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Calculation methods for energy efficiency and energy consumption variations at country, region and city levels

Méthode de calcul pour l'efficacité énergétique et les variations de consommation d'énergie aux niveaux national, régional et urbain

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO 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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This document was prepared by Technical Committee ISO/TC 301, *Energy management and energy savings*.

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

Introduction

Due to the increasing role of energy efficiency improvements and of controlling the energy consumption growth in international climate and energy policies, there is a need for harmonization of methods to evaluate the impact of these policies at the international level.

This document is concerned with the evaluation of energy consumption and energy intensity changes through explanatory factors, as well as the calculation of an energy efficiency index, at national and regional levels. The practical application can be different due to specific restrictions, such as methodologies, availability of data at lower levels of disaggregation, or difficulty in understanding and communicating.

The methods presented here can provide valuable insights into trends in energy use and factors linked to those trends. Still, not all aspects of the phenomena that affect energy use are accounted for by the methods in this document, as these methods are primarily descriptive. While the analysis presented here can reveal patterns or shifts in patterns of energy use, they do not necessarily reveal causality, an aspect that can also require additional analysis.

The user should be aware of some issues associated with the methods presented in this document. Some of these arise from analytic issues. For example, whether to combine all fuels in a sector into a single energy variable or to treat them separately is a question best addressed by clear reference to the purpose of the analysis using the methods presented here. Other aspects are phenomena not explicitly included in the methods presented here. An example is the role of the prices of energy or other goods, which can require additional methods.

This document is composed of three different calculation methods:

— evaluation of structure effects in the variation of energy intensity;

— calculation of energy efficiency indices;

— decomposition analysis of energy consumption variation.

Energy intensity is often considered as an indicator of energy efficiency at aggregate level when limited data are available. Their use as a proxy for energy efficiency can be improved by removing from their variations changes in economic structures: this is the objective of the first part of this document.

With more detailed data on energy consumption available by subsectors or energy uses (e.g. space heating) or by modes of transport (e.g. cars), it is possible to assess energy efficiency trends through a more accurate indicator than energy intensity, called "energy efficiency indices": this is the objective of the second method of calculation presented in this document.

The variation of energy consumption can be related to change in economic activity, to energy savings as well as to other explanatory factors: the purpose of the third method of calculation described in this document is to present the method of decomposition of changes in energy consumption. It makes use of indicator-based savings, i.e. energy savings calculated according to the indicator-based method, as described in ISO 17742.

This document considers all end-use sectors, such as industry, transport, households, services (also known as the "tertiary sector") and agriculture. It does not generally incorporate the energy supply sectors, such as power plants, refineries or coal mines. However, the integration of the power sector can be considered in the decomposition of the primary energy consumption to account for the effect of variations in energy efficiency and energy mix in the power sector.

Energy consumption considered in this document excludes feedstock energy, such as oil feedstock used to produce plastics or natural gas used as a feedstock for the production of fertilisers, as they are not affected by energy efficiency policies.

This document can be used by any interested parties (decision-makers, companies, researchers, NGOs, etc.) that want to understand changes in the energy intensity or the energy consumption, as well as to assess energy efficiency by sector over a specific period.

This document is part of a set of documents developed by TC 301 (see Figure 1) and builds on the general principles outlined in ISO 17743, including reporting and system boundaries, and on the energy savings calculations presented in ISO 17742.

