
**Energy efficiency and savings
calculation for countries, regions and
cities**

*Calcul de l'efficacité énergétique et des économies d'énergie pour les
pays, villes et régions*

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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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT), see the following URL: [Foreword — Supplementary information](#).

The committee responsible for this document is ISO/TC 257, *Evaluation of energy savings*.

Introduction

Due to the recognized role of savings in international climate and energy policy, e.g. expressed by International Energy Agency,^[9] there is a need for harmonized methods at the international level. In addition, many countries that have formulated policies and targets have a need for evaluating the energy savings achieved, or the impact of implemented policies, and need these calculation methods as well.

This International Standard concerns savings at the level of countries, regions, and cities. The practical application can be different due to specific restrictions, such as the availability of data at lower levels.

This International Standard is meant to calculate both realized savings (ex-post evaluation) as well as expected savings (ex-ante evaluation). The latter is only possible if detailed data on future energy developments is available.

This International Standard can be used by any stakeholder (decision makers, companies, NGO, etc.) that wants to quantify the energy savings over a specific period.

This International Standard is part of a set of International Standards developed in TC 257 (see [Figure 1](#)) and builds on the general principles outlined in ISO 17743, including reporting and system boundaries.

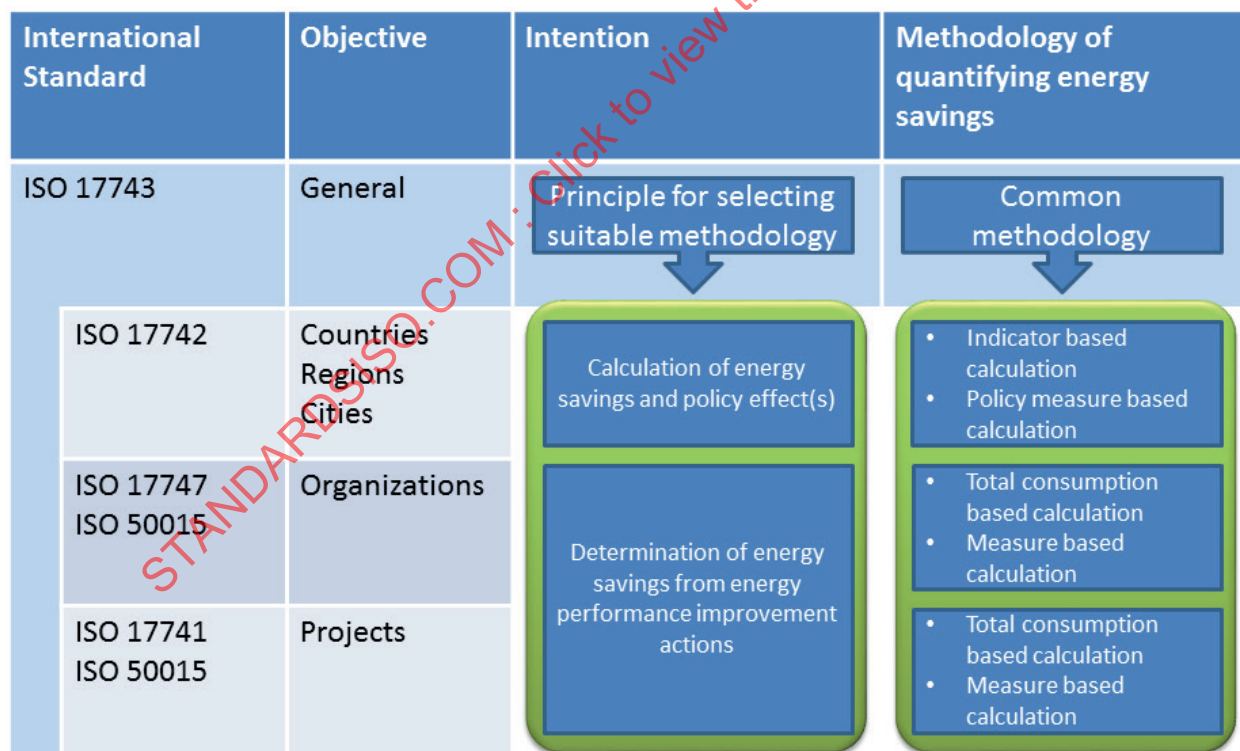


Figure 1 — Work programme of ISO/TC 257

This International Standard covers both indicator-based and measure-based calculation methods. The indicator method is based on energy indicators (e.g. mean gas consumption per dwelling) which are

often calculated from statistical data. The measure-based method considers the saving effect of policy measures or measures taken by other stakeholders to enhance energy efficiency.

The indicator-based and measure-based calculation methods are presented as two separate calculation methods. Using a combination of indicator-based and measure-based methods is not part of this International Standard. However, the differences and application of both methods are highlighted.

This International Standard provides a general framework for calculating energy savings. For the indicator-based methods, examples of specific calculations per indicator are presented separately in [Annex A](#).

When applying this International Standard, the user can choose between different variants of the indicator- or measure-based method. In order to be transparent on the way results have been obtained, the user of this International Standard has to specify the variant used when presenting the results.

In order to ensure the credibility of the results, all savings calculations have to be documented to the point of allowing them to be duplicated or reproduced by an independent analyst. The requirements are specified in detail when this International Standard is elaborated for concrete calculation applications (see also ISO 17743).

The energy-saving types to be calculated, and the characteristics of the indicator-based and measure-based methods, are presented in [Clause 3](#). The standard on the indicator-based calculation method is described in [Clause 4](#) and that on the measure-based calculation methods in [Clause 5](#). [Annex A](#) provides some example indicators that can be used in indicator-based calculations. [Annex B](#) shows the levels of detail at which measure-based methods can be applied.

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Energy efficiency and savings calculation for countries, regions and cities

1 Scope

This International Standard provides a general approach for energy efficiency and energy savings calculations with indicator-based and measure-based methods for the geographical entities countries, regions, and cities.

This International Standard considers all end-use sectors, such as households, industry, tertiary (services, etc.), agriculture, and transport. It does not incorporate calculation of energy efficiency and energy savings in energy supply sectors, such as power plants, refineries, and coal mines.

Energy consumption does not include feedstock energy, such as oil products for the production of plastics.

This International Standard is not intended to be used for calculating energy savings of individual households, organizations, companies, or other end users.

Energy from renewable energy sources “behind-the-meter” (e.g. from solar water heating panels) decreases the amount of supplied energy and can be part of the calculated energy savings. Users of this International Standard should be aware that this energy from renewable energy sources behind-the-meter can also be claimed as part of the total energy from renewable sources.

2 Terms and definitions

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

2.1

adjustment factor

quantifiable parameter affecting energy consumption

Note 1 to entry: In this International Standard, adjustment factors for indicator-based methods are restricted to corrections for variations in weather conditions.

Note 2 to entry: In this International Standard, adjustment factors for measure-based methods include production throughput, weather conditions, working hours, behaviour related parameters (e.g. indoor temperature and light level), etc.

Note 3 to entry: Factors at high aggregation level that affect the savings attributed to policies or programs (e.g. free rider effect or rebound effect) are not part of the adjustment factors.

[SOURCE: ISO 17743, modified — with notes instead of examples.]

2.2

city

geographical area under control of a municipal administration

Note 1 to entry: The municipal administration is subject to provincial and national governance.

2.3

country

geographical area under control of a national government

Note 1 to entry: According to the definition of the UN Statistical Office.

2.4

deemed savings

default value for unitary energy savings, estimated and/or agreed to by stakeholders

Note 1 to entry: The default value can be based on available measurements or calculations.

2.5

diffusion indicator

indicator showing the penetration of energy-saving devices, systems, or practices

EXAMPLE Number of solar water heaters, efficient lamps or electrical appliances with a label A+ or A++, fraction of passenger transport by public modes, or transport of goods by rail and water.

2.6

double counting

counting the savings for a combination of facilitating measures, focusing on the same end-user action, as the sum of what would be saved by each measure alone, when the combined savings is less than the sum

Note 1 to entry: In this International Standard, double counting is not valid for elementary units of action (e.g. the saving effect of insulation and high efficiency boiler) where it is termed technical interaction.

Note 2 to entry: In this International Standard, double counting is used for calculation at high aggregation level (e.g. all dwellings), while the term consequential effects can be used at lower aggregation level (e.g. individual company) in other International Standards.

[SOURCE: CEN 16212, modified — definition adapted.]

2.7

driver

quantity that is assumed to predominantly influence the level of energy consumption under consideration in indicator-based methods

Note 1 to entry: A driver can be an activity (e.g. production) but also a property of a system (e.g. amount of floor space).

2.8

elementary unit of action

entity for which unitary energy savings can be defined and summed up

Note 1 to entry: Generally, it relates to an energy using system or a participant in an energy savings programme.

2.9

end-user action

energy efficiency improvement measure implemented on the site of an end user

2.10

energy baseline

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

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

Note 2 to entry: An energy baseline can be adjusted using variables affecting energy use and/or consumption such as production level, degree days (outdoor temperature), etc.

Note 3 to entry: With respect to energy performance, the definition for this International Standard only concerns energy efficiency.

[SOURCE: ISO/IEC 13273-1, 3.3.10, modified — adapted notes.]

2.11**energy carrier**

substance or phenomenon that can be used to produce mechanical work or heat or to operate a process

EXAMPLE Electricity, hydrogen, and automotive fuels that can be used by energy using systems.

[SOURCE: ISO/IEC 13273-1, 3.1.2, modified — without note.]

2.12**energy consumption**

quantity of energy applied

Note 1 to entry: The unit of energy consumption can be expressed related to the involved energy carrier but also in the standard unit for energy, Joule.

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

2.13**energy consumption in final units**

final energy when energy carriers are counted according to their energy content

Note 1 to entry: The energy content values can be taken from energy statistics where they are applied to sum up the energy consumption of different energy carriers.

2.14**energy consumption in primary units**

final energy when energy carriers are counted according to the energy consumption needed to deliver them to the end users

Note 1 to entry: For instance, the consumption of electricity is multiplied with a factor of 2,5 when the conversion of fuels to electricity has an efficiency of 40 %.

Note 2 to entry: In this way, it is possible to account for the fact that savings on final energy consumption can also reduce transformation losses in the energy supply system.

2.15**energy efficiency**

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

EXAMPLE Energy conversion efficiency; energy required/energy used; output/input; theoretical energy used to operate/energy used to operate.

[SOURCE: ISO/IEC 13273-1, 3.4.1, modified — without notes.]

2.16**energy efficiency improvement**

increase in energy efficiency as a result of technological, design, behavioural, and/or economic changes

[SOURCE: ISO/IEC 13273-1, 3.4.3]

2.17**energy efficiency improvement measure**

action normally leading to an energy efficiency improvement which can be verified, measured or estimated

Note 1 to entry: Measure encompasses both end-user action and facilitating measure.

