3.2
boundary
physical or site limit and/or organizational limit as defined by the *organization* (3.16)

Note 1 to entry: The boundaries of the organization could be different from the boundaries used for the determination of energy savings.

Note 2 to entry: The determination of energy savings can include one or more boundaries, e.g. of one or more *energy performance improvement actions* (3.10), or of parts of the organization.

EXAMPLE Equipment; a system; a process; a group of processes; a room; a building; a site; an entire organization; multiple sites under the control of an organization.

[SOURCE: ISO 50001:2011, 3.1, modified — The term has been changed from the plural ("boundaries") to the singular ("boundary") and the definition has been modified accordingly; Notes 1 and 2 to entry have been added and additional examples have been included.]

3.3
delivered energy
energy (3.5) arriving at the *boundaries* (3.2) of an *organization* (3.16)

Note 1 to entry: Delivered energy includes *primary energy* (3.17) produced (e.g. oil from a well) or renewable energy generated onsite (e.g. electricity from photovoltaic panels).

3.4
double counting
summing the individual energy savings from two or more *energy performance improvement actions* (3.10) when they influence the *energy consumption* (3.8) of each other either positively or negatively

Note 1 to entry: In cases where there are interactive effects between the energy performance improvement actions (EPIAs), the energy savings due to the combined effect of these EPIAs may be different from the sum of the energy savings from the individual EPIAs.

3.5
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 types of energy, including renewable, which can be purchased, stored, treated, used in equipment or in a process, or recovered.

Note 2 to entry: In other contexts, energy can be defined as the capacity of a system to produce external activity or perform work.

Note 3 to entry: Examples of other like media include hot water, and intermediate products or by-products, such as biogas or coke oven gas.

[SOURCE: ISO 50001:2011, 3.5, modified — Notes 1 and 2 to entry have been modified and Note 3 to entry has been added.]

3.6
energy accounting
system of rules, methods, techniques and conventions used to measure, analyse and report *energy consumption* (3.8)

3.7
energy baseline
quantitative reference(s) providing a basis for comparison of *energy performance* (3.9)

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

Note 2 to entry: An energy baseline can be normalized using *relevant variables* (3.18) impacting *energy use* (3.11) and/or *energy consumption* (3.8), e.g. production level, degree days (outdoor temperature).

[SOURCE: ISO 50001:2011, 3.6, modified — Note 2 to entry has been modified and the original Note 3 to entry has been deleted.]

3.8
energy consumption
quantity of *energy* (3.5) applied

[SOURCE: ISO 50001:2011, 3.7]

3.9
energy performance
measurable results related to energy efficiency, *energy use* (3.11) and *energy consumption* (3.8)

Note 1 to entry: In this International Standard, energy performance generally refers to energy consumption only.

[SOURCE: ISO 50001:2011, 3.12, modified — The original Notes 1 and 2 to entry have been deleted because they were specific to energy management, and a new Note 1 entry has been added.]

3.10
energy performance improvement action
EPIA
action or measure or group of actions or measures implemented or planned within an *organization* (3.16) intended to achieve energy performance improvement through technological, managerial or operational, behavioural, economic, or other changes

[SOURCE: ISO 50015:2014, 3.5, modified — The word “economical” has been replaced by “economic”.]

3.11
energy use
manner or kind of application of *energy* (3.5)

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

[SOURCE: ISO 50001:2011, 3.18]

3.12
energy using system
physical items with defined *boundaries* (3.2) using *energy* (3.5)

EXAMPLE Facility; building; part of a building; machine; equipment; product.

[SOURCE: ISO/IEC 13273-1:2015, 3.1.9, modified — The word “system” has been deleted from “system boundaries”.]

3.13
indirect energy effect
effect on organizational *energy performance* (3.9) beyond the direct effect of an individual *energy performance improvement action* (3.10)

[SOURCE: ISO 50015:2014, 3.3, modified — The words “the energy performance improvement action” have been replaced by “an individual energy performance improvement action” and the original example has been deleted.]

3.14
non-routine adjustment
adjustment made to the *energy baseline* (3.7) to account for unusual changes in *relevant variables* (3.18) or *static factors* (3.20), outside the changes accounted for by *normalization* (3.15)

Note 1 to entry: Non-routine adjustments may apply where the energy baseline no longer reflects *energy use* (3.11) or *energy consumption* (3.8) patterns, or there have been major changes to the process, operational patterns, or *energy using systems* (3.12).

Note 2 to entry: For routine adjustments, normalization is used.

Note 3 to entry: Non-routine adjustments are needed when a change in static factors occurs after the *baseline period* (3.1).

[SOURCE: ISO 50015:2014, 3.16 modified — The words “routine adjustment” have been replaced by “normalization” in the definition and Notes 2 and 3 to entry have been added.]

3.15
normalization
process of routinely modifying energy data in order to account for changes in *relevant variables* (3.18) to compare *energy performance* (3.9) under equivalent conditions

[SOURCE: ISO 50006:2014, 3.13, modified — Note 1 to entry has been deleted.]

3.16
organization
company, corporation, firm, enterprise, authority or institution, or part or combination thereof, whether incorporated or not, public or private, that has its own functions and administration and that has the authority to control its *energy use* (3.11) and *energy consumption* (3.8)

Note 1 to entry: An organization can be a person or a group of people.

[SOURCE: ISO 50001:2011, 3.22, modified — The word “energy” has been added before “consumption”.]

3.17
primary energy
energy (3.5) that has not been subjected to any conversion or transformation process

Note 1 to entry: Primary energy can be either a non-renewable or a renewable energy, or a combination of both.

[SOURCE: ISO/IEC 13273-1:2015, 3.1.6, modified — The words “energy conversion” have been replaced by “any conversion or transformation process”.]

3.18
relevant variable
quantifiable factor that impacts *energy performance* (3.9) and routinely changes

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

[SOURCE: ISO 50006:2014, 3.14]

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

3.20
static factor
identified factor that impacts *energy performance* (3.9) and does not routinely change

EXAMPLE 1 A static factor can be a change in *energy using systems* (3.12) (design of installed equipment, range of products, building), or a change in organization (e.g. outsourcing or insourcing of activities, sale of subsidiary companies) or a change in the number or type of building occupants (e.g. office workers).

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

EXAMPLE 3 Changes to operational patterns, such as the number of weekly production shifts, or the number of working days in a supermarket chain.

[SOURCE: ISO 50006:2014, 3.17, modified — Example 1 has been modified and Example 3 has been added.]

4 Preliminary considerations and boundaries

4.1 Preliminary considerations

Before determining energy savings, the organization should establish:

- the objective of determining energy savings, e.g.
  - for compliance purposes;
  - for use in annual reporting;
  - to form part of an energy management system, such as ISO 50001;
  - to calculate the financial return of energy performance improvement actions (EPIAs);
- the organization for which energy savings are being determined;
- the parties responsible for the determination of energy savings, their roles and their relationship with the organization;
- the parties who will receive the results;
- a summary of the type of data to be used, including their periodicity and the intervals for which they are to be collected and analysed.

4.2 Approaches to determining energy savings

4.2.1 Two approaches to determining energy savings

There are two approaches to determining energy savings:

a) an organization-based approach: the change in the total energy consumption of the organization or its constituent parts (a form of "top down" approach);

b) an EPIA-based approach: aggregating energy savings from identified EPIAs (sometimes referred to as being a "bottom up" approach).

The choice between these two approaches may depend on the objective of determining energy savings, or how the boundaries are identified.

4.2.2 Organization-based approach

The organization-based approach is commonly used in the following cases:

- for periodic reporting of the energy savings of an organization within its boundaries with respect to legal or other requirements;
- for assessing the energy savings of an organization as a part of an energy management system.

Dividing an organization into constituent parts may be a useful tool in the organization-based approach if the energy consumption of each can be analysed separately.

EXAMPLE 1 An organization consists of three departments: manufacturing, transportation and sales. It determines the energy savings of each individual department and then sums the energy savings from those parts, i.e. by using an organization-based approach. However, if the three departments cooperate by introducing EPIAs to reduce empty return trips, waiting times, total annual drive mileage, etc. by optimizing manufacturing schedule, sales planning, vehicle routeing, etc., it might also be possible to determine energy savings by summing the individual EPIAs (an EPIA-based approach).

The division of an organization into its constituent parts may be based on the following considerations:

a) based on physical items: the division is based on energy using systems whose performance is separately analysed and for each of which separate energy savings targets are set;

EXAMPLE 2 An integrated consumer products manufacturer might divide the organization into each of its manufacturing facilities and a building in which the corporate office is located.

EXAMPLE 3 An organization which manufactures washing machines in one plant or plants and semiconductors in another plant or plants might be divided on the basis of product types.

NOTE An organization can use a single facility to make multiple products or multiple facilities to make different products.

b) based on organizational requirements: the division is based on business units whose performance is separately analysed and for each of which separate energy savings targets are set;

c) based on sites: the division is based on geographical locations for each of which performance is analysed and separate energy savings targets are set.

EXAMPLE 4 An organization which makes fertilizers might be divided on the basis of its manufacturing sites.

If an organization is divided into its constituent parts in order to determine energy savings, the reasons for the division should be documented.

4.2.3 EPIA-based approach

An EPIA-based approach is commonly used to determine the effect of one or more EPIAs on the energy savings of the organization. The organization should include all EPIAs that positively or negatively impact energy performance within the organizational boundaries. EPIAs may include operational and capital improvement actions. The organization may seek to identify all actions that impact energy performance, whether or not they were initially intended to be an EPIA.

It is not always cost effective to measure energy savings from each individual EPIA. In such cases, energy savings from a representative sample may be used. The organization should document:

— the reasons why the sampling method is used;

— the reasons why the sample is representative of the variation in energy consumption;

— the method used to extrapolate results from the sample EPIAs to all EPIAs.

Sampling may be carried out by the following methods:

a) in a temporal sense (time), e.g. metering occurring for part of the time;

b) in a physical sense (see example 2 below).

EXAMPLE 1 In an organization with many employees, an effective approach to measuring the energy savings from behavioural measures (such as campaigns designed to get employees to switch off lights or computers when not in use) might be to use a sample of employees.

EXAMPLE 2 It might not be cost effective to monitor energy savings (e.g. by installing additional metering) from all machines when a substantial number of similar machines are upgraded. In this case, a sample of a smaller number of machines might be taken. If the data from the sample are found to be representative, the energy savings can be extrapolated to arrive at the total energy savings.