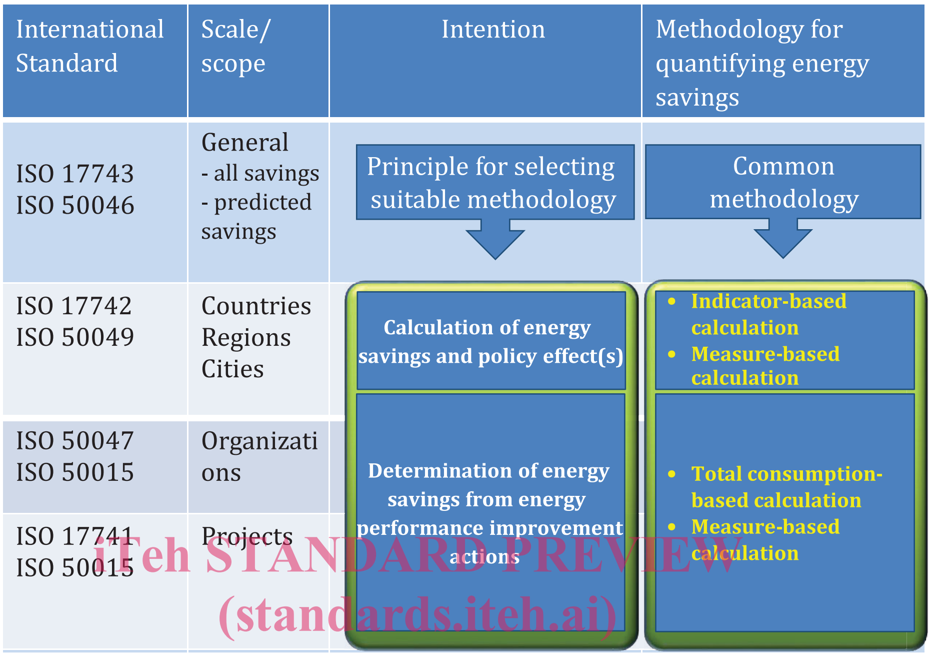


Figure 1 — Relationship between documents

The document covers more precisely three types of calculation methods based on energy efficiency indicators. Compared to ISO 17742, it details more advanced methodologies that facilitate a more comprehensive understanding of changes in: a) energy intensity, b) energy efficiency and, finally, c) energy consumption. The evaluation of energy efficiency trends relies on the calculation of energy efficiency indices. Variations in energy consumption are explained from a decomposition into different explanatory factors, one of which being energy savings. Therefore, this document complements ISO 17742 on energy savings calculation methods. More specifically, it complements how ISO 17742 deals with indicator-based methods. For each calculation method, examples of specific calculations are presented separately in Annexes A to C.

When applying this document, the user can choose between different options of the methods proposed. In order to be transparent in the way results have been obtained, the user of this document should specify the methodology used when presenting the results.

The general methodologies to evaluate trends in energy intensity, energy efficiency and energy consumption and its link to energy savings are presented in Clause 4. The calculation of the influence of structural changes in the energy intensity variation is described in Clause 5. The calculation method for the energy efficiency index is described in Clause 6. Finally, the method of decomposition of the energy consumption is given in Clause 7. Annexes A to C provide examples to illustrate various types of calculations. Annex D presents the methodology of climatic corrections, as most of these calculations should be done with energy efficiency indicators adjusted to a normal climate.

Calculation methods for energy efficiency and energy consumption variations at country, region and city levels

1 Scope

This document gives guidelines for methods for analysing changes in energy efficiency and energy consumption, and for measuring energy efficiency progress, for countries, regions and cities. It is composed of three different calculation methods:

— evaluation of structure effects in the variation of energy intensity;

— calculation of energy efficiency indices;

— decomposition analysis of energy consumption variation.

This document is applicable to providing an aggregated statistical evaluation for a country, region or city. It does not apply to calculating changes in the energy consumption or in energy efficiency at the individual consumer's level (e.g. households, organizations, companies).

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

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

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

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

3.1
activity factor
variation in the energy consumption levels of a sector or subsector due to the variation of the activity of the sector for a given period

Note 1 to entry: The quantification of this factor depends on the driver used to measure the activity.

3.2
apparent energy efficiency improvement
increase in *energy efficiency* (3.5) without correction or adjustment (i.e. gross value resulting from a calculation)

3.3
base year
reference year in the calculation

Note 1 to entry: It is usually the first year of calculation.