2.18

energy end user

individual or a group of individuals or organization with responsibility for operating an energy using system

Note 1 to entry: The energy end user can differ from the customer who might purchase the energy but does not necessarily use it.

[SOURCE: ISO/IEC 13273-1, 3.1.12]

2.19

energy savings

reduction of energy consumption compared to an energy baseline

Note 1 to entry: Energy savings can be realized or expected.

Note 2 to entry: Energy savings can be the result of implementation of an action(s) or of autonomous progress.

[SOURCE: ISO/IEC 13273-1, 3.3.11, last part of definition and notes adapted]

2.20

energy use

manner or kind of application of energy

Note 1 to entry: Characteristics of energy use include, but are not limited to, the purpose of the use, source(s) choice, and application.

[SOURCE: ISO/IEC 13273-1, 3.1.14]

2.21

energy using system

physical item with defined system boundaries, using energy

Note 1 to entry: An energy using system can be one or many plants, processes, parts of a process, buildings, parts of a building, machines, equipment, products, etc.

[SOURCE: ISO/IEC 13273-1, 3.1.11]

2.22

facilitating measure

energy efficiency service or an improvement programme offered to an energy end user

Note 1 to entry: A facilitating measure is offered by a stakeholder that is not the energy end user.

EXAMPLE A subsidy scheme for insulation of dwellings or a label on the efficiency of appliances.

2.23

feedstock energy

energy of raw materials which is used for non-energy purposes

EXAMPLE Oil for producing plastics and natural gas for producing fertilizers.

[SOURCE: ISO/IEC 13273-1, 3.1.3, modified — adapted example.]

2.24

final energy

energy as delivered to the energy using system

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

[SOURCE: ISO/IEC 13273-1, 3.1.13]

2.25**free rider effect**

provision of financial incentives for saving measures to end users who would have taken the measures anyway

EXAMPLE Savings arising from subsidies, or tax reductions, provided to end users that would have taken the measures anyway.

Note 1 to entry: The free rider effect can be estimated through, for example, a comparison with energy savings realized in similar circumstances but without the subsidy scheme.

2.26**gross energy savings**

energy savings using adjustment factors, but except correction for double counting, multiplier effect, free riders, and rebound effect

Note 1 to entry: Gross energy savings include adjustment factors mentioned in [2.1](#).

2.27**indicator-based method**

determination of energy savings from the variation of energy consumption indicators over a period

EXAMPLE For industry, a decrease in energy consumption per tonne of steel is accounted for as savings.

2.28**indicator-based savings**

energy savings calculated with indicator-based methods

2.29**measure-based method**

determination of energy savings from end-user actions using unitary energy savings and elementary units of action

Note 1 to entry: If end-user actions are due to facilitating measures, such as policy, the measure-based methods consider savings due to policy.

EXAMPLE In case of a subsidy scheme for boilers in households, the savings are calculated from the average savings per boiler (compared to a chosen reference boiler) times the number of subsidized boilers (corrected for free riders that apply for subsidy but would have installed the efficient boiler anyway).

2.30**measure-based savings**

energy savings calculated with measure-based methods

2.31**multiplier effect**

effect of a facilitating measure after the measure has ended or in fields outside the focus

EXAMPLE Temporarily promotion of efficient appliances changes the market for these appliances in such a way that further penetration occurs after ending the promotion activity.

Note 1 to entry: In the standard, the multiplier effect is used for calculations at high aggregation level (e.g. all dwellings), while the term consequential effects can be used at lower aggregation level (e.g. individual company) in other standards.

2.32**net energy savings**

energy savings with use of the adjustment factor(s) and, if relevant, correction factors for double counting, multiplier effect, free riders and rebound effect

2.33

rebound effect

change in energy using behaviour that yields an increased level of service and that occurs as a result of taking an end-use action

EXAMPLE Some households can take some of the benefits of energy efficiency improvements to their home in the form of higher internal temperatures, and so use more energy than might be calculated from the end-user action.

Note 1 to entry: The rebound effect can take many forms. Apart from the case in the example (higher internal temperature setting) the effect is often difficult to determine.

2.34

region

geographical area with the ability to influence energy savings, not being a city or a country

2.35

saving lifetime

number of years for which savings of end-user actions remain present

Note 1 to entry: The savings lifetime can take into account deterioration of yearly savings.

EXAMPLE See list of specified lifetimes in Annex of Reference [8].

2.36

specific energy consumption

quotient describing the total amount of energy necessary to generate a unit of output, activity, economic value, or service

EXAMPLE Gigajoule (GJ) per ton of steel, annual kilowatt hour (kWh) per square meter (m²), litres of fuel per kilometre (km), etc.

[SOURCE: ISO/IEC 13273-1, 3.1.17]

2.37

structure effect

changes in activities or characteristics of energy using systems that affect energy consumption, not being energy savings

EXAMPLE Intensity of use for appliances, occupation rate for buildings, and shift in between sectors for industry.

Note 1 to entry: The actual form of the structure effects differs for the various aggregation levels in calculations (country, sector, organization, building, etc.).

Note 2 to entry: For the indicator-based method, the effect of the driver on energy consumption is, by definition, not part of the structure effect.

Note 3 to entry: For the measure-based method, the demarcation between structure effect and savings can be dependent on formulating policy as savings measure or another measure (e.g. speed limits for traffic to avoid accidents or to save petrol).

2.38

system boundary

physical or site limits as defined for a stated purpose

EXAMPLE A process; a site; an organization; a city, a region, or a country.

Note 1 to entry: The stated purpose could be for a management system, or for a savings program with a given national, regional, or local scope.

[SOURCE: ISO/IEC 13273-1, 3.3.2, modified — example with extended scope, notes adapted.]

2.39**technical interaction**

relation of the elementary unit of action to the surrounding technical system, or to other elementary units of action, which influences the unitary energy savings

Note 1 to entry: In case of technical interaction between two elementary units of action, both energy savings cannot be simply summed up.

EXAMPLE The combination of thermal insulation and a new efficient boiler where the combined savings are smaller than the sum of the savings for each unit of action apart.

2.40**unitary energy savings**

calculated energy savings per elementary unit of action

Note 1 to entry: Also called “unitary gross annual energy savings”. Gross depicts that corrections can be made.

3 Savings to be calculated**3.1 General**

This Clause is an introduction to [Clauses 4](#) and [5](#) on indicator-based and measure-based methods. It describes common issues, such as the need for differently defined energy savings and the various ways to calculate them. This should clarify what kind of savings the standards for indicator-based and measure-based calculation methods provide.

The indicator-based method considers observed trends for energy consumption and the drivers behind these trends, normally at an aggregated level. Therefore, it is sometimes called top-down method, e.g. in Reference [\[12\]](#).

The measure-based method considers the saving effect of measures, i.e. end-user actions taken, or the facilitating measures enabling them. Because of the focus on specific measures, it is sometimes referred to as bottom-up method, e.g. in Reference [\[12\]](#).

Savings are calculated for a period of time, normally one or more calendar years. A distinction can be made between past years or future years.

The indicator-based method makes use of statistical data and is normally restricted to calculating realized savings in past years. However, if a comparable set of data are available, e.g. from an energy scenario study, the method can be applied for future years.

The measure-based method can apply to observed as well as estimated data and can calculate realized savings for past years as well as expected savings for future years.

3.2 Types of savings to be calculated**3.2.1 Energy savings as part of energy consumption development**

Energy consumption trends are defined by:

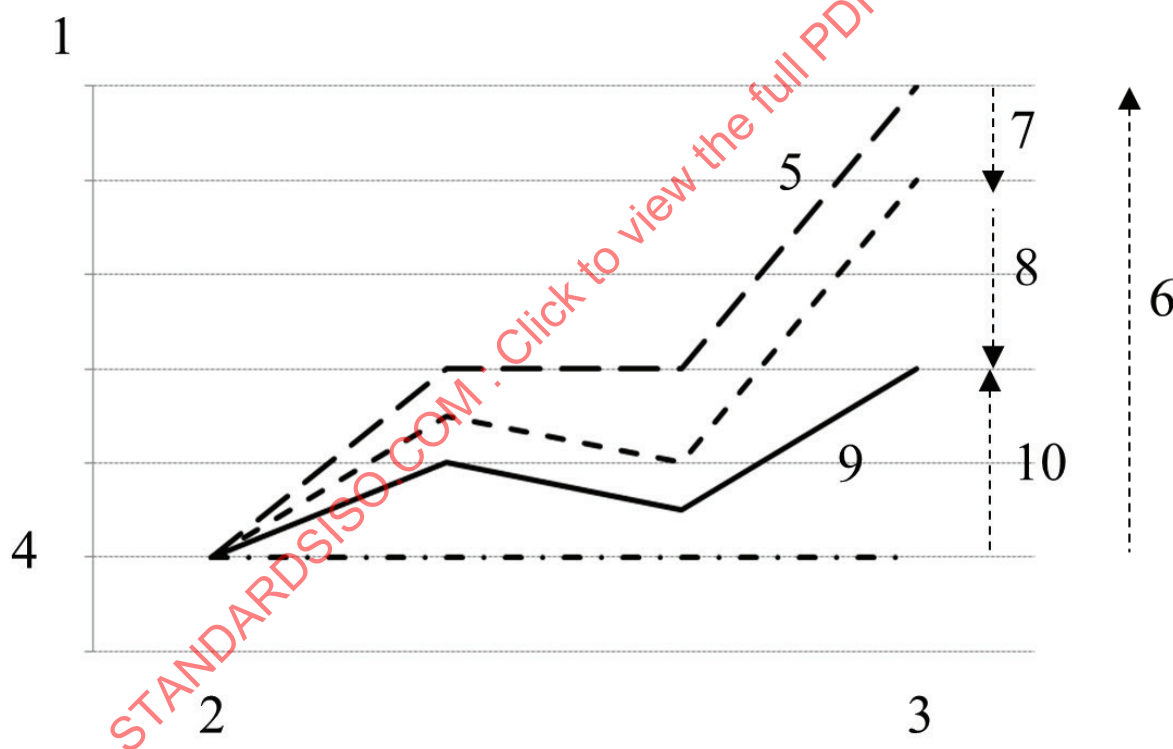
- volume effect: increase or decrease of socio-economic activities;
- structure effect: changes in the composition of the activities;
- energy savings.

The relation between energy consumption trends and the three effects is shown in [Figure 2](#). The explanation following the keys goes as follows.

Key 4 represents energy consumption in the base year. If everything keeps the same, energy consumption is constant up to the year of calculation. But due to changes in activities, energy consumption changes as well (uppermost line, Key 5). The increase for the calculation year is the volume effect (Key 6). At the national level, this can be a trend according to the GDP growth. At the levels of sectors, the volume effect can regard the number of households, the production of industry, or the amount of transported goods.

Changes in the type of activities can influence energy trends, e.g. a lagging growth of energy intensive industry or saturation for ownership of cars. This is called the structure effect (Key 7). However, the structure effect can also stimulate 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 2](#) shows an increase in energy consumption compared to the base year (Key 10). But the actual energy consumption can also decrease, e.g. in case of a small increase for activities, a mitigating structure effect, and large energy savings.