NOTE The determination of energy savings through projects within an organization is addressed by other standards.

More information about how to reconcile between the two approaches is included in Annex B.

4.3 Determining the boundaries

The organization should select boundaries appropriate to the purpose of determining energy savings. The boundaries can be for the entire organization or some of its constituent parts.

EXAMPLE 1 A single building; a university campus or shopping centre; all the operations within a single manufacturing plant or process; all buildings owned by a public authority within an administrative district; all the buses operated by a transit authority.

However, the boundaries of the energy savings determination can be different from those of the organization, e.g. in the following cases:

— where energy is stored within the organization boundaries;

— where energy is exported across the organization boundaries;

— where primary energy is generated on site;

— where goods or people are transported by or on behalf of the organization;

— where transportation energy is used by employees when undertaking work for the organization (e.g. salesmen or consultants travelling to customers' premises);

— where suppliers manufacture components or provide services, and inclusion is mandated externally.

It may be necessary to establish multiple boundaries if they can be well-defined. For example, where an organization wishes to determine energy savings from operations in several locations, each of which manufactures components of a single final product or service and the components are transported between the plants.

EXAMPLE 2 Company level energy used by a car manufacturer where the cars are assembled in one country, but the engines and transmission units are manufactured in another country. In this case, the total company energy consumption will exceed the sum of the energy consumed by the factories in the two countries due to the energy consumed in transportation.

Specifying the boundaries in an organization-based approach can sometimes be easier than in an EPIA-based approach.

Organizations often seek to determine total energy savings across the organization by using an EPIA-based approach. In this case, it may be useful to define boundaries which are specific for each EPIA. The boundary of one EPIA may overlap with that of another EPIA.

Figure 1 illustrates an organization which consists of three divisions: production (manufacturing), distribution and sales, and a head office.

— Figure 1 a) shows the physical boundaries of the organization. There are three factory buildings, an office building and a utility building containing a combined heat and power (CHP) plant. Each physical building could also be used as boundaries for determining energy savings, an organization-based approach.

— Figure 1 b) shows boundaries of the organization based on business units: the head office, with separate sales, distribution and production divisions. It determines the energy savings of each individual business unit and then sums the energy savings from those constituent parts, which is also an organization-based approach.

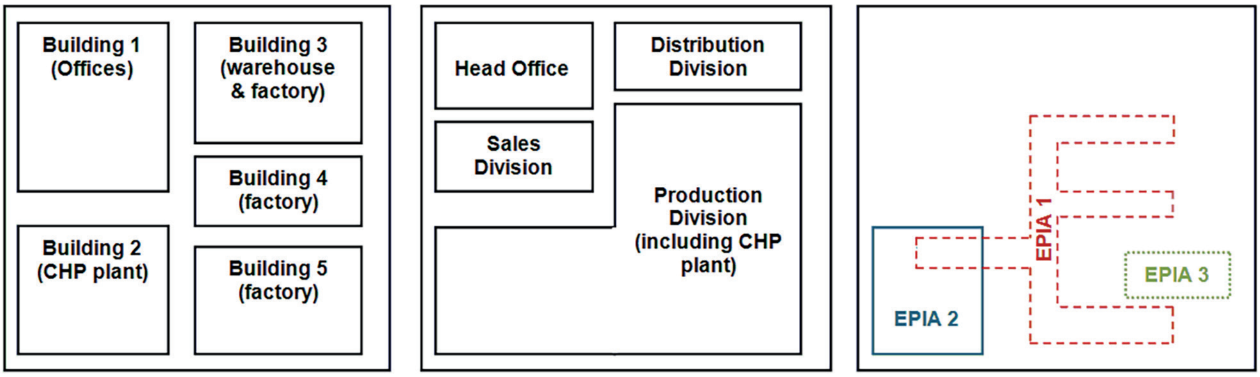
— Figure 1 c) shows boundaries based on EPIAs undertaken by the organization:

  — EPIA 1 reduces the energy consumption in the three production plants and consequently reduces steam load on the CHP plant;

  — EPIA 2 increases the power generation from the CHP plant, leading to lower purchase of electricity imported from the grid;

— EPIA 3 is improvement of a production line (an energy using system) in building 5 only.

The boundary of EPIA 1 overlaps with that of EPIA 2. Moreover, the total area of EPIA boundaries is smaller than the whole organization, as none of the EPIAs have affected energy consumption in the head office or sales divisions (based in building 1) or the distribution division (based in the warehouse part of building 3).



a) Physical boundaries (location)   b) Business unit boundaries   c) EPIA-based boundaries

Figure 1 — Examples of boundaries

The total area within the EPIA boundaries may not encompass the whole organization. The boundaries of an EPIA should be specified so as to include at least the main effect of the EPIA.

The boundaries of the organization should be comparable in the baseline and reporting periods. The organization should document and report on the boundaries selected.

5 Energy accounting

5.1 General principles of energy accounting

The determination of energy savings should extend to all types of energy consumed within the boundaries of the organization.

NOTE When determining energy savings by aggregating energy savings from EPIAs, it might not be necessary to account for types of energy that are not affected by the EPIAs.

Energy accounting should be appropriate to the purpose of determining energy savings. The process and results of energy accounting should be documented and reported and used consistently.

An example of energy accounting in the cement industry is given in Annex C.

5.2 Measurement of energy consumption and stocks

Measurement devices such as meters may be used to collect data, including pressure, temperature, mass, volumetric flow and calorific value to calculate energy consumption by using engineering formulae and conversion factors. The energy consumption data may also be available directly from meters (whether read directly by the organization or taken from a supplier invoice).

The organization should apply conversions consistently and document how conversions were made.

Where metering is not practical, the Formula (1) may be used to calculate energy consumption, E:

$$E = V_{open} + V_{add} - V_{close} - V_{loss} \quad (1)$$

where

V_{open} is the opening stock;

V_{add} are the additions to stock;

V_{close} is the closing stock;

V_{loss} are stock losses or sales.

NOTE Stock changes can be calculated based on level, volume, pressure or mass measurement when using Formula (1).

The energy content of fuels (the amount of energy potentially available within each unit of fuel) may vary with factors such as density or the calorific value of its components. Conversion factors from units as sold (such as cubic metres, litres or tonnes) to energy units may be available from the supplier.

EXAMPLE The energy content of diesel can vary over time due to changes in composition with the gradual introduction of blended biofuels, which will generally reduce its calorific value.

In some cases, it may be necessary to choose between use of gross calorific value and net calorific value in energy savings calculations. More frequent measurements may be necessary if the calorific value of the fuel varies between batches and suppliers.

If consumption data for a type of energy are not readily available, then additional sub-meters may need to be installed.

5.3 Types of energy with relatively insignificant consumption

In general, all types of energy should be taken into account for the purpose of determining energy savings. However, types of energy for which the quantity consumed is relatively insignificant in both the baseline and reporting periods, and where the consumption does not vary significantly between the periods, may be omitted from the determination of an organization's energy consumption. Types of energy that are relatively insignificant individually may be significant when considered in aggregate.

EXAMPLE 1 The use of propane for forklifts has been determined by the organization to be "relatively insignificant" and omitted because it is less than 0,1 % of the total energy consumed by the organization.

Because energy savings may be a small percentage of total energy consumption, caution should be exercised when making a decision to exclude any type of energy whose consumption is of a similar order of magnitude to that of the expected energy savings figure.

If the type of energy consumed by a particular activity changes between the baseline and the reporting period (e.g. through "fuel switching") and the consumption of either type of energy is not negligible in comparison with the energy consumption in either period, then both types of energy should be included in both periods.

NOTE When determining energy savings by aggregating energy savings from EPIAs, it might not be necessary to account for types of energy that are not affected by the EPIAs.

EXAMPLE 2 In the baseline period, an organization only uses natural gas to raise steam in its boilers. In the reporting period, it installs a backup boiler that uses fuel oil (by "fuel switching") in order to benefit from a tariff that limits the use of gas at periods of high regional demand. Consumption of fuel oil has been determined to be "relatively insignificant" in the reporting period as the backup boiler is rarely used; however, in order to reflect total energy consumption accurately and not to overstate energy savings, it cannot be omitted as being relatively insignificant.

The reasons for omitting a type of energy should be documented.

5.4 Expressing energy consumption in common units

The organization should choose a common unit in which energy is measured (e.g. Joules, kilowatt-hours) to undertake its energy accounting. A common unit allows for comparison of relative consumption of multiple energy types and their aggregation. All conversions to express as a chosen common energy unit, including any factors used, should be used consistently and documented.

5.5 Primary and delivered energy

5.5.1 General

The organization should decide if energy savings are to be calculated on a primary or delivered energy basis.

NOTE 1 Whether a particular type of energy used by the organization is described as primary energy can depend, for example, on its origins or on accepted industry practice.

NOTE 2 Primary and delivered energy can differ because of losses in transmission and distribution.

EXAMPLE 1 Electricity generated by an on-site gas turbine is usually converted to a delivered energy basis by using the gas consumption of the gas turbine. This can then be converted into primary energy by using the same method applied to any other delivered energy.

EXAMPLE 2 Steam and electricity generated from an onsite CHP plant can be converted to a delivered energy basis by using the fuel consumption of the CHP. The fuel consumption can then be allocated between steam and electricity using consistent rules chosen by the organization (e.g. by reference to the energy content of the two products).

EXAMPLE 3 Energy from coal can be described as primary and delivered if available from an on-site mine (located within the boundaries).

EXAMPLE 4 Energy from electricity can be described as delivered if it is imported across the boundaries. In this case, the conversion factor to a primary energy basis will usually account for losses made in power plants, transmission and distribution outside the boundaries and can be provided by the supplier or using national or regional factors.

EXAMPLE 5 Electricity can be described as primary if generated from onsite renewables, such as photovoltaics or a wind turbine. In this case, the electricity is both primary and delivered.

When calculating energy savings using an EPIA-based approach, energy conversions prior to the EPIA boundaries need to be considered if accounting for energy on a primary basis.

Reasons for expressing the energy consumption in primary terms include the following:

a) national targets for energy savings are set with reference to the primary energy content, e.g. of electricity generated from thermal power stations;

b) demonstrating the primary energy impact of CHP compared to electricity imported from the grid;

c) benchmarking the energy performance of organizations that may use a different mix of types of energy;

d) comparing energy savings of multiple locations within an organization.