Note 2 to entry: The year can be calendar or fiscal. All data should have the same definition of year, whether calendar or fiscal.

3.4
behavioural factor
factor that shows the impact on the variation of energy consumption or on an energy indicator of changes in the behaviour of consumers

EXAMPLE Change in the level of thermal comfort with a higher or lower use of heating or air cooling equipment.

3.5
energy efficiency
ratio or other quantitative relationship between an output of performance, service, goods, commodities or energy and an input of energy

[SOURCE: ISO/IEC 13273-1:2015, 3.4.1, modified — The symbol has been deleted and "commodities" has been added.]

3.6
energy efficiency improvement
increase in *energy efficiency* (3.5) as a result of technological, behavioural and/or economic changes

[SOURCE: ISO/IEC 13273-1:2015, 3.4.3, modified — "technological, behavioural and/or economic changes" has replaced "technological, design, behavioural or economic changes".]

3.7
energy efficiency index
index measuring the increase in *energy efficiency* (3.5) compared to a *base year* (3.3)

EXAMPLE 100 for base year.

3.8
energy intensity
quotient describing the total energy consumption per unit of economic output

Note 1 to entry: The economic output should be measured at a constant price.

Note 2 to entry: The intensity can be interpreted as the amount of energy required to produce one unit of activity expressed in monetary terms (GDP or value added).

Note 3 to entry: The intensity can also be used at sector level (e.g. industry, residential, services). In that case, it is often referred to as "sectoral energy intensity".

Note 4 to entry: The term "energy intensity" is sometimes used with the same meaning as *specific energy consumption* (3.17), but this is not the case in this document.

[SOURCE: ISO/IEC 13273-1:2015, 3.1.14, modified — The example has been deleted and Notes 1, 2, 3 and 4 to entry have been added.]

3.9
energy savings
reduction of energy consumption compared to an energy baseline at same level of service

Note 1 to entry: Energy savings are positive when they reduce consumption. Due to some external factors that cannot be accounted for, consumption can increase instead of decrease: this phenomenon is referred to as "negative energy savings".

3.10
energy use
application of energy

EXAMPLE Ventilation; lighting; heating; cooling; transportation; data storage; production process.

Note 1 to entry: Energy use is sometimes referred to as "energy end-use".

[SOURCE: ISO 50001:2018, 3.5.4]

3.11
energy using system
physical items with defined system boundaries, using energy

EXAMPLE Plant, process, building, machines, equipment, product.

[SOURCE: ISO 50047:2016, 3.1, modified — The example has been replaced.]

3.12
explanatory factor
factor explaining the variation in an indicator or in the energy consumption

Note 1 to entry: It is different from the concept of "relevant variable" as defined in other standards as a "quantifiable factor that impacts energy performance and routinely changes" (e.g. ISO 50006:2014, 3.14). "Relevant variable" is more related to the performance of an *energy using system* (3.11), whereas "explanatory factor" relates to a sector and to both its consumption and performance. "Relevant variable" is more a micro concept, whereas "explanatory factor" is a macro concept.

3.13
final energy
energy as delivered to an *energy using system* (3.11)

Note 1 to entry: This concept is sometimes referred to as "delivered energy".

[SOURCE: ISO/IEC 13273-1:2015, 3.1.11, modified — Note 2 to entry has been deleted.]

3.14
fuel substitution factor
factor that shows the impact of fuel substitutions between types of energy with very different end-use efficiency on the variation of an energy indicator

3.15
indicator-based savings
energy savings (3.9) calculated by *indicator-based methods* (3.16)

[SOURCE: ISO 17742:2015, 2.28]

3.16
indicator-based method
determination of *energy savings* (3.9) from the variation of energy consumption indicators over a period

[SOURCE: ISO 17742:2015, 2.27, modified — The example has been deleted.]

3.17
specific energy consumption
quotient describing the total energy consumption per unit of output or service

EXAMPLE Gigajoule (GJ) per ton of steel, annual kilowatt-hour (kWh) per square meter (m^2), litres of fuel per 100 kilometre (km).