In summary, energy savings is the difference between energy consumed in the calculation year and energy consumed in the base year adjusted for the volume effect (increase or decrease in socio-economic activities) and the structure effect (changes in the composition of energy using activities).



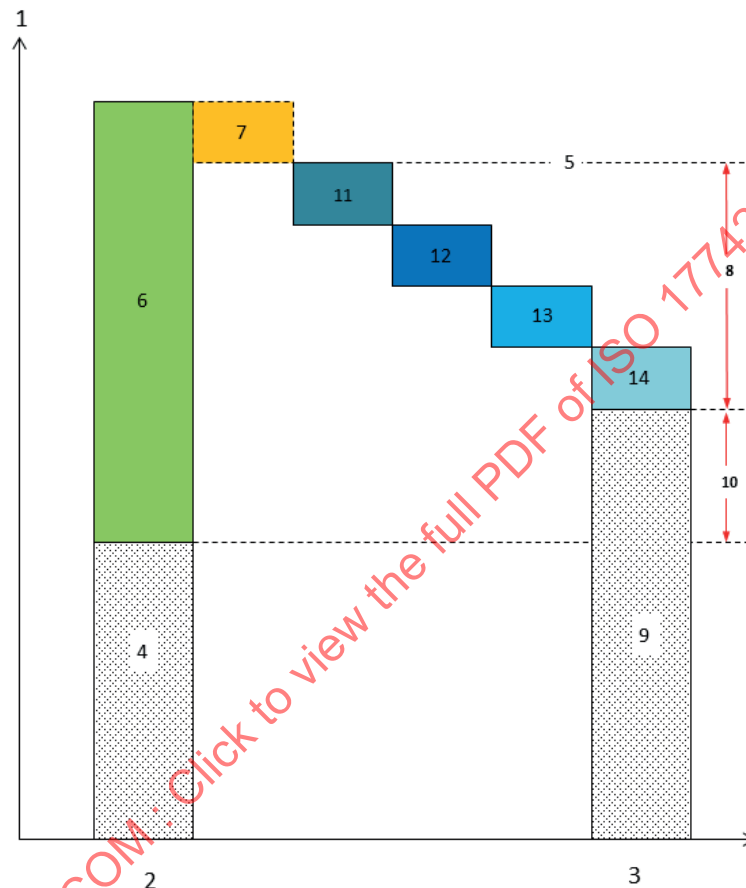
Key

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

Figure 2 — Trends for energy consumption and adjacent energy savings

3.2.2 Contributions to change of various types of energy savings

Figure 3 shows how the change in energy consumption over a period (Key 10) can be split into different contributions. The base year energy consumption (Key 2) changes due to volume effect (Key 6), structure effect (Key 7), and total savings (Key 8), resulting in the actual energy consumption (Key 9) for the calculation year.



Key

- | | | | |
|---|---|----|--|
| 1 | energy consumption (unit) | 8 | total savings |
| 2 | base year | 9 | energy consumption in calculation year |
| 3 | calculation year | 10 | observed change energy consumption |
| 4 | energy consumption in base year | 11 | autonomous savings |
| 5 | energy trend (due to socio-economic activities) | 12 | deliberate action savings |
| 6 | volume effect | 13 | policy direct savings |
| 7 | structure effect | 14 | policy indirect savings |

Figure 3 — Split of change in energy consumption including policy/deliberate savings

The total savings can be divided further into autonomous savings (Key 11), deliberate savings (Key 12), and direct or indirect policy savings (Keys 13 and 14).

Autonomous savings occur without a deliberate intervention to save energy, from either the users, themselves, or the policy makers. Technology might progress, even without any policy, e.g. introduction of hybrid vehicles, or production of base chemicals at lower temperature by using catalysts.

Savings due to policy measures are called policy-induced savings. These are important from the viewpoint of policy effectiveness (see [3.2.3.1](#)). Policy can have a direct result (Key 13), e.g. national standards about maximum energy consumption of appliances. Or it can have an indirect result (Key 14), for example requirements placed on other organizations (e.g. lowering of the speed limit implemented for safety reasons results in energy savings).

Other savings can be realized by stakeholders, such as socially responsible companies, non-governmental organizations (NGO), or cities on their own accord. These deliberate savings (Key 12) are neither autonomous nor policy induced. The deliberate and policy savings can overlap, e.g. because behavioural changes as to use of appliances have a smaller effect when appliances consume less electricity due to minimum efficiency standards. Therefore, the three saving effects do not add up to the overall effect.

When policy measures to stimulate savings are already in place for a long time, the demarcation between autonomous savings (Key 11) and policy/deliberate savings (Keys 12-14) can be difficult to determine.

3.2.3 Savings types for different cases

The type of savings to be calculated depends on

- the purpose of the calculations,
- the type of measure taken, and
- type of input data used.

3.2.3.1 Purpose of savings calculations

In the field of monitoring and evaluation, distinctive purposes are recognized: the evaluation of energy trends and the evaluation of policy/program effects.

a) Evaluation of energy trends

For given socio-economic developments, the total energy savings define the actual trend in energy consumption. Therefore, total savings are calculated to provide insight in energy consumption trends. If targets for total consumption have been formulated, calculations of realized savings are needed as part of the target evaluation (see Reference [\[10\]](#)).

b) Evaluation of energy-saving policy

At the level of countries, regions, or cities, policy makers often formulate targets for energy savings and introduce a set of facilitating measures, such as subsidies for efficient energy using systems, a savings program of an agency or an obligation for energy companies to save energy at their clients' premises. In order to define a target or introduce measures, an ex-ante evaluation is performed that shows expected policy savings. When policy makers want to check the actual effect of their facilitating measures, an ex-post evaluation is performed, where realized, policy savings are calculated to rate the effectiveness of policy.

Other stakeholders mentioned earlier can also take deliberate actions that provide extra savings beyond what should already be realized without the actions. For instance, as part of so-called bottom-up initiatives, (groups of) energy users save energy. In this case, savings are calculated as possible savings (ex-ante) and actual savings to check the results (ex-post). These program savings count to the policy/deliberate savings (see [Figure 3](#)).

3.2.3.2 Type of measures

Savings are the result of Energy Efficiency Improvement (EEI) measures that can have the following meanings:

- end-user action;
- facilitating measure.

End-user actions are energy efficiency improvement measures implemented by an energy user, e.g. installing a high-efficiency boiler replacing a less efficient boiler. The end-user actions can be of a physical, organizational, or behavioural nature. The actions can be stimulated by facilitating measures, such as subsidy schemes or voluntary agreements, but that is not always the case.

The savings from end-user actions are part of total savings. They can contribute to the policy/deliberate savings if they are not autonomously taken. Facilitating measures do not by themselves result (directly) in energy savings. Instead, they are targeted to the implementation of end-user actions that would not have taken place without the facilitating measure, e.g. a subsidy programme for households. The savings effect of a facilitating measure becomes visible in the form of end-user actions and their effect on energy consumption.

The savings from facilitating measures are part of the policy/deliberate savings. In case of direct or indirect results of policy measures, it counts as policy savings. In case of initiatives by societal organizations (such as industry trade associations, environmental NGOs, or other private sector groups that may wish to influence energy consumption), it has to be decided whether the savings count as deliberate savings or as policy savings.

3.2.3.3 Type of data used

The following types of data are used:

- a) aggregated statistical data: for geographic entities (country, region, or city) aggregated statistical data are generally available: Gross Domestic Product (GDP), total number of households, total employment in services, total production in industrial sectors, etc. These data can be used to determine energy efficiency indicators, such as energy consumption per unit of GDP (in GJ per currency unit) or specific energy consumption per ton of steel (see [Annex A](#) and Reference [3]). These indicators are used to calculate total savings (see [3.3.1](#));
- b) detailed data from surveys: detailed data from focused surveys are often needed for the calculation of savings of specific end-user action such as roof insulation for existing dwellings. In this case, the savings are calculated from the number (dwellings with the roof insulated) and the specific savings (savings per insulated roof). In case of specific facilitating measures, such as a subsidy for roof insulation, also the amount of subsidized roofs must be known. The calculated savings can be either total savings or policy/deliberate savings, depending on the energy baseline chosen (see [3.3.3](#)).

In savings calculations, data other than aggregated statistics or detailed data from surveys may also be used. These comprise specific statistical data, such as number of dwellings per type or floor space in offices, and the results of large surveys, such as on kilometres driven by car or ownership of appliances. The type of savings calculated depends on the calculation method (see [3.3](#)).

3.3 Methods, applications, and calculated savings

3.3.1 Indicator-based calculation method

The indicator-based method uses energy-indicators that relate energy consumption to a driver, a quantity that is assumed to define the energy consumption under consideration. The change in the indicator value can be used to calculate the total energy savings (see [Clause 4](#) and examples in [Annex A](#)).

At the national level, the indicator is used to express energy consumption per unit of GDP (Euro, \$, Yen, etc.). The change in the national GJ/unit value does not provide a reliable estimate of the savings, because it is influenced by developments for the sectors that depart from the national trend. Therefore, indicators per sector are to be applied. However, these indicators are also influenced by developments inside the sector. Therefore, indicators are defined at the level of subsectors or even targeted energy uses, such as space heating in dwellings.

The indicators at lower aggregation level relate energy consumption to a driver that is correlated to this consumption. For example, gas consumption for space heating is related to the number of dwellings. The decrease in the indicator “average gas use per dwelling” is used to calculate the savings for space heating energy consumption.

This approach, with disaggregation of national energy consumption to a level where meaningful savings indicators can be defined, is often called top-down. Known applications are the IEA indicators on energy savings^[10] and the indicators from the EU database Odyssee.^[3]

The change in indicator value can be due to policy measures, other initiatives, or a result of technological trends or high energy prices. Therefore, the calculated savings effect concerns total savings.

Indicators in the indicator-based approach generally relate to aggregates: total number of households, total employment in services, total production in industrial sectors, etc. Thus, the indicator-based approach is based on statistical data for geographical entities such as countries, regions, or cities. Sometimes figures at a more disaggregated level are used, e.g. energy consumption and production in subsectors of industry, or total fuel use of cars and the distance driven by the cars.

3.3.2 Hidden structure effects in the indicator-based method

In indicator-based methods, energy consumption is related to a driver at the lowest possible aggregation level. In this way, the most suitable driver can be found to explain changes in energy consumption.

However, even at a low aggregation level the energy consumption trend can incorporate the effect of so-called hidden structure effects which influence the calculation of savings. For instance, average gas consumption per dwelling can be influenced by changes in the type of dwellings or the occupation rate, and by replacement of room heating with central heating. For energy-intensive industry, energy consumption per ton of output can be influenced by the capacity utilization rate.