Standard practice in some countries is to use delivered energy for determining energy savings. Reasons for expressing the energy consumption in delivered terms include the following:

a) this approach is linked to energy bill data;

b) delivered energy is also widely used in the energy management of organizations, as it highlights energy savings from actions taken by the organization within its designated boundaries, as distinct from energy savings resulting from actions by other parties, such as electricity suppliers;

c) the treatment of renewable energy in primary energy terms may also be subject to legal and other requirements.

NOTE 3 When organizations make a financial evaluation of EPIAs, they will often use delivered energy (as it relates more closely to energy bills), even though their overall energy savings might be determined on a primary energy basis.

NOTE 4 In some instances, fuel switching (e.g. when using electricity instead of fuel oil in a boiler) can result in a decrease in energy consumption on a delivered energy basis, but also in an increase in energy consumption on a primary basis. However, this might not be the case if the water is heated using a high efficiency heat pump with energy savings arising on a delivered as well as a primary energy basis.

Groups of organizations or organizations that operate in different locations should ensure that they have the data required for energy accounting on a consistent basis.

The decision to use primary or delivered energy should be documented and reported.

5.5.2 Conversion of delivered energy to primary energy

To convert to a primary energy basis, delivered energy should be multiplied by an energy conversion factor (m_{i}). This factor may be:

— based on legal or other requirements;

— site specific;

— provided by a third party;

— a regional or national default value.

The energy conversion factor may vary by type, country and region. Unless the organization is mandated to use an energy conversion factor based on legal or other requirements, site specific factors should be used, if available. Where there are no site-specific energy conversion factors, the organization may use energy conversion factors provided by a third party, such as energy utility companies. Default values should only be used when other options are not available.

Conversion of delivered energy for type *i* to primary energy is expressed by Formula (2):

$$E_{\mathrm{p},i} = m_i E_i \quad (2)$$

where

$E_{\mathrm{p},i}$ is the primary energy consumption of type *i*;

m_i is the energy conversion factor for type *i*;

E_i is the delivered energy consumption of type *i* in common units.

The choice of factors (m_i) should be documented and used consistently.

6 Data preparation for determination of energy savings

6.1 Selection of time periods

Energy savings are determined by the difference in energy consumption between two comparable time periods (a baseline period and a subsequent reporting period) which are equivalent in length. Between the baseline and reporting periods, the organization may or may not have implemented one or more EPIAs.

Time periods may be classified as follows:

a) Shorter than a year: A shorter period may be used where energy consumption is seasonal (e.g. a vegetable canning factory, ski resort). If energy consumed in the ''out of season" period is considered, it may not lead to reliable energy savings. The baseline period should represent all operating modes of the facility and should span a full operating or production cycle from maximum energy consumption to minimum based on observed data.

b) A year: When consumption of energy is weather sensitive, a period of one year is commonly used.

c) In excess of one year: Longer periods in excess of one year may be appropriate when there is no single year which is considered to be typical (e.g. in a winery where production volumes may vary significantly between years).

Gaps or other significant changes in energy consumption should be accounted for and documented (e.g. leap years, periods of commercial office vacancy, closure of a factory for renovation).

The organization may also calculate energy savings with and without one or more EPIAs, e.g. as follows:

— comparing similar organizations with and without a particular EPIA, e.g. comparing shops in a chain where some have had a lighting upgrade but others have not;

— where EPIAs are reversible (known as on/off tests), e.g. in a building energy management system which may be reset or recalibrated: in this case, the baseline and reporting periods may be selected that are adjacent to each other in time.

NOTE A similar approach can be used to estimate potential energy savings from proposed EPIAs, often modelling several alternatives.

The time periods chosen and the reasons for choosing them should be documented.

6.2 Establishing the energy baseline

When determining organization-based energy savings, a single energy baseline measuring the energy consumption within the organization may be used. This enables energy savings from all EPIAs to be seen in aggregate. If the organization is divided into constituent parts, an energy baseline will be needed for each part.

If an EPIA-based approach is used for determining the organization's energy savings (see 4.2.3), a separate energy baseline may be needed for each EPIA.

The energy baseline can be determined:

— by using a fixed period (usually a representative year);

— by using the average of a number of periods (if a single period is not representative).

The organization may select either a fixed baseline period (usually a year against which all subsequent energy savings will be measured) or a moving baseline period (typically the previous year). A fixed baseline period is commonly used if the organization has a long-term target for energy savings. A moving baseline period is more useful for looking at year on year changes in energy performance.

The baseline period used and its determination should be documented.

6.3 Non-routine adjustments

Energy consumption may be impacted by relevant variables and static factors during the baseline and reporting periods. Normalization is used to account for changes in relevant variables.

Non-routine adjustments are made to the energy consumption in the baseline and/or reporting periods:

— if the static factors have changed between the two periods;

— if relevant variables have been subject to unusual changes in at least one of the two periods.

A common non-routine adjustment to the energy baseline results from changes in the boundaries, e.g. due to the sale or purchase of subsidiary companies, the expansion, opening or closure of factories, plants or other premises by the organization, or outsourcing or in-sourcing of activities.

EXAMPLE In the baseline period, a company owns a fleet of delivery vehicles. In the reporting period, it has outsourced this activity to an external delivery company. To be consistent, either the fuel used for transportation by the company in the baseline period needs to be eliminated, or the delivery company's energy consumption needs to be accounted for.

Static factors should be monitored for change throughout the reporting period. The reasons, methods and assumptions used in making non-routine adjustments should be documented.

6.4 Normalization for relevant variables

6.4.1 General principles

Energy consumption is impacted by relevant variables. Normalization should be used so that the effect of abnormal values of the relevant variables can be removed from energy consumption for comparison between the baseline period and reporting periods.

EXAMPLE 1 For changing weather conditions, degree days can be used as a relevant variable to normalize energy consumption in buildings, where a significant proportion of the energy used in the building is for space heating or cooling.

Statistical tests (e.g. p-value criterion) may be useful in deciding which relevant variables (if any) significantly affect energy consumption and should be used for normalization.

Depending on the objective of determining energy savings, it may be appropriate to normalize:

— baseline period energy consumption (see 6.4.2.1, forecast normalization);

— reporting period energy consumption (see 6.4.2.2, retrospective normalization);

— baseline period and reporting period energy consumption (see 6.4.2.3, reference conditions normalization).

The three different methods will not produce the same results. When the determination of energy savings is repeated over time, the normalization method should not change. The method chosen should be documented and if it is changed, the reasons should be documented.

In some cases, it is difficult to normalize the total energy consumed by the organization by using a single model.

Situations in which normalizing prior to aggregating energy consumption may be a good approach include the following:

— differences in baseline and reporting period conditions;

— the number, complexity and interactions of variables affecting energy consumption;

— differences in the products manufactured by the constituent parts of an organization;

— differences in energy using systems;

— differences in the types of energy used;

— conditions differing by site location (e.g. degree days).

In these cases, dividing the organization into its constituent parts based on energy using systems, organizational requirements or sites (see 4.2.1) and normalizing energy consumption separately before accounting for energy savings in aggregate will simplify the model and help in reducing the uncertainty of the determination of energy savings.

EXAMPLE 2 An organization manufacturing and selling furniture might normalize energy consumed in its manufacturing plants for number of units produced, while its showrooms might normalize energy consumption for weather (degree days).

Annex D shows an example of normalization in the cement industry. Annex E shows an example of an organization constituted by three parts, each of which produces different products. Normalization of energy consumption of each part separately before aggregating energy savings gives a better result than normalization as a whole after aggregating total energy consumption.

If it is decided not to carry out normalization when determining energy savings, this should be documented and used consistently.

Where the unadjusted energy savings are required, it may not be permitted to normalize for relevant variables. Any such requirement should be documented and reported.

6.4.2 Methods of normalization

6.4.2.1 Forecast normalization (reporting period basis)

The forecast normalization method compares actual reporting-period energy consumption to the normalized baseline period energy consumption. The normalized baseline period energy consumption is the estimated energy consumption using reporting-period relevant variable levels, as if the baseline period operating equipment and practices were still in place.

NOTE The terms “estimated”, “expected” and “predicted” are often used interchangeably. In this International Standard, the term “estimated energy consumption” is used for the value that might be expected or predicted.

This requires the development of a model describing energy consumption as a function of the relevant variables for the baseline period. This model is then used to calculate the estimated energy consumption for the baseline period under the reporting-period conditions.

6.4.2.2 Retrospective normalization (baseline period basis)

The retrospective normalization method compares actual baseline period energy consumption to the normalized reporting-period energy consumption. The normalized reporting-period energy consumption is the estimated energy consumption using baseline period relevant variables levels, as if the reporting period operating equipment and practices had been in place in the baseline period.

As with forecast normalization, this method requires the development of a model describing energy consumption as a function of relevant variables, but in this case for the reporting period. This model is then used to calculate the estimated energy consumption for the reporting period under the baseline period conditions.

Retrospective normalization may be useful if a facility has limited data for energy consumption and corresponding relevant variables for the baseline period but detailed data for energy consumption and corresponding relevant variables for the reporting period.

EXAMPLE 1 Retrospective normalization can be applied if there are monthly or more frequent data corresponding to the energy consumption data for the reporting period, but only annual energy consumption and production for the baseline period.

EXAMPLE 2 Retrospective normalization can be necessary if the baseline period has been fixed by legal or other requirements (e.g. a government requiring all energy savings made by companies to be reported against a 1990 base year).

6.4.2.3 Reference conditions normalization

This method normalizes energy consumption for both the baseline period and the reporting period using a set of reference conditions and compares the two.

For this method, it is necessary to establish reference conditions reflecting typical historical and likely future conditions. Reference conditions that can be considered include the following:

— production levels;

— weather: use of a typical meteorological year.

EXAMPLE This approach is useful when the energy savings are affected by weather conditions which might be mild, extreme or typical. Forecast or retrospective normalization enable energy savings to be calculated using the baseline or reporting period weather conditions, respectively. This weather dependency of the energy savings can be avoided by using the reference conditions method and normalizing to a typical meteorological year or other reference conditions.

The reference conditions method is useful for continuous tracking of energy savings, as it is independent of the baseline period conditions.

The choice of reference conditions should be justified and documented and reported.

6.4.3 Summary of normalization methods

Table 1 provides a summary of normalization methods.