[SOURCE: ISO/IEC 13273-1:2015, 3.1.15]

3.18
structure effect
structural effect
measure of the variation in energy consumption or in *energy intensity* (3.8) due to a variation in economic structures

Note 1 to entry: Structure effects may refer more generally to any changes in the share of different activities (e.g. industrial branches in total value added of industry, transport modes in total traffic).

Note 2 to entry: “Hidden structure effect” refers to structure effects that exist but cannot be quantified due to a lack of data.

4 Factors to be calculated

4.1 General

4.1.1 Overview of methods included in the document

This clause is an introduction to Clauses 5, 6 and 7 on methods to assess energy intensity and energy efficiency trends and to analyse the energy consumption variation. It describes common issues, such as the different explanatory factors that need to be considered in these assessments (case of energy intensity and energy consumption) or excluded to measure energy efficiency improvements and the various ways to calculate them. This clause clarifies what kind of explanatory factors are covered in this document.

Explanatory factors of changes in energy intensity or in energy consumption and energy efficiency trends are calculated for a given period of time, normally one or more calendar years. The methods make use of statistical data and are normally applied to calculate explanatory factors, such as energy savings or energy efficiency improvements made during the past years. However, if a comparable set of data is available such as projections, e.g. from an energy scenario outlook, the methods can be applied for future years.

This document refers to the so-called “top-down” method of calculating energy savings as reported in ISO 17742 and ISO 17743, based on statistical energy efficiency indicators. The first and third methods analyse observed trends in energy intensity indicators (see Clause 5) and in energy consumption (see Clause 7) through the identification of some of the explanatory factors behind these trends. The second method (see Clause 6) proposes an energy efficiency index that is as far as possible corrected for factors that are not linked to energy efficiency.

4.1.2 Objectives of calculations

The main objective of this document is to help monitor energy efficiency targets, on energy intensity, on energy consumption or on energy efficiency improvements. More generally, this document can help to understand variations observed in energy intensity and energy consumption. It is critical for the analysis presented in this document to be useful that these objects of the analysis be carefully specified to align with the policy questions the analysis will inform. Mis-specifying the analytic objects can undermine the usefulness of the analytic framework presented in this document. For examples, see 4.2.4.

The target on energy intensity reduction used to be the most popular target linked to energy efficiency policy[9], as it is simple to define and to monitor. Separating structure effects can help in understanding the distance to the target and why targets are not reached. However, the scope of energy efficiency target is now broader and includes targets on energy savings, energy consumption and energy efficiency progress.

If targets on total primary or final energy consumption have been formulated, understanding the factors behind the observed variation in the energy consumption is useful each time there is a deviation as compared to the target.

EXAMPLE Annex XIV of Article 24 of the EU Energy Efficiency Directive requires that “in sectors where energy consumption remains stable or is growing, Member States shall analyse the reasons for it and attach their appraisal”.

The methodology proposed in this document can be used to fulfil such a reporting requirement. More generally, it allows evaluating the contribution of energy savings in the variation of energy consumption.

Policymakers often formulate targets for energy efficiency improvements but lack instruments to measure them. Energy efficiency indices help in formulating and monitoring such targets. In general, they provide a quantitative assessment of the magnitude of energy efficiency improvements.