One way to eliminate some hidden structure effects is further disaggregation of energy consumption and relating it to a more closely correlated driver. For households, separate indicators can be defined per type of dwellings (detached or multi-family houses). For industry, the analysis can be done at the level of products (cement or steel) or by introducing a performance factor (see example A.3.2). Due to restricted data availability, it is not always possible to eliminate hidden structure effects. In that case, it is important to know whether these structure effects change rapidly. If they change only gradually, there is no distortion of calculated savings in the short run and they can be neglected.

3.3.3 Measure-based calculation method

The measure-based methods focus on cases like the following:

- a specific type of end-user action, e.g. installing high efficiency boilers replacing a less efficient boiler. The calculated savings are derived from the number of actions (penetration of high efficiency boilers) and the savings per action (efficient boiler). The type of savings depends on the way the penetration and specific savings are counted. If only extra effects due to facilitating measures are taken into account, the calculation provides policy/deliberate savings; with all effects counted the result concerns total savings. Often detailed survey data are needed for these calculations. Due to the focus at specific end-user actions or facilitating measures, which ask for detailed data at a low aggregation level, this approach is sometimes called bottom-up;
- policy evaluations where the focus is on specific facilitating measures, such as an audit scheme. The savings effect is the sum of the effects for the different end-user action types related to the facilitating measure (e.g. roof insulation advised in the audit). The savings per end-user action are

calculated as described above. Because it concerns only extra effects due to the facilitating measure, the sum over all end-user actions represents policy/deliberate savings;

- savings programme from non-government entities, such as energy companies. The program savings are the sum of the effects for the different end-user action types that are stimulated through the programme. The type of savings reported depends on the way the effects of end-user actions are counted. As described in the first case, the effect of the programme concerns total savings or deliberate savings depending on how effects are counted;
- targeted energy uses, such as “new dwellings”. The calculated savings are derived from the number of new dwellings and the savings per new dwelling. Here more than one facilitating measure and various types of end-user actions can play a role (e.g. regulation and energy taxes stimulating all types of insulation, boilers, and waste heat regeneration). Again, the calculated effect can concern total savings or policy/deliberate savings, depending on how observed effects are taken account of.

Measure-based calculations normally ask for detailed data, such as the number of subsidized boilers or the appliances sold in each label category. These data are mostly, but not necessarily, of a non-aggregate statistical nature.

3.3.4 Energy baseline and additional savings in the measure-based method

In measure-based calculations, a choice must be made how to deal with autonomous developments (see 3.2.2). More broadly formulated, it concerns the issue of the additionality of the savings of an EEI measure. In turn, additionality asks for the definition of an energy baseline that represents the situation in the absence of the measure.

In the example of a subsidy scheme for high efficiency boilers, the baseline can be the “normal” penetration trend of these boilers without subsidies. The additional number of high efficiency boilers is the difference between actual and baseline numbers.

For the specific savings per high efficiency boiler also a baseline is needed. This is the reference system against which the high efficiency boiler is compared, for instance the “generally installed” boiler type. The lower energy consumption compared to the baseline represents in this example the additional savings per high efficiency boiler.

Both the “normal” penetration level and the “generally installed” reference system can be debated. Different baseline can be defined; therefore, additional savings from measure-based calculations are highly dependent on baseline choices.

Depending on the chosen energy baselines the calculated savings can represent solely the effect of facilitating measures, but can also represent total savings. These issues are elaborated on in [Clause 5](#).

In indicator-based calculations, no distinction is made as to the cause of end-user actions. Therefore, the indicator-based methods in this International Standard do not need to specify baselines in order to calculate total savings. However, the base year has a role, because changes in indicator values are normally defined against the value in the base year. In this way the base year situation serves as an implicit baseline for indicator-based methods.

3.3.5 Aggregated results of indicator-based and measure-based methods

Indicator-based methods calculate savings for subsectors or targeted energy uses, such as space heating in dwellings or electricity for aluminium production. In some cases, the indicator is defined at the level of energy using systems (e.g. average electricity use of refrigerators) which resembles an end-user action (see [Table 1](#)). At all levels, the indicator-based calculated savings consider total savings.

The results can be aggregated to total savings at the level of sectors and savings at country (region, city) level (see [Table 1](#)). The set of indicators should cover (almost) all energy consumption in order to provide reliable figures at aggregated level.

Table 1 — Savings types per aggregation level for indicator-based and measure-based methods

Aggregation level	Indicator based	Measure based
End-user action	Total savings	Total or policy/deliberate savings
Facilitating measure	(Not applicable)	Policy/deliberate savings
Targeted energy use	Total savings	Total or policy/deliberate savings
Sector	Aggregate of total savings	Aggregate of total or policy/deliberate savings
Country, region, city	Aggregate of total savings	Aggregate of total or policy/deliberate savings

NOTE “Total savings” is not to be understood as an aggregate, but as one type of savings (autonomous + policy/deliberate, see [Figure 3](#)).

Measure-based methods calculate savings for specific end-user actions, for facilitating measures or for targeted energy uses (see [Table 1](#)). In most cases, the type of savings depends on the energy baseline chosen. Only in case of facilitating measures the result is restricted to policy/deliberate savings.

Savings can be aggregated to the country (region, city) level, provided that (most) policy measures or other initiatives are covered. The aggregated results can represent total savings or policy/deliberate savings.

3.3.6 Demarcation and integration of indicator-based and measure-based methods

3.3.6.1 Demarcation of application of methods

The measure-based method (see [3.3.3](#)) and the indicator-based method (see [3.3.1](#)) differ in many aspects: type of data used, aggregation level in application, type of savings provided, etc. However, the distinction between indicator-based and measure-based methods is not always as clear as described earlier. If an indicator considers energy use at a low aggregation level, e.g. electricity consumption of refrigerators, then the scope of the indicator coincides with that of a specific end-user action (buying a high efficiency refrigerator) and, possibly, with that of a facilitating measure (a labelling scheme for efficient refrigerators). In that case, the indicator-based and the measure-based approach can deliver more or less comparable savings results.

3.3.6.2 Integration of results of both methods

Policy savings are part of total savings (see [Figure 3](#)). From a policy viewpoint, it is important to know which part of total savings (often calculated using indicator-based methods) is due to policy efforts (normally calculated using measure-based methods). However, at the moment no attempt is made to combine the indicator-based and measure-based methods into one integrated calculation system (see analysis of integration in Reference [6]). The standard provides separate indicator-based and measure-based calculation methods.

3.3.7 Incorporation of other policies that affect energy consumption

Energy consumption not only can be decreased through energy savings and saving policy but also through

- influencing structure effects that reduce energy consumption, and
- other policies than policies focusing on energy savings.

Changes in the composition of socio-economic activities can increase or decrease energy consumption (see [Figure 3](#)). Sometimes a change in activity, leading to lower energy consumption, is deliberately sought for.

An example of the first category is a policy on shifting inland road transport to transport by ship, where transport by ship consumes less energy per amount of goods. In this case, the effect on energy consumption can be counted as (policy) savings, despite the fact that it concerns a shift in activities

and there are actually no efficiency gains for goods transport by truck and ship. However, the overall efficiency of all goods transport is increasing.

An example of the second category is a policy to reduce road accidents by imposing lower driving speed limits. Because cars use less fuel per kilometre driven at lower speed, this safety policy also saves energy. Often, these saving effects of non-saving policies are accounted for when energy savings have also been taken into account in the decision to implement the policy.

An example of a combination of both categories is a policy to remove small polluting cement production sites, which have a relatively low energy efficiency. Here, the main reason for policy action is the environment, but energy savings are realized as well. When large cement companies take over the small-scale production, this means a shift in the structure of the cement sector. There is no efficiency gain for the large producers, but average energy consumption per ton of cement is decreasing.

It must be remarked that, once structure effects or non-saving policies are part of energy savings accounting, they should remain so when the effect on energy consumption reverses.

4 Indicator-based savings calculations

4.1 Indicators and calculation of savings

4.1.1 Energy efficiency indicators

Energy indicators relate energy consumption to a driver, preferably a physical output or the number of energy-consuming systems. The change in the indicator value over a period of time is used to calculate indicator-based energy savings. [4.1.2](#) and [4.1.3](#) consider the applicability of indicators for energy savings calculations.

Because energy indicators are generally based on observed data, they are normally restricted to ex-post evaluations of realized energy savings. However, with detailed future energy trends (scenarios) indicator-based savings can be calculated ex-ante as well.

The indicator-based method does not look into the cause for a change in indicator values. Therefore, the contribution of deliberate actions, such as policy measures, to the calculated savings cannot be shown.

4.1.2 Structure effects and disaggregation

At a high aggregation level, the energy consumption trend can incorporate the effect of structural changes, thereby influencing the calculation of savings (see [3.3.2](#)). Therefore, indicators should be corrected as far as possible for structural changes, in order to be used for the calculation of energy savings.

One way to reduce the so-called structure effects due to structural changes is disaggregation of activities. For instance, instead of analysing the ratio between energy consumption and production at the overall industry level, the analysis can be done at the level of cement or steel production. For households, separate analyses for space heating, hot water use, and appliances can be done, each with their own driver, e.g. number of dwellings, number of occupants, and ownership of appliances, respectively. Indicators at a lower aggregation level are distorted less by structure effects in the calculation of energy savings, but demand reliable data at subsector level.

The indicator can also be corrected for factors that mask the envisaged energy savings. For instance, energy use for space heating can be corrected for the shift from room heating to central heating which leads to extra energy consumption and, possibly, negative observed energy savings. By correcting for increased energy demand due to the shift to central heating, the indicator typically provides positive energy savings. However, this correction is not needed if envisaged savings incorporate increased demand due to central heating.

Due to restricted data availability, it is not always possible to correct for factors that are considered structure effects. Statistically, based indicators represent aggregated developments for groups of end

users, either their total energy consumption or parts thereof. Next to the national level, indicators can cover geographical segments, such as regions, if statistical data are available.

4.1.3 Indicator choice and savings definition

The choice of indicators can define what energy savings encompass. For instance, in transport of persons (see [A.4.2](#)) a choice can be made between

- fuel consumption per person-kilometre by car,
- fuel consumption per kilometre driven by car, and
- annual fuel consumption per car.

In the first example, the average number of persons per car trip influences the indicator value. The savings of a policy to stimulate carpooling counts to the calculated savings. In the second example, this is not the case. In the third example, fuel use is not corrected for changes in annual amount of kilometres driven per car. Therefore, the savings due to a policy on less driving with a car become part of the calculated savings. However, an autonomous trend for more driving with the car has a negative contribution to the calculated savings.

More elaborate indicators are possible that take account of the weight of the car, changes in the use of air-conditioning, and driving patterns (e.g. due to congestion). If the focus is only on technical efficiency, corrections should be made for all factors except engine and transmission efficiency, low drag aerodynamic design, and use of lightweight materials. In this case, the other factors constitute structure effects.

If the focus is also on limiting car use (e.g. through a modal shift, encouraging the use of bicycles or public transport), a more appropriate indicator is fuel use per person-kilometre over all modes of transport (see [A.4.3](#) on modal shift).