Table 1 — Summary of normalization methods

Criteria	Normalization method		
	Forecast	Retrospective	Reference conditions
Reporting period energy consumption	Actual reporting period energy consumption	Reporting period model using baseline period conditions	Reporting period model using reference conditions
Baseline period energy consumption	Baseline period model using reporting period conditions	Actual baseline period energy consumption	Baseline period model using reference conditions
Assumptions regarding operating equipment and practices	Baseline period operating equipment and practices in place	Reporting period operating equipment and practices in place	Baseline and reporting period operating equipment and practices using reference conditions

6.4.4 Determination of normalized energy consumption

6.4.4.1 General

The forecast and retrospective methods require a model to be fitted to the data from either baseline or reporting period, respectively. The reference conditions method requires a model to be fitted to the data from both baseline and reporting period. The model is then used to calculate normalized energy consumption. The modelling approaches in 6.4.4.2 to 6.4.4.5 can be used.

6.4.4.2 Fitting the model

The first step is to fit a model which describes the energy consumption as a function of relevant variables. In general terms, the relationship can be expressed as follows:

$$E = \mathrm{f}\left(x_1, x_2 \ldots x_n\right) \tag{3}$$

where

E is the energy consumption;

x_i are relevant variables;

f() is a function of the relevant variables.

NOTE 1 It is also possible to use a condition-based model where a different formula applies on either side of a threshold value, so that, for example:

$$E = \mathrm{f}\left(x_1, x_2 \ldots x_n\right) \text{ -- if } x_i > N$$

$$E = \mathrm{g}\left(x_1, x_2 \ldots x_n\right) \text{ -- if } x_i \le N$$

EXAMPLE 1 The state of a plant includes not only “in operation” but “part-load” and “standby”. This might require a condition-based model if it cannot be treated as an outlier.

EXAMPLE 2 The energy consumption characteristic might change according to the quality and the kind of raw materials (a relevant variable) which are the input to the plant. Depending on the quality parameters (e.g. hardness index exceeds a threshold value), then this might require a condition-based model.

NOTE 2 If there are no relevant variables that exhibit a statistically significant correlation to energy consumption, then it might be that the only model would be $E = E_{b0}$, where E_{b0} is a constant. This is the case of a simple metric. In this case, it is not possible to undertake normalization.

The choice of model should be based on physical relationships or other considerations. These may be used to select the relevant variables and the expected form of the model. These considerations can lead to a simple formula as well as a more complex system of formulae.

6.4.4.3 Examples of commonly used models

6.4.4.3.1 Example 1: Ratio of energy consumption to a single relevant variable

Although simple to use, this method does not consider base load energy consumption or any other consumption not related to throughput.

The ratio model takes the form:

$$E = bx \tag{4}$$

where

E is energy consumption;

b is a constant, sometimes known as the specific energy consumption (SEC);

x is the relevant variable.

6.4.4.3.2 Example 2: Linear regression model

The linear regression model takes the form:

$$E = E_{b0} + b_1 x_1 + ... + b_n x_n \tag{5}$$

where

$x_1 ... x_2 ... x_n$ are relevant variables;

E_{b0} is base load energy or energy consumption which is not related to a relevant variable.

Developing the model will often require statistical testing (e.g. p-value criterion) and screening to determine which terms to include.

NOTE This model is most commonly used with one relevant variable in the form shown in Formula (6) (also known as the simple linear regression model):

$$E = E_{b0} + b_1 x \tag{6}$$

6.4.4.3.3 Example 3: Complex model

a) Polynomial model: This is a linear regression model including terms in integer powers of the individual relevant variables and products of these variables. A second order polynomial in x_1, x_2 and x_3 can be expressed as:

$$E = E_{b0} + b_1 x_1 + b_2 x_2 + b_3 x_3 + b_4 \left(x_1\right)^2 + b_5 \left(x_2\right)^2 + b_6 \left(x_3\right)^2 + b_7 x_1 x_2 + b_8 x_2 x_3 + b_{b9} x_3 x_1 \tag{7}$$

b) General nonlinear model: This form allows terms that are nonlinear in the estimated coefficients.

6.4.4.4 Considerations in model preparation

In order to fit a model for its energy consumption, the organization should use historical data reflecting its operating patterns. In most cases, the model needs to use data spanning 12 months to ensure seasonal variations are reflected. The method used for preparation of a model such as regression analysis may not work properly for irregular periods of energy consumption, although averaging the data over longer periods of time can reduce random errors but not the systematic errors. In the case of monthly data, the problem of calendar mismatch is faced due to following reasons:

— months are of different lengths, depending on the month and whether or not it is a leap year;

— weeks do not overlap neatly with months.

By using daily or hourly energy consumption, production and degree days, the accuracy of the base load energy figure determined through regression analysis can be improved:

a) in the case of buildings, it is important to use data for days and times with similar energy operating patterns, e.g. working weekdays, occupied hours, weekends;

b) production and energy consumption data of a continuous process plant should be modelled on the basis of daily production and energy consumption;

c) other plants may use hourly, daily, weekly or monthly data, as appropriate.

Data gathered at more frequent intervals (“interval data”) may help improve the accuracy of the model.

It is important to build the model on data that are representative of the normal energy behaviour of the organization. Data should be screened prior to use. Outliers may be removed unless high variability is a characteristic of the system.

EXAMPLE Data from shutdown periods with no production are an example of an outlier in a continuous production plant.

When using an EPIA-based approach, it is preferable that the modelling and normalization methods should be selected according to the characteristics of each individual type of EPIA (e.g. all variable speed drives should have the same model and normalization method), rather than using a single normalization method for all EPIAs. The models and normalization methods for each type of EPIA should be documented.

6.4.4.5 Considerations in determination of model validity

The model for the normalization of energy consumption may be validated using statistical techniques such as *t*-test, chi-squared test, null hypothesis test, Fischer’s exact test, taking into account the purpose of determining energy savings. Typically, these tests determine a value which shows statistical significance if below a threshold (i.e. critical value).

a) Valid quantitative range of model variables: For the model to be valid in determining normalized energy consumption, the average value of the relevant variable used to determine the normalized consumption from the model should fall within one of the following:

  — the range of observed data that went into the model;

  — a pre-determined number of standard errors from the mean of the data that went into the model.

b) Model testing: For the model to be considered valid, both the following conditions should meet threshold values:

  — at least one of the variables in the model has a p-value less than a pre-determined level;

  — an F test for the overall model fit has a value less than a pre-determined level.

NOTE A threshold value of ≤ 0,1, corresponding to a 10 % significance level, is typically used.

The result of the statistical relationship between energy consumption and relevant variables is above a pre-determined level (e.g. the coefficient of determination, $R^2 > 0{,}75$), demonstrating that there is a good correlation between energy consumption and relevant variables.

The results of the validation and model testing should be documented and reported.

7 Calculation of energy savings

7.1 General principles

After identifying the boundaries of an organization, and the baseline and reporting periods (see 6.2), the energy consumption for each period should be:

a) expressed in common energy units (see 5.4);

b) converted to primary or delivered energy as selected by the organization (see 5.5);

c) adjusted for non-routine adjustments and normalized for the relevant variables (see 6.3 and 6.4).

NOTE 1 It is often possible to normalize first, using the initially measured energy units, or after either of the other steps listed above.

After applying these, the energy savings of the organization are the difference in the energy consumed within the boundaries between the baseline period and the reporting period (where the two periods are equivalent in length), allowing for any non-routine adjustments, if any.

The basic formulae to sum the energy savings of a single type of energy, *i*, are given in Table 2.

Table 2 — Formulae for energy savings of a single type of energy

	Method of normalization		
	Forecast	**Retrospective**	**Reference conditions**
Energy savings	$E_{b,i,n} - E_{r,i}$	$E_{b,i} - E_{r,i,n}$	$E_{b,i,n} - E_{r,i,n}$

Key

$E_{b,i}$ energy consumption of type *i* in the baseline period

$E_{r,i}$ energy consumption of type *i* in the reporting period

$E_{b,i,n}$ normalized energy consumption of type *i* in the baseline period

$E_{r,i,n}$ normalized energy consumption of type *i* in the reporting period

NOTE 2 If more energy is used in the reporting period than the baseline period, the calculation will show negative energy savings.

Where there are multiple types of energy, energy savings may be determined in one of two ways:

— Case 1: Determine the energy savings of each type of energy after normalization, express them in common units and sum these to obtain energy savings;

— Case 2: After expressing in common units, combine the consumption of each type of energy, then normalize to determine the energy savings.

In either case, normalization may be undertaken using any of the methods described in this International Standard. Both cases may also be applied when using either primary or delivered energy.

For Case 1, the methods of normalization in Table 3 apply.

Table 3 — Formulae for energy savings for multiple types of energy: Case 1

	Method of normalization		
	Forecast	**Retrospective**	**Reference conditions**
Energy savings	$\sum\left(E_{b,i,n} - E_{r,i}\right)$	$\sum\left(E_{b,i} - E_{r,i,n}\right)$	$\sum\left(E_{b,i,n} - E_{r,i,n}\right)$

EXAMPLE 1 In an office building, gas is only used for heating, but electricity is used for multiple purposes. It might be appropriate to normalize gas consumption using heating degree-days in both the baseline and reporting period for a reference period in which the ambient temperatures were average. Electrical consumption has not been normalized. Both gas and electricity consumption will have been expressed in common energy units.

For Case 2, the methods of normalization in Table 4 apply.

Table 4 — Formulae for energy savings for multiple types of energy: Case 2

	Method of normalization		
	Forecast	Retrospective	Reference conditions
Energy savings	$\left(\sum E_{\mathrm{b},i}\right)_{\mathrm{n}} - \sum E_{\mathrm{r},i}$	$\sum E_{\mathrm{b},i} - \left(\sum E_{\mathrm{r},i}\right)_{\mathrm{n}}$	$\left(\sum E_{\mathrm{b},i}\right)_{\mathrm{n}} - \left(\sum E_{\mathrm{r},i}\right)_{\mathrm{n}}$

EXAMPLE 2 A factory makes a complex product that uses both gas (in furnaces, for raising steam and other purposes) and electricity (for cooling and use in power drives). In this case, it might be appropriate to first express in common units and then normalize total energy consumption (aggregated energy consumption of gas and electricity).

NOTE 3 Cases 1 and 2 can also be used for the summation of energy savings from parts of an organization or for individual EPIAs.