4.1.3 Types of explanatory factors to be calculated

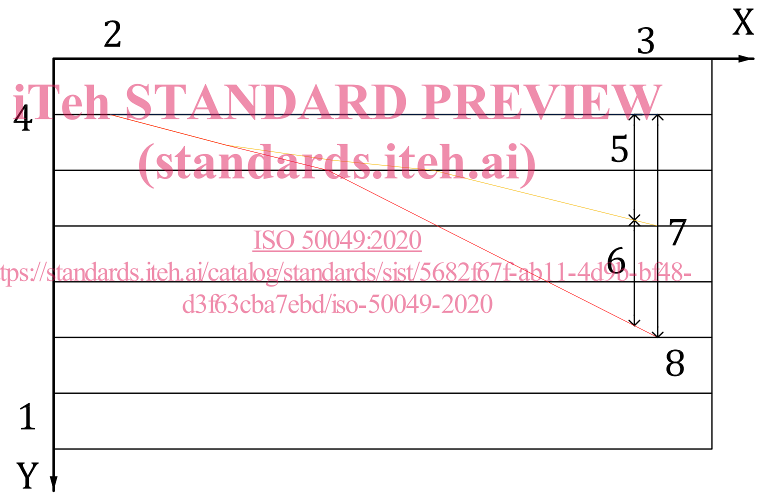
4.1.3.1 General

The three methods have in common to either quantify the effect of structure effects or to remove them as far as possible to assess energy efficiency trends.

4.1.3.2 Energy intensity

Energy intensity trends are influenced by changes in the structure of economic activities (e.g. increase in the share of the service sector in the GDP or of energy intensive branches in industry), as well as by other factors. These other factors include many influences, such as energy efficiency improvements, but also other effects (e.g. modal shift in transport, change in the mix of product/process in industry, changes in ownership of household equipment, climatic changes).

The relationship between energy intensity trends and structure effects is shown in Figure 2. Key 2 represents energy intensity in the base year. If everything is kept constant, the energy intensity will be constant up to the calculation year (Key 3). In reality, the energy intensity has decreased up to the calculation year (Key 8) because of two effects: changes in the structure of economic activities, called the "structure effect" (Key 5), and changes in the energy intensity of subsectors, mainly linked to energy efficiency improvements, called the "energy intensity effect" (Key 6).



Key

X year

Y energy intensity

1 unit of the energy intensity (e.g. MJ/$ at constant price)

2 base year

3 calculation year

4 energy intensity at base year

5 structure effect of the observed energy intensity

6 energy intensity effect

7 observed change in energy intensity

8 observed value of energy intensity at calculation year

Figure 2 — Trends in energy intensity and structure effect

4.1.3.3 Energy consumption variation

Variations in energy consumption result from the effects of three main factors: activity, structure effect and energy savings, and possibly of some less important factors.

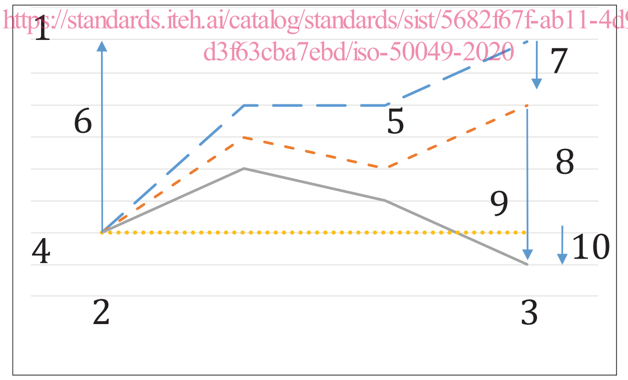
The activity factor corresponds to the impact of variations in socio-economic activities (e.g. number of households, production of industrial branches, equipment ownership, the traffic of goods and passengers) on the energy consumption variation.

The structure effect factor measures the impact of changes in the composition of economic activities at the macro level (i.e. in GDP structure), but also among various energy consuming activities (e.g. share of energy intensive industries, share of branches in the service sector, share of road transport in total freight transport, share of public transport in total passenger transport) on the energy consumption variation.

The energy savings factor measures the impact of decreases in specific consumption at end-use level on energy consumption.

The relationship between energy consumption trends and these three factors is shown in Figure 3. Key 4 represents energy consumption in the base year. If everything is kept constant, the energy consumption will be constant up to the year of calculation (Key 3). However, changes in activities will lead to a variation of energy consumption (uppermost line, Key 5). The increase in consumption for the calculation year from Key 4 to Key 5 is the activity factor (Key 6).