In the following general calculation of indicator-based savings, no choices are made as to the appropriate indicator. The user of the standard has to decide what type of indicator fits best to the focus and definition of energy savings. Depending on this choice, corrections have to be made for factors that are considered structure effects in that specific case.

In some cases, the choice of alternative indicators not only depends on the focus and the preferred scope for energy savings but on data availability. For instance, for countries without separate data on space heating, an alternative indicator could be used, e.g. consumption of all non-electric energy per dwelling. The use of alternative indicators is justified by the fact that it enables each country to use at least one indicator to assess the energy savings. There is of course a trade-off with the accurateness of the calculated savings.

4.2 General calculation of indicator-based energy savings

4.2.1 Calculation approach

Calculation methods generally are composed of two main elements:

- a) a calculation model or formula, including adjustments;
- b) data collection and parameters to be used.

In the following Clause, Subject I, the general indicator-based calculation model, is described. Subject II, data collection and parameters, is part of the calculations for specific indicators. Therefore, it is not treated here.

The calculation steps are as follows:

- definition of indicator types ([4.2.2](#));

- calculation of indicator values ([4.2.3](#));
- calculation of energy savings per indicator ([4.2.4](#)).

Other issues related to the calculation of indicator-based energy savings are described in [4.3](#).

4.2.2 Step 1: Choice of indicator types

The choice of indicator types can be based on the targeted energy use for which savings must be calculated, e.g. a (sub)sector or an energy using system. For indicator-based energy savings calculations, the following indicator types can be used.

4.2.2.1 Indicator type A

Specific energy consumption at subsector level relates energy consumption to physical quantities (e.g. GJ/tonne of steel for Iron and Steel sector or MJ/ton-km for goods transport) for a given period, usually a year. At sector level, e.g. industry as a whole, no physical production of a uniform nature can be defined due to the diversity of production. Therefore, specific energy consumption is only defined at subsector level (three or more digits in the international classification of economic activities).

If no physical output is available, a production index can be used that is based on value added at constant prices. This driver acts as a proxy for physical output.

4.2.2.2 Indicator type B

Specific energy consumption for energy using systems relates total energy consumption for specific systems to the number or size of systems. If number is used, this will yield the annual energy consumption per system, e.g. GJ/dwelling, kWh/refrigerator or l/car. If size is used, this provides, for example, an indicator GJ/m² of building floor space.

4.2.2.3 Indicator type C

Diffusion indicators that show the penetration of energy-saving systems are sometimes used where annual energy consumption data are not available at a detailed enough level. In that case, energy savings can be calculated with the diffusion indicator, in combination with given energy savings per system. Examples of diffusion indicators are the number of energy efficient cars or the A-label fraction for appliances.

Specific energy consumption indicator types A and B differ as to the type of driver (see [4.2.3.2](#)), i.e. the item which energy consumption is related to. However, the same calculation method is used for the two types of indicators. Diffusion indicators form a special category for which alternative calculation rules apply.

Diffusion indicators resemble sometimes cases in measure-based calculations, e.g. for refrigerators with efficiency labels. However, here it regards the total savings and not the effects of saving programs as in measure-based methods.

4.2.3 Step 2: Calculation of indicator values

4.2.3.1 Adjustment of energy consumption for weather

For the indicators of specific energy consumption (indicators type A and B), an energy consumption figure is needed. For diffusion indicator, type C no energy consumption figure is needed as deemed energy savings are used (see [Annex A](#)).

Energy consumption figures should be adjusted for deviations from average weather conditions that influence energy consumption. For an analysis based on annual data, a representative adjustment approach is given by Formula (1). The adjustment can consider space heating and space cooling. The

adjustment is necessary for sectors with significant use of energy for heating or cooling (e.g. mainly residential and tertiary sectors). The basic adjustment of Formula (1) is

$$E_{WN}(t) = E_A \times [1 + (F_W - 1) \times F_{SHC}(t)] \quad (1)$$

where

E_{WN} is weather adjusted (normalized) energy consumption;

E_A is annual energy consumption from statistics;

F_{SHC} is space heating or cooling fraction of yearly consumption dependent on weather;

F_W is adjustment factor for weather (larger or smaller than unity);

t is year of calculation.

For heating, the adjustment is based on the number of heating degree-days (HDD), representing the number of degrees that the mean temperature over the day is below a given threshold value during the heating season. This threshold temperature can vary between countries. The adjustment factor here is the ratio between the normal number of degree-days and the actual number of degree-days. The “normal” winter is based on a long-term mean number of degree-days, usually over 20 to 30 years.

NOTE Some countries have, however, shortened the reference period and are calculating the average since 1990 to account for the fact that winters have become warmer since 1990. Some countries are in addition changing the period (moving reference period), which means that the number of normal degree-days is not fixed.

The correction is only applied to the part of energy consumption that is weather dependent. For households, the fraction SHC covers space heating but not energy use for hot water or cooking. If no data are available, the fraction can be estimated.

In countries with hot summers, cooling degree days (CDD) can be used as a weather adjustment on electricity consumption. The approach is similar to that for heating but uses the number of cooling degree-days, i.e. the number of summer days with a temperature above a base temperature, which is usually significantly higher than that for heating degree-days (e.g. 25 °C). Countries with continental or extreme weather can require for adjustments for both heating and cooling degree days.

Adjustment of energy consumption does not comprise corrections for other adjustment factors, such as occupation rate for buildings or production level.

More elaborate adjustment for weather can be applied if this leads to better calculated savings, e.g.:

- correction restricted to a certain fraction of the space heating consumption (e.g. 90 % in Reference [3]), to account for the fact that energy consumption proves not to be entirely dependent on degree-days;
- adapted degree-days: city or regional level degree-days. At national level, degree-days as weighted value of city and regional degree-days when these differ substantially per region of a country;
- weighted degree-days per month to account for differences between heating in autumn and spring.

The choices made in weather adjustment should be specified when presenting the calculation results.

4.2.3.2 Definition of driver types and system boundaries

Energy consumption per subsector or targeted energy use is related to a driver (see [Annex A](#)). Depending on the type of indicator, the following driver types are valid.

Driver type A: physical quantity (production), traffic data, etc.

NOTE If not available, a production index based on value added in constant prices can be used.

For industry sectors, the value of driver type A is defined as the net yearly production of a physical commodity of a uniform nature, expressed in an appropriate unit. The value is expressed in an index of production for multi-product branches. In case of hidden structure effects, e.g. higher energy consumption per driver unit due to a lower capacity utilization rate, an adapted driver quantity can be chosen (see example [A.3.2](#)).

Driver type B: number or size of energy using systems.

The value of driver type B is defined as the number (average over a year) of a uniform energy using system, or defined as the size of an energy using system, such as a building.

For diffusion indicators (indicator type C), no energy consumption and adjacent driver is needed as energy savings are directly calculated from the deemed savings per system and the number of systems.

The system boundaries follow from the chosen indicator. For example, for average energy consumption per dwelling, the system normally regards all permanently occupied dwellings and their energy consumption for heating the dwelling. In some cases, the chosen driver cannot match the system boundaries, e.g. if occupation rates are not known and the total number of available dwellings is the driver quantity.

4.2.3.3 Calculation of indicator values

For indicators of specific energy consumption (i.e. except diffusion indicator), the value is calculated according to Formula (2), where the weather adjusted energy consumption is divided by the driver quantity (DV) for year t .

$$V_{IN}(t) = E_{WN}(t)/DV(t) \quad (2)$$

where

V_{IN} is indicator value;

E_{WN} is weather adjusted (normalized) energy consumption;

DV is quantity for driver;

t is year of calculation.

4.2.3.4 Diffusion indicator

For diffusion indicators, the indicator value is equal to the number of energy-saving systems, e.g. the total number of solar water heaters installed on dwellings. The indicator also can be expressed as a rate of penetration, e.g. fraction of dwellings equipped with water heaters or share of public transport.

4.2.4 Step 3: Calculation of energy savings per indicator

4.2.4.1 Change in indicator value

For specific energy consumption indicators (i.e. except diffusion indicators), the change in the indicator value is calculated according to Formula (3). If there are energy savings, the value of the indicator will decrease with time and the change will be a positive value.

$$C_{\text{IND}} = V_{\text{IND}}(t_0) - V_{\text{IND}}(t) \quad (3)$$

where

C_{IND} is change in indicator value;

V_{IND} is indicator value;

t_0 is base year;

t is year of calculation.

If the indicator value for year t is higher than for t_0 , a negative value will result unless structure effects are taken into account (see 5.3.4). It should be ensured that the level of disaggregation should remain the same over the calculation period.

For diffusion indicators (type C), the change in indicator value is equal to the increase in number of saving systems. See Formula (4).

$$C_{\text{DIND}} = D_{\text{IND}}(t) - D_{\text{IND}}(t_0) \quad (4)$$

where

C_{DIND} is change in diffusion indicator value;

D_{IND} is diffusion indicator (number or fraction) of saving systems;

t_0 is base year;

t is year of calculation.

If the diffusion indicator is expressed as an absolute number, the change applies to absolute numbers as well. If the diffusion indicator is specified as a fraction, e.g. for solar boilers the fraction of dwellings equipped with such a boiler, the change in the fraction must be multiplied by the number of dwellings.

4.2.4.2 Energy savings per indicator

For indicator types A and B, the energy savings per indicator are calculated from the change in indicator value times the driver quantity in the year of calculation. See Formula (5).

$$ES_{IND} = [V_{IN}(t_0) - V_{IND}(t)] \times DV(t) \quad (5)$$

where

ES_{IND} is energy savings per indicator;

V_{IND} is indicator value;

DV is quantity for driver;

t_0 is base year;

t is year of calculation.

For example, the energy savings for cement production at year t are derived from the change in mean energy consumption per tonne of cement between year t and a reference year t_0 . This quantity in GJ/tonne is multiplied by the total production of cement in year t .

For diffusion indicators (type C), energy savings are calculated as shown in Formula (6).

$$ES_{DIND} = [V_{DIND}(t) - V_{DIND}(t_0)] \times E_{DS}(t) \quad (6)$$

where

ES_{DIND} is energy savings per diffusion indicator;

V_{DIND} is diffusion indicator value;

ES_D is deemed energy savings;

t_0 is base year;

t is year of calculation.

The calculation of deemed energy savings is part of the description of specific indicators (see example of diffusion indicator in [A.2.6](#)).

The calculated energy savings per indicator represent savings for a given sector or subsector or targeted end-use (type A), or for energy-using system (type B or type C).

4.3 Computational issues in the calculation of indicator-based savings

4.3.1 General

For the calculation of indicator-based savings, the following computational issues are associated with the steps in the preceding clauses:

- variants of the calculation method;
- energy consumption units;
- overall savings.