7.2 EPIA-based approach to determining energy savings

7.2.1 General principles

The basic formulae to sum the energy savings of multiple EPIAs are given in Table 5.

Table 5 — Formulae for energy savings of multiple EPIAs

	Method of normalization		
	Forecast	Retrospective	Reference conditions
Energy savings	$\sum\left(E_{\mathrm{b},j,\mathrm{n}} - E_{\mathrm{r},j}\right)$	$\sum\left(E_{\mathrm{b},j} - E_{\mathrm{r},j,\mathrm{n}}\right)$	$\sum\left(E_{\mathrm{b},j,\mathrm{n}} - E_{\mathrm{r},j,\mathrm{n}}\right)$

Key

$E_{\mathrm{b},j}$ energy consumption within the boundaries of EPIA *j* in the baseline period

$E_{\mathrm{r},j}$ energy consumption within the boundaries of EPIA *j* in the reporting period

$E_{\mathrm{b},j,n}$ normalized energy consumption within the boundaries of EPIA *j* in the baseline period

$E_{\mathrm{r},j,n}$ normalized energy consumption within the boundaries of EPIA *j* in the reporting period

The formulae in Table 5 can only be used without correction if the EPIAs do not impact the energy consumption of one another. Otherwise corrections should be done to account for indirect energy effects and to correct for double counting.

7.2.2 Indirect energy effects

Typically the sum of individual energy savings from individual EPIAs is different from the total energy savings due to indirect energy effects.

An indirect energy effect may arise when a reduction in energy consumption following an EPIA leads to an increase in energy consumption elsewhere within the organization.

EXAMPLE 1 Improving the lighting energy efficiency by using LEDs in an office building will increase the requirement for heating due to lower incidental gains from the more efficient lights.

Indirect energy effects can sometimes lead to greater than expected energy savings elsewhere within the organization.

EXAMPLE 2 Improving the lighting energy efficiency by using LEDs in an office building that uses a cooling system will lead to additional energy savings from cooling system as well as from lighting.

7.2.3 Avoiding double counting

Double counting effects can arise where an EPIA in one part of an energy using system reduces the total demand (and hence the energy savings) from other EPIAs made in another part of the system. In such cases, the total expected energy savings will be lower than the sum of the energy savings that would have occurred if each EPIA had been made in isolation.

EXAMPLE 1 In a building renovation, energy savings might be calculated from the improvement of building envelope (e.g. by insulating roofs, walls or upgrading glazing) and by the improvement of heating system (higher efficiency boilers, better controls). The combined calculated energy savings will be lower than the individually calculated energy savings due to lower heat losses through the roof, walls and window reducing the heat demand from the heating system.

Another type of double counting is if the same energy performance improvement is attributed in full for two different EPIAs. Although the energy savings from that improvement may be attributable to both EPIAs, the overall energy savings should be counted only once.

EXAMPLE 2 A company replaces its old lighting with LEDs, and at the same time runs a staff campaign reminding them to switch off lights when not in use. The managers responsible for both the lighting upgrade and the behaviour claim that the energy savings are theirs. To avoid double counting, the measured energy savings need to be apportioned between the two EPIAs.

The following steps can be taken to avoid double counting:

— determine energy savings for each EPIA: in this step all energy savings from that EPIA should be included whether they relate solely to that EPIA or also to other EPIAs;

— identify the related EPIAs for each double counted energy saving;

— if the contribution of each EPIA can be determined through theoretical or engineering analysis, it should be allocated according to the relative proportion and extract the double counted energy savings;

— if it is difficult, some allocation rules should be established, e.g. choosing the most strongly related EPIAs: in such a procedure, statistical methods are sometimes effective.

When there is no adequate way to avoid double counting, the summation of the unavoidable double counting should be subtracted after the aggregation of energy savings from all EPIAs.

The approach taken to the identification and avoidance of double counting should be used consistently and documented.

7.3 Ensuring consistency between organization-based and EPIA-based approaches

When it is possible to determine energy savings at both the organizational level and through summing energy savings from EPIAs within the organization, comparing their results provides a reality check and opportunities for analysing the discrepancies and looking for their causes. Examples of such causes are:

— increases in energy consumption in parts of an organization not implementing EPIAs could offset or hide the energy savings from EPIAs;

— EPIAs do not achieve the expected energy savings, for any reason (e.g. equipment does not achieve claimed energy savings, operational control issues, rebound effects);

— EPIAs exclude end user actions that were not identified initially as affecting energy performance;

— normalization for some relevant variable or for non-routine adjustments for autonomous progress has been omitted;

— measurements are inaccurate;

— normalization has been carried out inappropriately.

See Annex B for further information.

8 Improving the accuracy of energy savings results

8.1 Data quality

The quality, precision and accuracy of data collected to calculate energy savings need to be considered if the calculated results are to be meaningful.

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

— the method of collection, i.e. manual or automatic readings sent to a centralized data collection centre;

— the source of data, e.g. third party weather station data (for degree days calculations);

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

— the accuracy of meters and measuring equipment;

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

— repeatability of data from the data source;

— validation of the data.

Data completeness includes ensuring adequate length of time for data to be collected across the organization for which energy savings calculations are to be performed. Where appropriate, data should be corrected for missing data or incorrectly recorded values.

Data should be collected consistently over the baseline and reporting period(s).

All measurements have inherent uncertainty and this may be limited by using the correct calculations and formulae for normalization or modelling.

As the baseline and reporting period data used to calculate energy savings can be very close in magnitude, perhaps differing by only a small percentage, inadequate data quality or inappropriate normalization can lead to high uncertainty and low significance of calculated energy savings values.

8.2 Errors in determining energy savings

Energy savings calculations may be affected by systematic and random errors. Systematic errors are bias in measurement, assumptions and analysis. Random errors are a result of the quality of measuring equipment, the measurement techniques and sampling. The process of normalization also introduces errors, as it is based on the use of models.

Errors may be caused by the following:

a) Manual errors: The accuracy of energy savings calculations may be affected by simple human error in the manual transfer of information and/or complex spreadsheet calculations (e.g. incorrect cell references or typographical errors in formulae). Checks and balances should be included in the process appropriate to the complexity of the calculations to minimize the risk of such errors.

b) Modelling errors: This could be due to an inappropriate functional form, exclusion of relevant variables or due to inclusion of non-relevant variables.

EXAMPLE In an organization, monthly sales are used as a relevant variable even though there is no cause and effect between energy consumption and sales. This is a case of the inclusion of a non-relevant variable. The organization can consider using production volume per day as a relevant variable.

c) Measurement errors: These may be caused by systematic and random errors. Drift during the period since meters were last calibrated can cause bias. Random errors can be a result of accuracy of sensors, transmitters, etc. The magnitude of such errors can be managed by periodic recalibration.

d) Sampling errors: This can be caused when the sample is not representative of the population or due to biased sampling.

Sources of error may also be unknown or non-quantifiable, such as meter selection with low repeatability or incorrect placement of measurement devices (e.g. orifice meters). These can be managed by proper selection and installation based on industry best practices.

8.3 Acceptable uncertainty criteria

The organization should set an acceptable level of uncertainty criteria before determining its energy savings. To be statistically valid, energy savings should be large relative to random statistical variations. This level should be documented and used consistently.

NOTE Typically, in the cases of forecast or retrospective normalization, a simplified criterion of energy savings greater than, for example, twice the standard error of the baseline or reporting period model will be used. In the case of reference conditions normalization, the standard error of the baseline model and reporting period model can be combined using statistical rules. If energy savings are less than the set level, then the organization can look for likely sources of error and take steps to reduce them.

9 Reporting energy savings

9.1 General

Energy savings should be documented and reported in a consistent manner between baseline and reporting periods, taking into account any requirements made by interested parties which can be either external (e.g. regulatory by government or a stock exchange) or internal (e.g. management of the organization). The report should list the types of energy that have been omitted on grounds of insignificance and the parts of the organization that have been excluded.

Where possible, the number of significant figures used for reporting should be set to reflect the level of uncertainty in the data.

EXAMPLE If the data are measured to within ± 2 %, it is preferable to express energy consumption as 217 MWh, rather than as 216,874 kWh, which implies that each kWh figure is significant.

9.2 Reporting considerations for groups of companies

Complex organizations often contain subsidiaries, plants or other facilities that are jointly controlled by different organizations. In determining the total energy savings for the complex organization, there may be a need to attribute and report energy savings from these jointly controlled units. The complex organization should first ensure that energy savings in these units are determined on a basis consistent with this International Standard in terms of energy accounting, baseline and reporting periods and decisions over normalization. Having determined the energy savings from each of the jointly controlled units, these separate energy savings may then be allocated to the complex organization, as required.

Allocation, aggregation and reporting may be done with reference to characteristics such as equity share, financial control, operational or management control. The basis or method for allocating energy savings to the organizations that jointly control all of or a part of the organization should be documented.

9.3 Communicating energy savings results

This International Standard explains in detail how energy savings are to be calculated in energy accounting units such as Gigajoules or kilowatt-hours. Depending on the objective of determining energy savings (see 4.1), communication of the results may also be made using energy performance indicators:

a) with reference to a change in specific energy consumption;