The structure effect is shown by Key 7. However, this structure effect can also raise energy consumption, e.g. through more intensive use of energy using devices (not shown here). Energy savings by definition lower energy consumption (Key 8). Together the three factors define the actual trend for energy consumption (Key 9). Figure 3 shows an increase in energy consumption compared to the base year (Key 10). The actual energy consumption can, however, also decrease, e.g. in the case of a small increase for activities, a mitigating structure effect and large energy savings (right side of Figure 3).



Key

1 energy consumption (unit)
2 base year
3 calculation year
4 energy consumption base year
5 energy trend due to socio-economic activities
6 activity factor
7 structure effect
8 total savings
9 actual energy consumption
10 observed change in energy consumption

Figure 3 — Trends for energy consumption and explanatory factors

4.1.3.4 Energy efficiency indices

Energy efficiency indices are indicators that measure energy efficiency trends. To be relevant, these indicators should be adjusted as much as possible for factors that are not linked to energy efficiency improvements, such as structure effects, but also other factors (e.g. change in equipment ownership, usage or type for households). This is done by calculating these indices at the most disaggregated level as possible to eliminate the most important structure effects.

4.2 Indicators, methods and applications

4.2.1 Indicators

The methods presented in this document rely on energy efficiency indicators that relate energy consumption to a driver, which is a quantity that is assumed to influence the energy consumption under consideration. The change in the indicator value is used to calculate the total energy savings or changes in energy efficiency (see Clause 5 and the examples in Annex B).

At an aggregated level, the indicator usually considered to assess energy efficiency is the energy intensity that relates the energy consumption (in GJ, toe, etc) to the GDP (in Euro, $, Yen, etc). The change in the total energy intensity (e.g. in GJ/monetary unit) does not provide a reliable estimate of energy efficiency improvements or energy savings, as it is influenced by developments at sector or subsector level that can deviate from the GDP trend. Therefore, indicators have to be applied at the level of subsectors or even energy uses, such as space heating in dwellings.

The indicators at the lower aggregation level relate energy consumption to an explanatory factor that is responsible for changes in this consumption. In indicator-based methods, energy savings or energy efficiency trends are calculated from changes in indicator values that are defined against the value in the base year (see ISO 17742).

EXAMPLE If in a country the average annual consumption of refrigerators owned by households has decreased from 500 kWh to 400 kWh between 2000 and 2015, i.e. by 20 % (400/500 – 1 × 100), it is considered that energy efficiency improved by 20 % for refrigerators in that country between 2000 and 2015. If the number of refrigerators is equal to 1,5 million in 2015, the amount of energy saved is equal to 1,5 × 10^6 × 100 kWh or 150 GWh.

This approach, with disaggregation of national energy consumption to a level where meaningful energy efficiency indicators can be defined, is called “top-down”. Known applications are the indicators from the EU database Odyssee[7], the IEA indicators[8][18] or other projects and databases (e.g. WEC[9], BIEE for Latin American and Caribbean countries[10], Medener for Mediterranean countries[11] or APERC for APEC economies[18]).

As explained in ISO 17742, changes in indicator value can be due to policy measures, technological trends, high energy prices or other factors. Therefore, the calculated savings or energy efficiency improvements concern total savings or total energy efficiency improvements.

Energy efficiency indicators are generally based on statistical data measured at a disaggregated level, e.g. energy consumption and production in subsectors of industry, or total fuel use of cars and the distance driven by the cars.

4.2.2 Types of data used

The following types of data are used:

a) statistical data;

b) detailed data from surveys or modelling.

Statistical data include final energy consumption by sector as well as macro-economic or sectoral data, such as GDP, the number of households, employment in services, production by industrial sector (value added or physical production). Depending on the geographic entities (country, region or city) not all aggregated statistical data are available: they are generally available at country level but at regional and, above all, at city levels, macro-economic or sectoral data are not usually readily available.