4.3.2 Variants of the calculation method

4.3.2.1 Smoothed indicator values

Annual indicator values sometimes show large fluctuations, even after adjustment for weather. Apart from imperfect data, other factors, such as short-term business cycles, can cause these effects. Especially deviations for the first and last year (which determine the total effect over a period) are to be avoided.

For that reason, it is recommended to use moving average values instead of annual values for the indicators. A three-year moving average is a minimum, provided that the data are available. It should be clear from the savings quantity that it concerns a moving average value.

NOTE 1 The method traditionally used in statistics to calculate the three-year moving average is to take for year t the average of $t - 1$, t , and $t + 1$. However, in that case the last observed year cannot be presented. Using years $t - 2$, $t - 1$, and t allows to deliver more recent saving figures, possibly at the cost of some accuracy.

NOTE 2 Weighted values can be used to give greater emphasis on more recent data, e.g. using $[3 V_t + 2 V(t - 1) + V(t - 2)]/6$ for a variable V over the most recent and two preceding time periods. For example, this approach can be used when it is known that there is a rapid uptake of a new technology over the three periods.

4.3.2.2 Moving base year calculation

Indicator-based savings are calculated from the change in the indicator value and the driver quantity. In the fixed base year approach, the calculation is done directly with the values in the starting year t_0 and end year t , without taking into account what happens in between [see Formula (5)].

In the moving base year approach, the savings are calculated year-by-year. In each year of the period, the savings follow from the one-year change in the indicator value and the current driver quantity. This means that in Formula (5), " t " represents every time a different year and t_0 represents the preceding year. The yearly savings are summed up over the period from t_0 to t . This approach, where the earlier year acts as the base year for the following year, is also called the chained calculation.

The choice between the two methods can depend on the following context.

- If the energy savings need to be calculated with reference to a specific year, the approach with a fixed base year is the most appropriate. Examples are a voluntary agreement or a policy commitment that is defined against a specific base year.
- If energy savings need to be calculated on an annual basis and summed over different periods, a moving reference year is more appropriate. The results can be calculated for any intermediate period, independent of a fixed base year.

When there are rapid changes between years, it is recommended to use the moving base year approach. The moving base year approach is more complicated but often delivers more precise energy savings than the fixed base year approach, especially when there are rapid changes in the driver (e.g. the stock of an appliance or vehicle) or in the specific energy consumption. Therefore, the moving base year approach is to be preferred for indicator-based savings calculations.

4.3.2.3 Driver quantity for base year or for year of calculation

Energy savings are calculated from the variation in the indicator value and the driver quantity (e.g. the decrease in gas use per dwelling times the number of dwellings). The driver quantity can be taken from the starting year (base year) or from the year of calculation, i.e. the year for which energy savings are calculated. In this International Standard, the driver quantity from the year of calculation is taken.

The results, when using driver values either base year or calculation year, is different, depending on the magnitude of variation for the driver quantity, as shown in the following example. The average annual electricity consumption of refrigerators decreases from 400 kWh/unit in 1990 to 300 kWh/unit in 2008.

The number of refrigerators rises from 0,6 million units to 1 million units in 2008. Using the driver quantity in the year of calculation 2008, electricity savings are $(400 - 300) \times 1\,000\,000 = 100$ GWh. With the driver quantity for the base year the savings are $(400 - 300) \times 600\,000 = 60$ GWh.

The choice should be consistent for all indicators. Especially in case large changes in the driver, the choice should be based on usefulness of results.

In order to limit the differences due to the driver quantity in the chosen year, the moving base year approach can be used as an alternative method of calculation (see [4.3.2.2](#)).

4.3.3 Energy consumption units

4.3.3.1 General

Energy consumption and savings can be expressed into various units, such as Joule, m³ for gas, litre for motor fuels, kWh for electricity, or tonnes of oil equivalent (toe). Monitoring bodies can express the energy savings in the most appropriate unit, e.g. litre of motor fuel for energy savings in cars. In line with ISO standardization, in calculations according to this International Standard these figures should be converted into the SI unit for energy consumption Joule (e.g. MJ, GJ, or PJ).

4.3.3.2 Energy savings in primary units

National statistical offices often provide energy consumption data in final energy units. This means that electricity is accounted for according to its heat content¹⁾. When these accounting rules are also used in the calculation of energy savings, this approach has two consequences:

- overestimation of the energy savings when substituting fuels by electricity because the production of the electricity consumed causes substantial conversion losses elsewhere;
- underestimation of the energy savings generated by electricity savings because the avoided conversion losses in power stations are not accounted for.

For this reason, the electricity savings can be calculated on the basis of energy consumption in primary units. A primary factor that represents the average energy input per kilowatt hour produced (the inverted mean efficiency) for the relevant power production system of a country should be used to convert final electricity consumption into primary units. The savings calculation now results in energy savings in primary units that account for losses in energy supply (in power plants and transport and distribution of electricity) related to the electricity saved.

NOTE Primary factor depends on the composition of electric power production, where different amounts of hydroelectricity, wind, coal, or nuclear define the factor.

For heat delivered to end users by a district heating system, a primary units approach can be applied. In the standard calculation method supply of district heat is accounted on energy content basis. No conversion losses are incurred at the end user, as is the case with converting fuel to heat in a boiler. As to the losses to produce the heat elsewhere, two cases can be distinguished: heat from power plants and heat from a central boiler.

If power plants also produce heat for use elsewhere (cogeneration units), less than one (extra) unit of fuel input is needed to produce one unit of heat. The final energy approach does not account for the very efficient production of the heat. The advantages can be assigned to the heat consumers converting the energy supplied into primary units with a primary factor smaller than unity. The lower energy consumption in primary units leads to higher calculated savings.

If the heat is produced in large boilers and distributed through a grid to the end users, the fuel use per unit of heat will often be higher than for the individual boiler, due to the distribution losses. In this case, a primary factor larger than unity can be used to convert heat consumption into primary units.

1) 1 kWh is equal to 3,6 MJ.

In order to enable calculations in primary units, total energy consumption needs to be divided into fuels, distributed heat, and electricity, as shown in the example of space heating in [Annex A](#).

The calculation of savings in primary units comes down to enlarging the system boundaries. Instead of taking into account the end users' place, also part of the energy supply system is taken into account.

It should be clearly stated in the reporting whether energy consumption in final or primary terms has been used.

4.3.4 Overall indicator-based energy savings

Energy-saving calculations, using a set of indicators, result in overall indicator-based energy savings that can be representative for all savings in a sector or country.

The total savings are calculated by summing up the energy savings derived for each indicator that covers part of end-use. In order to avoid overlap in the savings per indicator, each part of end-use should be covered by only one indicator when aggregating overall indicator-based energy savings.

Summing up might concern also negative savings (see [4.4.1](#)).

In order to have overall savings, data on all indicators should be available, which go beyond statistical data provided in the energy balances. [Annex A](#) provides an overview of possible indicators and connected data.

4.4 Reliability of saving figures

4.4.1 Indicators resulting in negative savings

For energy consumption indicators, such as presented in [Annex A](#), normally a decreasing indicator value is found over time. This is interpreted that energy savings have been realized.

However, in some cases the observed indicator trend shows an increase, resulting in negative energy savings.

The result can correspond to real decreasing energy efficiency; in that case the negative savings should be reported. It can also be due to an insufficient level of disaggregation, thereby mixing real savings with structure effects. If it is not possible to correct for these structure effects, it should be clearly stated that no savings have been calculated due to structure effects. In that case, no savings will be presented, even if they become positive in a later period.

4.4.2 The quality of indicator-based energy-saving figures

In order to calculate energy efficiency as the ratio between an input of energy and an output, both need to be clearly defined and be measurable. The quality of the calculated saving figures can be rated by determining the uncertainty margin for the resulting figures, as done in Reference [\[10\]](#). In this study, a margin for the indicator value is calculated through a standard formula that combines the error margins in the energy and activity data, used to calculate the indicator value. The margin for the change in the indicator value is determined through another standard formula that converts the margins in two indicator values into a margin for the difference.

However, this analysis is rarely done due to the complexity of the procedure. Therefore, this International Standard does not provide guidelines for a quantitative rating of the quality of the saving figures.

But preferred practice would direct that rating the quality of the savings figures, qualitative if not quantitative, be undertaken whenever possible. An alternative for a quantitative rating is a qualitative description of the process of calculating energy savings based on indicators. According to Reference [\[10\]](#), the following factors define the quality of results:

- the status and gathering method of the data sources used;

- the appropriateness of the chosen driver;
- length of period for which energy savings are calculated;
- aggregation level of presented saving figures.

4.4.2.1 Status of data sources

The status can be divided in official statistical data, results from structurally held surveys, up to incidental small surveys and expert estimates. However, official data are not always more reliable than surveys executed by other organizations. Important factors that affect data quality are as follows.

- How comprehensive are data sets? Is there complete reporting?
- If based on a statistical sample, did that sample frame include the whole city/region/country applying it to?
- What are the statistical error bounds/confidence levels for the quantities being used from statistics?
- How consistent is the series collection over time? Have there been disruptions or changes in the method midstream?
- How consistent are the series values over time? Do they contain unexplained outliers?
- How are non-statistical data obtained, through direct measurement or reporting by respondents that are not experts?
- How are non-statistical data upscaled to the regional level?

All data should be retained for documentation purposes and the sources of all data documented in any reports.

4.4.2.2 The appropriateness of the chosen driver

This defines whether the change in indicator value represents energy savings. Often, this change is influenced by hidden structure effects (see 4.1.2). The more hidden structure effects, the lower the chance that the “true” savings are calculated. Therefore, appliers of this method can perform an analysis of possible hidden structure effects for each indicator. In this respect the following examples can be looked at Reference [11].

Hidden structure effects for residential indicators are the following:

- changes in floor space (if not using an indicator fuel consumption per m² floor space);
- changes in the number of occupants;
- changes in the composition of the dwelling stock (detached versus apartment);
- daily occupation rate due to aging (more) of having a job (less).

Hidden structure effects for the services sector are the following:

- floor space per employee (if number of employees is used as the driver);
- occupation rate of office rooms (working part-time or sometimes at home);
- opening hours for shops (if turnover is used as driver);
- introduction of air-conditioning in existing buildings;
- medical treatment trends (shorter stay, less beds but more intense use of appliances);
- changes for restaurant (fast food versus slow food);

- centralized services/big buildings or decentralized services/small buildings.

Hidden structure effects for industrial indicators are the following:

- high-performance steel demanding more treatment (for ton of steel as driver);
- intermediate inputs instead of raw materials (for output as driver);
- shifts between contributions of branches in subsectors (if turnover is used as driver).

Further information on (removal of) hidden structure effects can be found in Reference [11].

4.4.2.3 Length of period

Savings calculated for one year are relatively unreliable, because the savings, often in the range of one percent of energy consumption, are of the same magnitude as the margin in the savings figure. This figure follows from a change in the indicator value based on changes in statistical figures with often a 1 % error margin. The relative margin can be of the order of 50 % or more. However, for a period of 10 years the savings becomes about 10 times higher, while the margin is still about the same, thus leading to a much smaller margin.