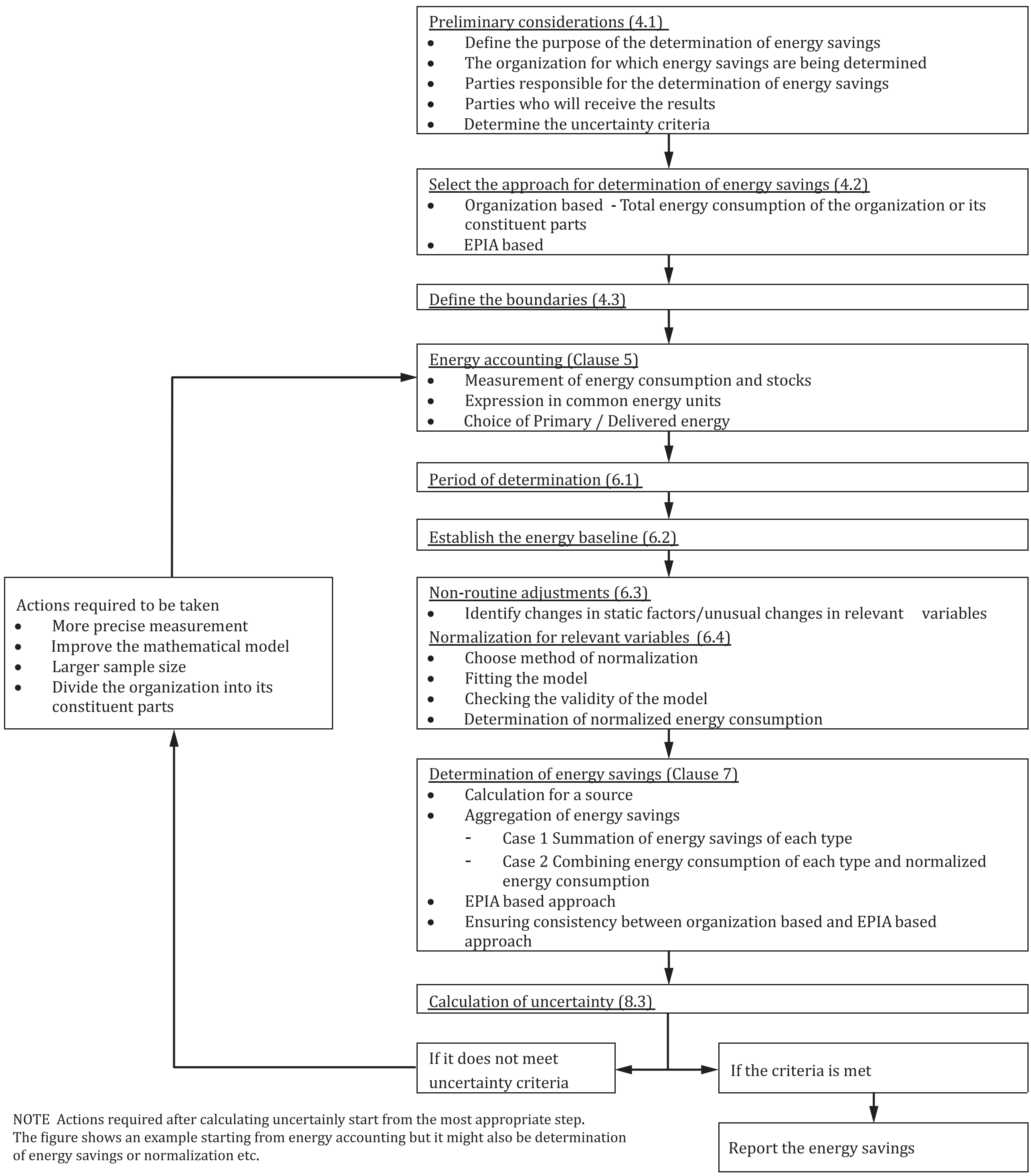
b) in terms of a change in energy intensity;

c) as a percentage.

See Annex F for more information on these approaches.

Annex A
(informative)

Flowchart for determination of energy savings



NOTE Actions required after calculating uncertainly start from the most appropriate step. The figure shows an example starting from energy accounting but it might also be determination of energy savings or normalization etc.

Figure A.1 — Flowchart for determination of energy savings

Annex B
(informative)

Reconciliation between organization level and EPIA-based energy savings

It is often useful to compare energy savings calculated at the organization level with energy savings calculated using the EPIA-based approach, as shown in Figure B.1. This provides a check on the energy savings summed from EPIAs. This may indicate that EPIAs are not achieving the expected energy savings. There may be many other reasons for differences, including the following:

— omitted EPIAs, including actions not identified initially as affecting energy performance;

— increases in energy consumption in parts of an organization not implementing EPIAs could offset or mask the energy savings from EPIAs;

— differences in energy accounting rules, measurement aggregation errors and uncertainties and errors in normalization;

— unaccounted changes in static factors;

— price effects, leading to a general awareness of the need to reduce energy consumption (or, more rarely, a lessening of control if prices fall) independent from identified EPIAs;

— improvements in the energy efficiency of new equipment installed, but not as part of an EPIA,

— increased energy consumption through the incorporation of additional features (together sometimes known as autonomous effects);

— operational management and control issues, including the effects of maintenance regimes;

— a rebound effect.

EXAMPLE Employees leave energy-efficient flat screen computer monitors on when they leave work each evening, as they know that they do not use much energy, even though they switched off CRT monitors in the past.

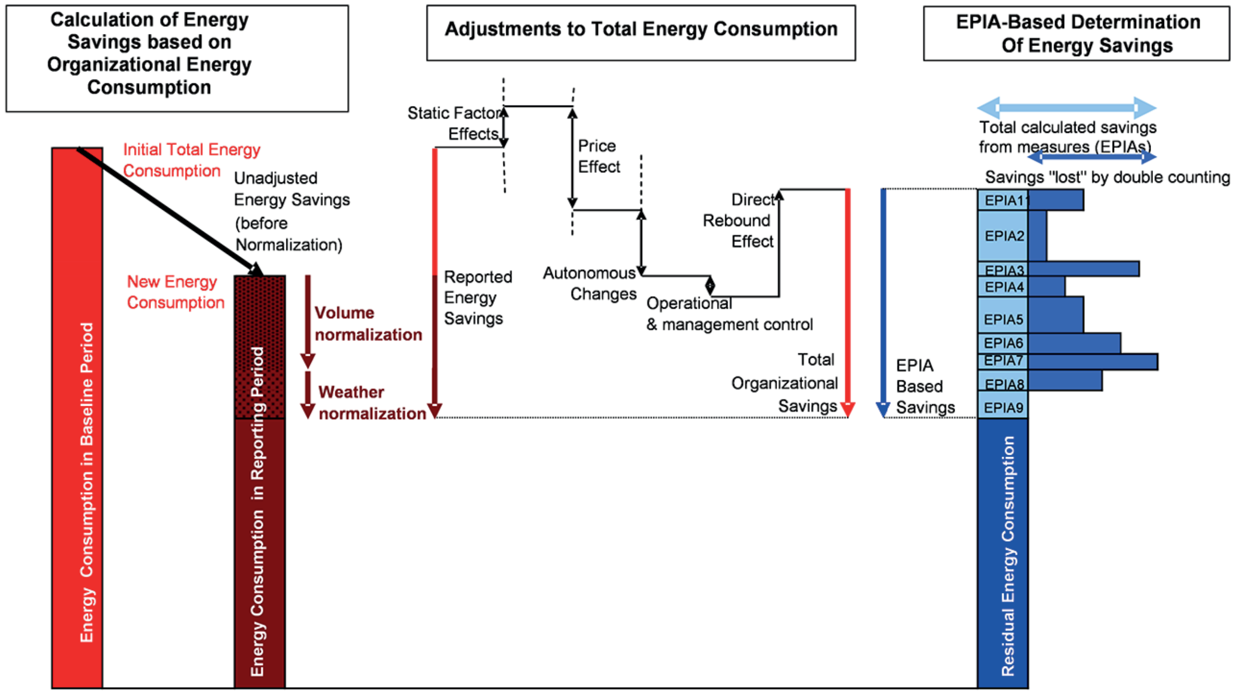


Figure B.1 — Schematic diagram of reconciliation between organizational-based and EPIA-based methods

Annex C
(informative)

Example of energy accounting in a cement plant

C.1 General

This annex gives an example of energy accounting in a cement plant, as described in Clause 5.

In the example in this annex, the plant produces several grades of cement. The plant also imports and exports a partially processed material namely clinker. The plant meets its electricity requirements from its own power plant and partially from the grid, and also exports electricity to the grid.

C.2 Objective of determining energy savings

The objective of determining energy savings is to meet the requirements of the management of the organization.

C.3 Boundaries

For the purposes of this annex, the plant's physical boundaries have been fixed as a single boundary, and captive mines and housing for employees have been excluded. Within this boundary, three separate boundaries are considered to meet the requirements of the management:

a) captive power plant and diesel generating sets;

b) production of clinker;

c) grinding of clinker to produce various grades of cement.

Figure C.1 illustrates the flow of energy and product/partially processed material within the organizational boundaries and other boundaries. The boundaries are shown by dashed lines.

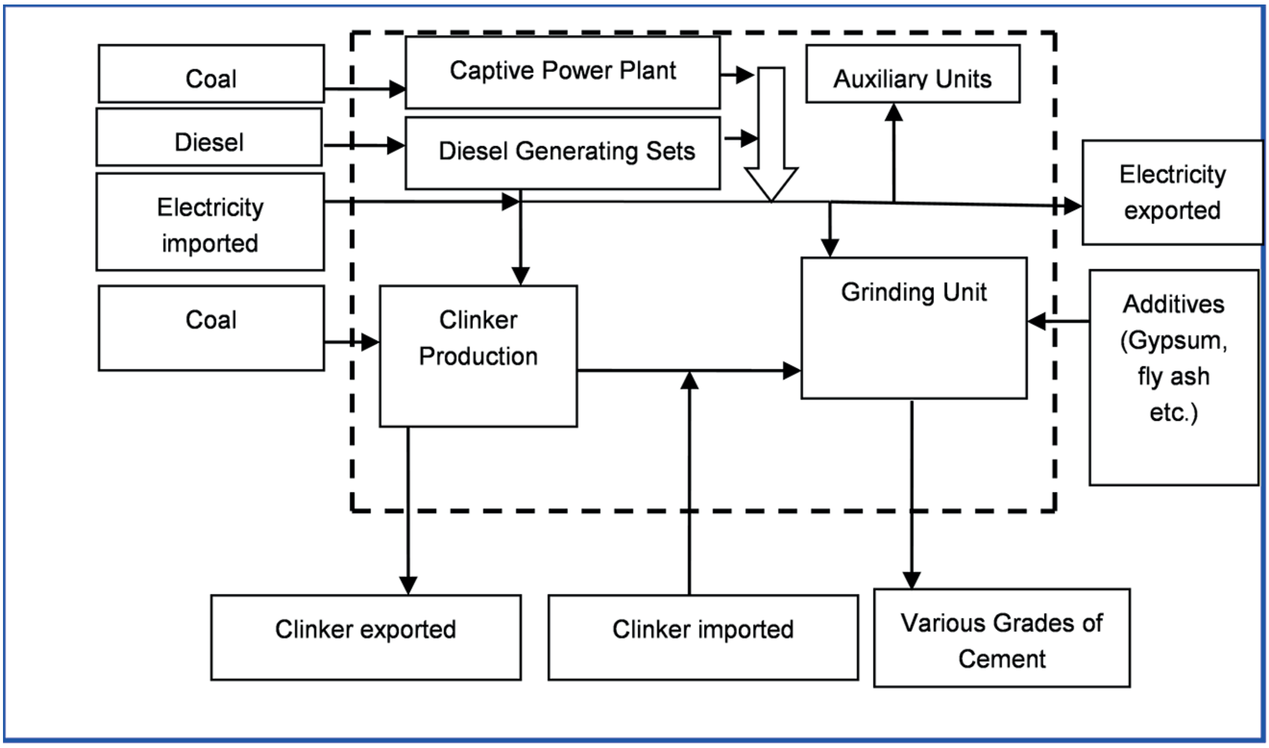


Figure C.1 — Flow of energy and product/partially processed material within the organizational boundaries and other boundaries

C.4 Identification of types of energy

The following types of energy which arrive at the boundaries and their use are considered:

a) electricity imported from the grid used in clinker production, grinding and for auxiliary units;

b) coal used as a fuel in the kiln for clinker production;

c) coal used as a fuel in the captive power plant;

d) diesel used as a fuel in the kiln for clinker production;

e) diesel for power generation in diesel generating (DG) sets.