4.4.2.4 Aggregation level of savings

When the savings connected to different indicators are aggregated, the margin for the aggregated savings is lower than that for the separate indicators. According to the law of large numbers, the positive and negative errors in the savings from separate indicators compensate each other, provided that the indicator changes are independent from each other.

In general, the quality of calculated savings figures is better for good data, few hidden structure effects, a longer evaluation period, and figures at the highest aggregation level.

An assessment of the quality of the indicator-based savings analysis incorporates a full description of

- data sources, each with a quality assessment,
- rationale for drivers included and drivers tried and not selected, with reason for not including, and
- discussion of differences and similarities with comparable analyses done.

5 Measure-based savings calculations

5.1 Measures and calculation of savings

5.1.1 Elementary unit of action and unitary energy savings

Energy savings are realized by end-user actions that can be of a physical, organizational, or behavioural nature. Physical actions relate to a change in equipment or systems, often as a result of an investment decision. Organizational actions represent changes in organizational processes that have an effect on energy use. One type of behavioural action is change in personal behaviour concerning daily energy use. For organizational and behavioural actions, there is generally no need for substantial investments.

An end-user action consists of an elementary unit of action, from which unitary energy savings arise that can be summed up to the total energy savings of the end-user action.

Examples of an elementary unit of action, by type of end-user action, are the following:

- physical: all kinds of equipment, buildings as physical unit, vehicle types, and specific industrial processes;
- organizational: company, institute, office, shop, and school;

- behavioural: appliance user, occupant of dwelling, employee, car driver, and participant in efficiency programme.

Examples of unitary energy savings are the following:

- physical: kWh savings for an “A” labelled refrigerator, m³ of gas savings for a higher standard new dwelling, lower l/km for a new car, and decrease in toe per tonne of cement for a factory;
- organizational: lower energy use of a school with good housekeeping system or a company with energy management system in place;
- behavioural: lower l/km for a participant in eco-driving schemes, and decrease in kWh use for a household receiving information on actual energy use.

Elementary units of action can be defined at very different, hierarchically related, aggregation levels:

- a) the overall system, such as a building, production process, road transportation of persons, an organization, a region, or a service;
- b) the subsystem, such as heating/cooling/ventilation, building envelope, lighting system, car, communication, and compressed air system;
- c) individual components, such as boilers, air-conditioners, appliances, internal combustion engine of a car, electric motors, etc.

The definition of the elementary unit of action incorporates the definition of adjacent system boundaries.

5.1.2 Energy baseline options for end-user actions

In order to calculate energy savings for given end-user actions, the energy use situation must be compared to a baseline situation, i.e. the situation without that action.

Baselines should be defined for the unitary energy savings. The chosen baseline influences, through the unitary savings, the calculated energy savings of an end-use action.

A baseline can also consider the number of elementary units of actions, particularly when a specific facilitating measure is being evaluated. The choice of baseline influences the number of elementary units of action and the size of the savings to be related to a specific facilitating measure. For example, the autonomous penetration of efficient electric motors needs to be taken into account when determining the extra penetration due to a subsidy scheme.

For physical end-use actions, different energy baseline situations can be relevant. Three situations can be used to group baseline options for an overall system, subsystem, or individual components:

- energy-saving add-on: features added to an existing system to improve energy efficiency while maintaining its original function;
- replacement: replacing a physical system with one with the same function but with better energy efficiency;
- new system: an energy using system for which no previous system has been in use.

These three situations can be organized in two general approaches for selecting the baseline situation:

- a) reference situation (case-related baseline), wherein the two most used ones are the following:
 - 1) based on a stock situation, e.g. the characteristics of the average installed energy using system, or the relevant part of (in case of early replacement of energy using systems the relevant part is not that with the normal lifetime, but the part with shorter lifetimes);

- 2) based on a market situation, e.g. the characteristics of the average energy using system available on the market, or relevant parts of it;

b) “before” situation (time-related baseline).

Option a is applicable to add-ons, replacements, and new systems. Option b is applicable to add-ons and replacement cases. Option b cannot be used for new systems (that do not replace another one), because there is no actual “before” situation. When option b is applied to add-on cases, the unitary energy savings are equal to the difference in energy consumption before and after the adaptation of the energy using system. In the replacement case, the before situation is the case without the replaced technical device.

For new systems, a virtual baseline situation has to be defined/created, e.g. for new dwellings with higher standards, this could be an equivalent dwelling constructed to the existing standard. A new piece of equipment could also be compared with other options, such as the market average or stock average of equipment serving the same function.

For organizational and behavioural actions, the baseline situation is in most cases option b, the consumption before implementation of the end-user action.

For physical, organizational, or behavioural actions, it is possible to distinguish two approaches, depending on the availability of energy consumption data for the elementary unit of action. In Approach I such data are directly available and in Approach II energy consumption is assessed using parameters, as explained in [5.2.2.2](#).

In all cases, it has been assumed that there is no change of the level of energy service provided: the change in energy consumption is solely due to energy efficiency improvements.

5.1.3 Savings types from measure-based calculations

Measure-based calculations focus on savings of specific end-user actions using energy baselines for unitary savings and elementary units of actions. Depending on the chosen baseline the calculation can result in policy induced savings or total savings. Care should be used in selecting baselines so that the resulting calculation best separates policy-induced savings from total savings for specific end-user actions.

Total savings encompass the savings that result from:

- on going technological development;
- end-user actions driven by (higher) energy costs;
- physical, organizational, or behavioural actions due to policy (facilitating measures);
- other physical, organizational, or behavioural actions.

If the energy baselines are chosen in such a way that they do not incorporate autonomous (technological and cost driven) savings, the calculated energy savings only consider savings due to policy or actions of other parties. Examples of actions from other parties include environmental campaigns by non-governmental organizations or actions by public housing corporations, labour unions, or socially responsible companies.

Energy baselines can also be defined in such way that the savings (almost) equal total savings, including autonomous and cost driven savings. For example, when defining the replaced system as the baseline, and counting any effect of the replacement irrespective of the cause, the result represents total savings.

5.2 General calculation of measure-based energy savings

5.2.1 Calculation approach

Calculation methods are generally composed of three main elements:

- a calculation model or formula including baselines and adjustments;
- data collection techniques, for data needed to feed the calculation model;
- a set of reference or default values.

In [5.2.2](#) to [5.2.5](#), the calculation model is described in detail. The calculations can be done at different levels of detail, taking into account data needs and reference values. The level of detail can vary at each step in the calculation.

The calculation level in relation to data collection and quality of savings figures is considered in [Annex B](#). The data collection techniques and reference/default values are not described here as they can only be specified for specific measure-based cases.

Next to the method described here, other methods exist to calculate the saving effect of (facilitating) measures at various aggregation levels. In some situations, it is possible to obtain savings estimates for an entire measure-based program or scheme through statistical techniques at aggregated level. In these cases, one or more of the following steps are not needed.

The measure-based calculation of energy savings per end-user action consists of the following steps:

- step 1: unitary gross annual energy savings;
- step 2: total gross annual energy savings;
- step 3: total annual energy savings related to area, groups of end users, etc.;
- step 4: total remaining energy savings for calculation year.

These steps are illustrated in [Figure 4](#) and described in [5.2.2](#) to [5.2.5](#).

The results from end-user actions can be summed to find the overall measure-based energy savings for a set of actions, taking into account any overlap, as described in [5.2.6](#).

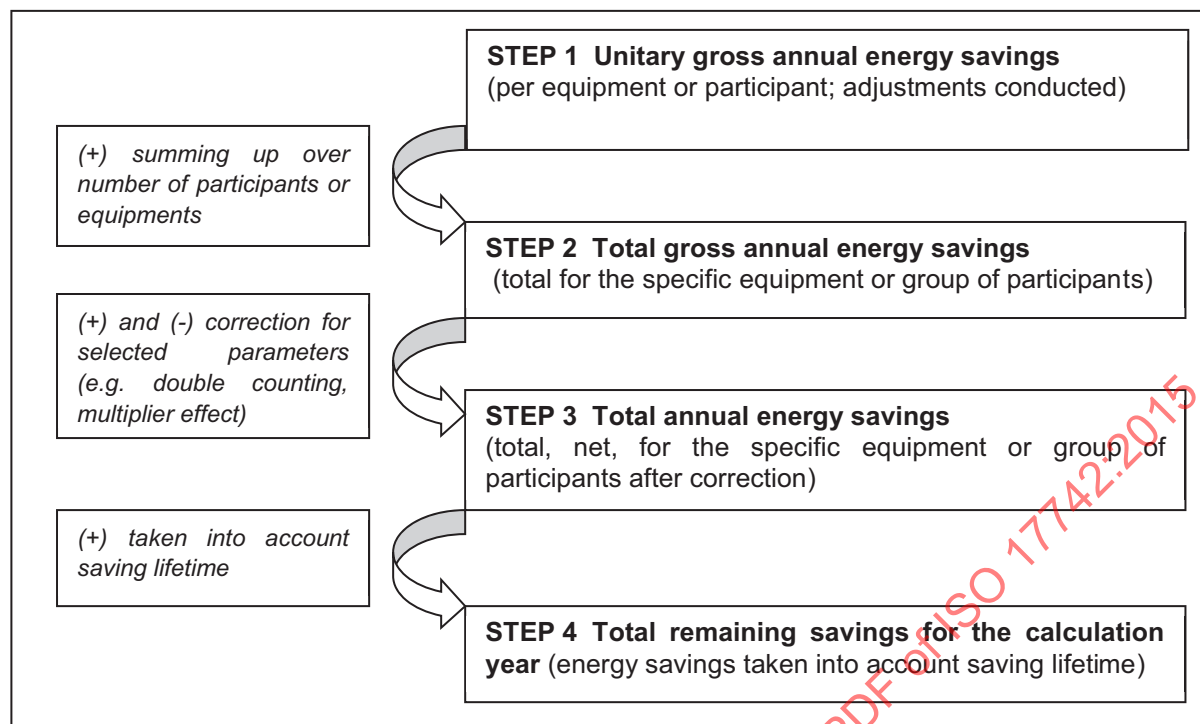


Figure 4 — Four steps in the calculation of measure-based energy savings

NOTE 1 Based on Vreuls et al. 2008[4]

NOTE 2 In step 2, the unitary savings are summed over all participants or equipment. In practice, this could also be the multiplication of the savings by the number of participants or equipment. Unitary savings times the number of elementary units (participant, equipment) provides gross annual savings. After correction for factors, to be chosen, annual savings result. The remaining part of these savings in the calculation year is determined using saving lifetimes. The results per EEI measure are summed up to find the overall measure-based energy savings. However, if the scope of two or more EEI measures overlaps, account will have to be taken of this overlap (see 5.2.6).

Each of these four steps holds several sub-steps in which specific calculations are made. The process of calculating measure-based energy savings is presented in Figure 5. In step 3, the corrections 3c-e are not always necessary.