Power generated in the captive power plant and DG sets is used in clinker production, the grinding unit and auxiliary units.

C.5 Measurement of energy consumption and stocks – delivered basis

Electricity imported from the grid is measured in kWh and is available directly from meters. Electrical energy consumed in clinker production, grinding units and auxiliary units in the plant is also measured in kWh and directly available from meters.

Diesel and coal are considered to constitute primary energy. The quantity of diesel consumed is measured by flow meters. The gross calorific value (GCV) of coal is measured by the plant from batches received from various suppliers. The consumption of coal, E_{coal}, is calculated using Formula (C.1):

$$E_{coal} = V_{open} + V_{add} - V_{close} - V_{loss} \quad (C.1)$$

where

V_{open} is the opening stock;

V_{add} are the additions to stock;

V_{close} is the closing stock;

V_{loss} are stock losses or sales.

The consumption of coal is also cross checked by weighing systems such as weigh feeders, belt weigher, volumetric feeder, solid flow meter, etc. The quantity of diesel consumed is measured by flow meters. Consumption of raw materials and finished products produced are similarly measured. The thermal energy used in captive power generation and DG sets, $E_{th,DG}$, is calculated using Formula (C.2):

$$E_{th,DG} = \left(m_{coal} \times E_{th,GCV,coal}\right) + \left(m_{diesel,DG} \times E_{th,GCV,diesel}\right) \quad (C.2)$$

where

m_{coal} is the coal consumed in captive power generation;

$E_{th,GCV,coal}$ is the GCV of coal;

$m_{diesel,DG}$ is the diesel consumed in DG sets;

$E_{th,GCV,diesel}$ is the GCV of diesel.

C.6 Expression in common energy units

The common unit of energy chosen is Gigajoules. Electricity imported from the grid is purchased in kilowatt-hours and expressed in Gigajoules by using Formula (C.3):

$$E_{1,GJ} = E_1 \times 3{,}6 \times 10^{-3} \quad (C.3)$$

where

E_1 is electricity imported from the grid expressed in kWh;

$E_{1,GJ}$ is electricity imported from the grid expressed in GJ.

Other fuels (coal and diesel) are converted using gross calorific value (GCV) in GJ/t or GJ/l.

The thermal energy used for captive power generation is already in GJ and needs no further conversion.

C.7 Conversion to primary energy

Electricity imported from the grid (delivered energy) is converted to primary energy by using Formula (C.4):

$$E_{\text{PGEE}} = m_1 \times E_{1,\text{GJ}} \tag{C.4}$$

where

E_{PGEE}	is the primary grid electricity equivalent;
m_1	is the energy conversion factor;
$E_{1,\text{GJ}}$	is electricity imported from the grid expressed in GJ, as calculated in Formula (C.3).

Thermal energy consumed in captive power generation, the captive power plant and DG sets [see Formula (C.2)] does not require any conversion as it is considered to be primary energy (i.e. the conversion factor is 1).

C.8 Energy consumption for clinker production

Thermal energy used for captive power plant and DG sets [see Formula (C.2)] is allocated to clinker production, the grinding unit, and auxiliary units based on electrical energy consumed in these units. The energy used in auxiliary units is apportioned between clinker production and grinding unit based on certain rules determined by the plant.

Based on the above allocated energy to the clinker production and apportioned energy from auxiliary units thermal energy used for clinker production is y % of the electrical energy generated in captive power plant and DG sets, as shown in Formula (C.5):

$$E_{\text{clinker}} = \left(E_{\text{th,total}} \times \frac{y}{100}\right) + \left(m_{\text{coal}} \times E_{\text{th,GCV,coal}}\right) \tag{C.5}$$

where

E_{clinker}	is the energy consumed for clinker production;
$E_{\text{th,total}}$	is the total thermal energy for captive power generation;
m_{coal}	is the coal consumed in the kiln for clinker production;
$E_{\text{th,GCV,coal}}$	is the GCV of coal.

The primary energy equivalent of electricity imported from the grid used for clinker production is calculated from Formula (C.4) by $E_{\text{PGEE}} \times \frac{y}{100}$.

Annex D
(informative)

Example of normalization of energy consumption in a cement plant

D.1 General

This annex details an example of forecast normalization (see 6.4.2.1) of equivalent thermal energy of electrical energy consumption for clinker production in a cement plant. The total energy savings of the organization are determined from those of its constituent parts (see 4.2.2). This example includes normalization for the part that produces clinker. Other parts could be similarly analysed but are not shown here. The unit imports electricity from the grid and does not generate any power on site.

The electrical energy consumption is measured for:

a) clinker production;

b) grinding of cement;

c) auxiliary units.

The energy consumption of auxiliary units is apportioned between clinker and grinding sections in a ratio of 70:30.

D.2 Normalization of electrical energy consumption for clinker production

D.2.1 Baseline period

Baseline period is established for a one year period from January 2013 to December 2013.

D.2.2 Relevant variables

The monthly production data and corresponding energy consumption data (for 12 months) are used. Quantity of clinker produced per day is used as the relevant variable as the monthly production is affected by the number of days in the month. However, other relevant variables which can be considered are raw material quality (hardness), fuel quality (petroleum coke or coal or alternate fuel) for clinker production.

D.2.3 Energy accounting

Table D.1 shows sample production data from a clinker plant.

Table D.1 — Sample production data from a clinker plant

Month in 2013	Clinker production t	Electrical energy consumption MWh E_A	Auxiliary unit electrical energy consumption MWh E_B	Total delivered electrical energy consumption MWh $E_C = E_A + 0{,}7E_B$	Total delivered electrical energy consumption GJ $E_D = 3{,}6E_C$	Total primary electrical energy consumption GJ $E_E = 3{,}16E_D$	Clinker produced per day t/day	Total primary electrical energy consumption per day GJ/day
January	125 189	7 671,3	399,1	7 950,7	28 622	90 443	4 038	2 918
February	119 003	7 111,7	352,3	7 358,3	26 490	83 704	4 250	2 989
March	129 481	7 826,3	510,2	8 183,4	29 460	93 091	4 177	3 003
April	96 042	6 553,7	431,8	6 856,0	24 681	77 991	3 201	2 600
May	98 995	5 813,2	272,4	6 003,8	21 614	68 297	3 193	2 203
June	122 702	7 068,0	355,1	7 316,6	26 340	83 230	4 090	2 774
July	123 097	7 144,5	366,9	7 401,3	26 645	84 194	3 971	2 716
August	101 239	6 130,7	348,1	6 374,4	22 948	72 512	3 266	2 339
September	109 970	6 311,4	338,0	6 548,0	23 573	74 486	3 666	2 483
October	110 449	6 322,3	327,4	6 551,5	23 585	74 527	3 563	2 404
November	66 317	4 062,0	266,3	4 248,4	15 294	48 328	2 211	1 611
December	106 405	6 394,7	309,9	6 611,6	23 802	75 211	3 432	2 426

NOTE 1 The energy consumption of DG sets and the power generated by them is ignored as it is small. This also results in simplification of calculations.

NOTE 2 The expression of energy units in GJ is carried out by multiplying the energy consumption in MWh by 3,6.

NOTE 3 In this example, the value of the energy conversion factor, m_1, for conversion to primary energy, is 3,16. The energy conversion factor can vary by type, country and region.

D.2.4 Model

The following model based on Formula (6) is used:

$$E_{th} = E_{b0} + b_1 x \qquad \text{(D.1)}$$

where

E_{th}	is the equivalent thermal energy of electricity consumed, in GJ per day;
E_{b0}	is the base load;
b	is a constant;
x	is the relevant variable (production of clinker, in t/day).

The data are statistically analysed by using a simple linear regression analysis.

D.2.5 Normalization

The result of the simple linear regression analysis is:

$$E_{\text{th}} = 229,9 + 0,643\,5x \quad \text{(D.2)}$$

where the base load (E_{b0}) is 229,9 GJ/day and the extra energy needed per tonne of clinker is 0,643 5 GJ/t.

Table D.2 shows sample outputs from regression analysis.

Table D.2 — Sample outputs from regression analysis

Regression statistics				
R square	0,907 0			
Standard error	125,703 7			
ANOVA (Analysis of variance)				
	F	**Significance F**	**Threshold F-value**	
Overall model	97,579 4	0,00	0,10	
	Coefficient	**Standard error**	**p-value**	**Threshold p-value**
Intercept	229,904 8	236,540 0	0,35	—
Relevant variable clinker production (t/day)	0,643 5	0,065 1	0,00	0,10

The model is considered valid as it meets the threshold requirements of F test and p-value of 0,10 each for clinker production per day as the relevant variable.

D.2.6 Calculation of energy savings

Using Formula (6), estimated energy consumption is calculated for the baseline period. Energy savings can then be calculated by using Table 2 (forecast method of normalization).

The graph of expected electrical energy consumed per day compared to clinker production per day is plotted in Figure D.1.

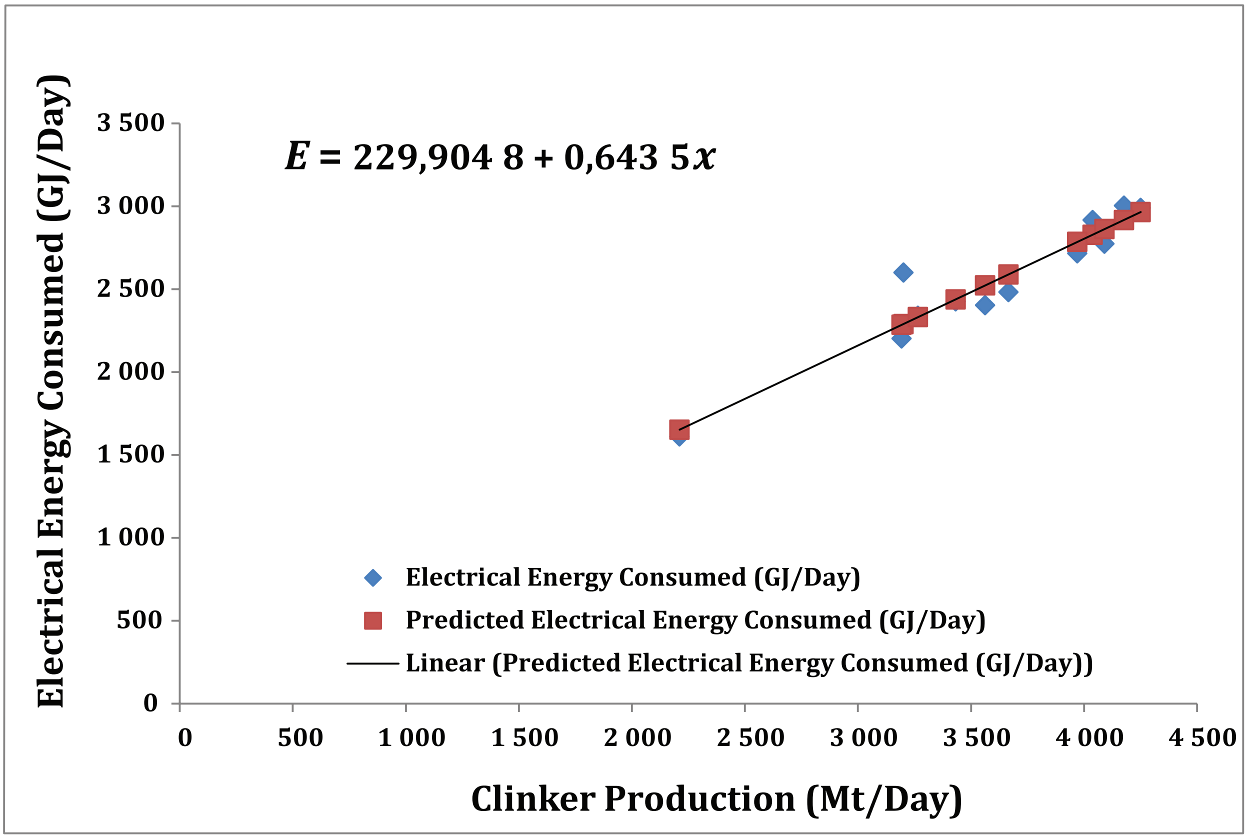


Figure D.1 — Clinker production

NOTE 1 No rounding off to significant digits is carried out until the final calculations of estimated energy consumption. The error in measurement of electrical energy consumption in kWh is 0,2 % of the reading, i.e. approximately 16 MWh.

NOTE 2 A factory that manufactures several products using a common facility, e.g. a heating furnace, generally measures energy consumption for each product (for each batch, if produced batch wise). Each product might have a significantly different relationship between energy consumption and production. For each product, the method described in this annex can be used. The estimated energy consumption for each product using the model for that product is aggregated to arrive at the normalized energy consumption of the facility.

Annex E
(informative)

Example of calculating energy savings for an organization producing various products

E.1 General

Even though production quantity is an important relevant variable there are many cases of continuous manufacturing processes in which the product is not uniform and the same equipment may be used to make a number of different product grades. There is also the possibility of an organization producing various products including the case in which the unit of production quantity differs between products.

Two typical analyses which can be applied for the above as below: the two methods described in Clauses E.2 and E.3 result in the same value of energy savings for the whole organization.

a) An organization consisting of parts of the organization each of which produce a product with a different unit. A typical analysis of summing up the energy savings of parts of organization is considered in Clause E.2.

b) An organization producing several products in a unit. The conversion is made to a major product which is sometimes also called index product as it accounts for most of the consumption. The method in Clause E.3 can be used for the determination of energy savings.

In the example case below, the company produces three products A, B and C.

— Product A: Unit is tonnes per year. This company is world class in energy efficiency for this product. Since the market demand for this product increased from the baseline period to the reporting period, the company increased its production. The company carried out many EPIAs in the production line of Product A.

— Product B: Unit is number of pieces per year.

— Product C: Unit is kilometres per year. This product is a wire.

For the purposes of normalization, forecast normalization (see 6.4.2.1) and the model in Example 1 (see 6.4.4.3) is used. This method does not consider base load energy consumption or any fixed non-throughput related consumption.

E.2 Calculation of energy savings from summing those in each part of the organization

As shown in Table E.1, the energy consumption for the company as a whole increased from 129 791 GJ per year to 142 351 GJ per year during the reporting period. Its absolute energy savings became negative as a result. However, by carrying out normalization for each product, the energy savings for that product are calculated and by summing the energy savings of the parts the energy savings for the organization is obtained.

Table E.1 — Calculation of energy savings from parts of the organization

Criteria		Product A	Product B	Product C	Total
Production	Baseline year	20 000 t/y	6 000 1 000 pieces/y	4 000 km/y	
	Reporting year	30 000 t/y	5 000 1 000 pieces/y	4 050 km/y	
Energy consumption	Baseline year	66 989 GJ/y	50 242 GJ/y	12 560 GJ/y	129 791 GJ/y
	Reporting year	83 736 GJ/y	46 055 GJ/y	12 560 GJ/y	142 351 GJ/y
Specific energy consumption	Baseline year	3,349 GJ/t	8 374 GJ/1 000 pieces	3,140 GJ/km	
	Reporting year	2,791 GJ/t	9 211 GJ/1 000 pieces	3,101 GJ/km	
Normalized energy baseline		100 483 GJ/y	41 868 GJ/y	12 717 GJ/y	155 069 GJ/y
Energy savings		16 747 GJ/y	−4 187 GJ/y	157 GJ/y	12 717 GJ/y

E.3 Product analysis and calculation for the whole organization

In this method, instead of processing the production figure for each product, they are added together as a weighted sum by converting the various products into a single number representing the equivalent output volume of one product which is called the index product or a major product or grade. The steps for calculation as shown in Table E.2 are:

a) conversion factor (energy factor for each product), which is the ratio of specific energy consumption (SEC) of that product to SEC of the major product, is calculated with reference to major product (in Table E.2, Product A is the major product);

b) equivalent production of a product is obtained by multiplying the production of that product in the reporting period by corresponding energy factor of baseline year;

c) total equivalent production is then calculated by summing-up equivalent production of all products;

d) normalized energy consumption of baseline period is calculated by multiplying the total equivalent production by the specific energy consumption of the major product during the baseline period;

e) energy savings with normalization is the difference between the normalized energy consumption of the baseline period and the energy consumption of the reporting period (forecast normalization).

Table E.2 — Calculation of energy savings of the organization based on equivalent production

Criteria	Product	Unit	Baseline year	Reporting year
Production	A	t/y	20 000	30 000
	B	1 000 pieces/y	6 000	5 000
	C	km/y	4 000	4 050
Specific energy consumption	A	GJ/t	3,349	2,791
	B	GJ/1 000p	8,374	9,211
	C	GJ/km	3,14	3,10
Energy consumption	Total	GJ/y	129 791	142 351
Energy savings without normalization	Total	GJ/y	—	–12 560
Conversion factor (Energy factor)	B to A	1 000 pieces/y to t/y	2,500 4	
	C to A	km/y to t/y	0,937 6	
Equivalent production of reporting period	B to A	t/y	12 502	
Reduced to major product by the energy factor of baseline year	C to A	t/y	3 797	
	Total	t/y	46 299	
Normalized energy consumption of baseline year		GJ/y	155 055	
Energy savings with normalization		GJ/y	—	12 704

The calculated result in Table E.2 is the same as that as shown in Table E.1 with a small difference caused by rounding.

Annex F
(informative)

Further information on communicating energy savings

F.1 General

Organizations should follow the guidance provided in this International Standard to determine energy savings in an organization, and then may optionally communicate the results using a variety of energy performance indicators (EnPIs) as in the following methods. ISO 50006 gives more information about how EnPIs may be used.

F.2 Energy savings as a change in specific energy consumption

Specific energy consumption relates energy consumption to a unit of activity within the organization.

EXAMPLE 1 Energy per square metre of floor area (used for offices or retail operations).

EXAMPLE 2 Energy per 1,000 tonnes of product (used in manufacturing or mining industries).

EXAMPLE 3 Energy per vehicle assembled (used by car or truck plants).

EXAMPLE 4 Energy per passenger-kilometre (used by airlines, railway or bus companies).

NOTE Using a ratio model (see Example 1 in 6.4.4.3) of energy consumption against output might give misleading results, e.g. by ignoring base load energy. Changes in product mix can also affect the validity of energy savings calculated.

F.3 Energy savings as a change in energy intensity

Some organizations are required to communicate their energy used per unit of financial output (turnover or, more rarely, gross added value), also known as energy intensity. When reporting on this basis, they should first determine energy savings in accordance with this International Standard, and then divide the resultant energy savings by the financial factor.

NOTE Energy intensity is sometimes used at a time of rapid organizational change, as well as allowing comparison between organizations of different sizes.

F.4 Percentage energy savings

Organizations are often expected to report energy savings not in energy units (such as kWh or GJ) but as a percentage reduction in energy use. In general, energy savings should be reported against the baseline period. In some cases, this period is set by other requirements, e.g. where organizations are expected to show a reduction in energy consumption against a specific year as part of a national energy savings target.

The general formula for percentage energy savings, in percent, is:

$$\frac{\Delta E}{E_{\mathrm{b}}} \times 100 \qquad \text{(F.1)}$$

where

ΔE are energy savings, determined in accordance with this International Standard;

E_b is the normalized baseline energy consumption.

Care should be taken to ensure that the energy baseline is normalized consistently.

Percentage savings may also be applied to changes in energy intensity or other energy performance indicators.

EXAMPLE Commercial buildings are required to reduce energy consumption per square metre of office space by an average of 2 % per annum over the period 2010 to 2020, using 2010 as the baseline period.

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