Step 1 encompasses adjustments as part of the calculation of the gross energy savings. The unadjusted energy savings (as used in ISO 17743) are not explicitly defined here.

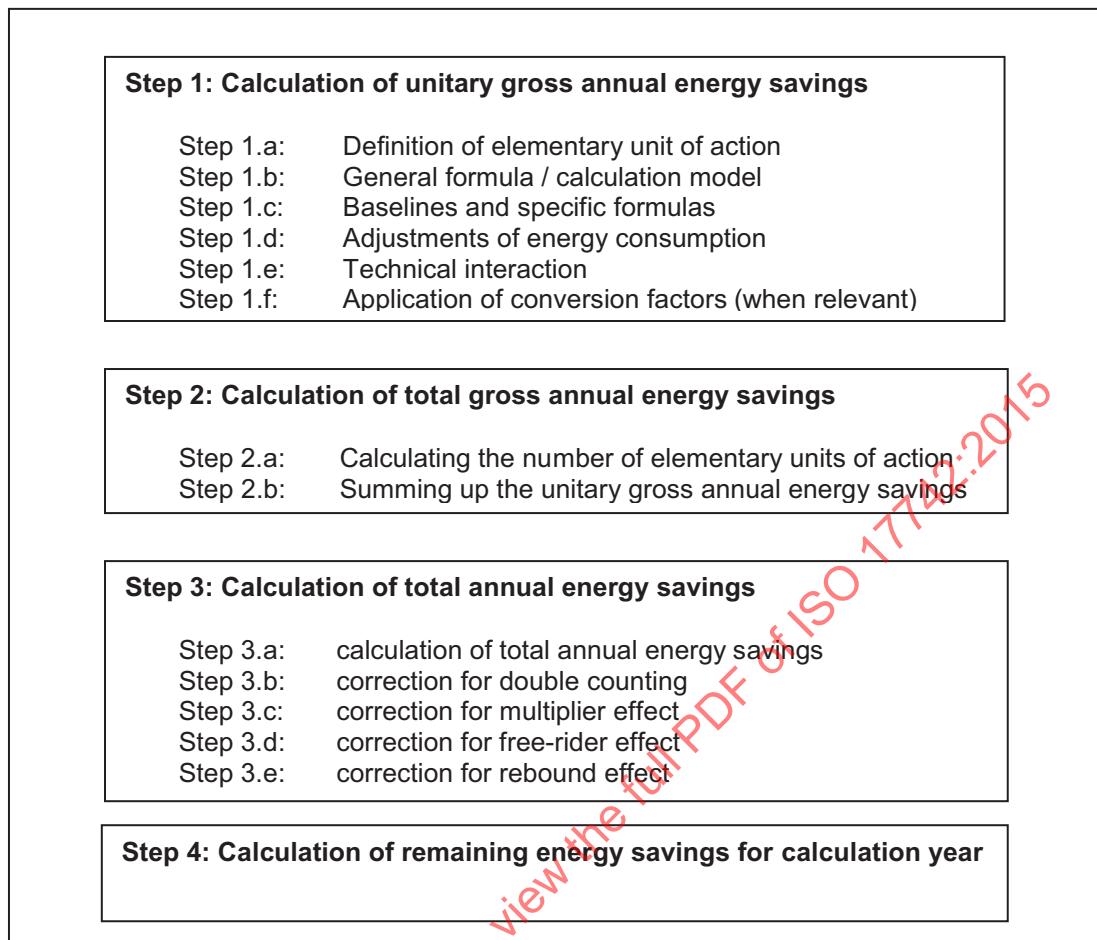


Figure 5 — Steps and sub-steps in the calculation of measure-based energy savings

5.2.2 Step 1: Calculation of unitary gross annual energy savings

5.2.2.1 Step 1.a: Definition of the elementary unit of action

Unitary savings are coupled to the chosen elementary unit of action, e.g. a new dwelling or a refrigerator. For a new dwelling, the unitary energy savings can represent a diminished energy use for space or water heating or other services such as lighting or air-conditioning, while for a refrigerator unitary energy savings are lower electricity use. In order to calculate unitary energy savings, the first step must be the definition of the elementary unit of action, including system boundaries.

The elementary unit of action can be defined at different aggregation levels, e.g. all households, all dwellings, all detached homes, the heating system, the boiler, and even the pump of the boiler.

If there are substantial changes in the services or properties of an elementary unit over time, e.g. from the CRT television to the flat screen television, this should be taken into consideration. For example, two different elementary units of action “CRT TV” and “Flat screen TV” can be defined, each with their own efficiency developments.

Apart from physical systems, the elementary unit of action can also represent an organizational entity or a participant (see examples in [5.1.1](#)).

The elementary unit of action should be chosen in a way that no major technical interaction with other elementary units of action is to be expected (see [5.2.2.5](#)). If this condition cannot be fulfilled, technical

interaction has to be taken into account to the extent feasible, the steps below should include actual field measurements of the potential effects.

- a) by identifying, documenting, and qualifying the potential technical interactions with the elementary unit of action and their influence on the unitary energy savings;
- b) by quantifying the influence of technical interactions on the unitary savings;
- c) and, if necessary, by adjusting unitary gross annual energy savings due to changing technical interactions for the situation without any end-user action and the situation with the end-user action (see step 1e technical interaction).

5.2.2.2 Step 1.b: General formula

5.2.2.2.1 Two approaches for unitary energy savings

The general formula to calculate unitary energy savings specifies how energy consumption and the change in energy consumption are determined. Two approaches can be used:

- Approach I for cases where consumption data are available;
- Approach II for cases where consumption data needs to be constructed.

5.2.2.2.2 Unitary savings Approach I, energy consumption data directly available

The situation without the implementation of the end-user action is denoted as (0) and the situation with implementation of the end-user action as (1). If the gross annual energy consumption (GAEC) for the situations without (0) and with (1) are directly known from energy bills or meter readings or measurement, in most cases the without action (0) is equal to the situation before implementation.

The general calculation formula is given in Formula (7):

$$ES_{GAU}(I) = [E_{GAEC}]_0 \times F_0 - [E_{GAEC}]_1 \times F_1 \quad (7)$$

where

- $ES_{GAU}(I)$ is gross annual unitary energy savings Approach I;
- $[E_{GAEC}]_0$ is gross annual energy consumption situation without action (baseline);
- $[E_{GAEC}]_1$ is gross annual energy consumption situation with action;
- F_0 is adjustment factor without action (baseline);
- F_1 is adjustment factor with action.

The use of the adjustment factors is intended to adjust the energy consumption for influences that are not to be accounted for in the calculation of energy savings such as weather conditions or occupancy levels. See step 1.d in [5.2.2.4](#).

5.2.2.2.3 Unitary savings Approach II, energy consumption data not directly available

The gross energy consumption is assessed using parameters that are relevant for energy consumption and for which data are available or can be estimated.

The general calculation formula is:

$$ES_{GAU}(II) = function(P_{00}, P_{01}...P_{0n}) \times F_0 - function(P_{10}, P_{11}...P_{1n}) \times F_1 \quad (8)$$

where

$ES_{GAU}(II)$ is gross annual unitary energy savings Approach II;

P_{0i}, P_{1i} ,
 $i=1\sim n$ are parameters;

F_0, F_1 is adjustment factor;

0 is without action (baseline);

1 is with action;

function an algorithm defining gross annual energy consumption.

In practice in most cases, the adjustment factor, F , is not used because adjustment is achieved mostly by means of modifiable parameters in the equation (see step 1.d).

EXAMPLE The replacement of a lighting system where the relevant parameters are

- parameter P : electrical power absorbed by the standard lamps [W], and
- parameter T : number of operating hours (h).

The formula for the unitary gross annual energy savings is

$$E_{GAUES} = P_0 \times T_0 - P_1 \times T_1 \quad (9)$$

In the replacement of a 60 W lamp by a 12 W compact fluorescent lamp (CFL) which both have 2 500 operating hours annually, unitary energy savings are $60 \text{ W} \times 2\,500 \text{ h} - 12 \text{ W} \times 2\,500 \text{ h} = 120 \text{ kWh}$. It is assumed that there is no change in the area illuminated and thus no need for adjustments.

The calculation formula offers considerable freedom in choosing parameters and calculation rules. However, it is important that these choices are accepted by the relevant parties. Therefore, the preferred order for the selection of the parameters and the formula is:

- a) internationally accepted formula;
- b) accepted formula by country/region/city;
- c) literature sources;
- d) self-developed and documented.

Preference 1 would typically be the case when other ISO/IEC standards are used.

Attention should be given to handle imperfect data collection, e.g. when for household lighting not the installed CFLs are researched directly, but sales data are used. The number might be too high as some CFLs are kept in stock by the household (as spare lamps), replace an already installed CFL, or are used not in the private house, but in a small and medium enterprise.

5.2.2.3 Step 1.c: Energy baselines and specific formulae

5.2.2.3.1 Two approaches

The baseline (i.e. the situation without the end-use action) can be handled in two approaches (see also 5.1.2). One approach is to use a reference situation (Approach A) and the other approach is to use the “before” situation (Approach B).

5.2.2.3.2 Energy baseline Approach A (Reference)

A reference situation is selected for the baseline situation. This can regard physical, organizational, and behavioural actions. The energy consumption is derived from a chosen reference device, such as (new) equipment, cars, or buildings. The following two reference cases, “market modelling” and “stock modelling”, can be identified [Formulae (10) and (11)].

In Formula (10), the choice of reference device is based on market modelling, i.e. a specific or average device available in the market for new devices. The reference market could be the city/region/country market or the worldwide market. The unitary energy savings are calculated according to Formula (10):

$$ES_{MUD} = E_{CRM} - E_{CNE} \quad (10)$$

where

- ES_{MUD} is market unitary energy savings of devices;
- E_{CRM} is energy consumption for present/reference market;
- E_{CNE} is energy consumption for new/efficient.

In Formula (11), stock modelling²⁾ instead of market modelling is applied to define the reference device. The reference device is based on (average) existing devices. The reference stock is usually the domestic stock or the stock in a comparable country. The energy savings are calculated according to Formula (11):

$$ES_{SUD} = E_{CES} - E_{CNE} \quad (11)$$

where

- ES_{SUD} is stock unitary energy savings of devices;
- E_{CES} is energy consumption for average/existing stock;
- E_{CNE} is energy consumption for new/efficient.

For new technologies no real world reference is available. Therefore, a virtual baseline situation has to be defined or created. For example, new dwellings with stricter building codes could be compared to dwellings built according to existing building codes.

5.2.2.3.3 Energy baseline Approach B (Before)

It is assumed that the “before” situation is a good reference. Often energy consumption data are available from measured or estimated data (e.g. using energy bills), normally over the year before implementation of the end-user action. This case is about add-ons and replacements to existing devices where the “before” energy consumption directly constitutes the baseline.

2) Stock modelling leads to similar baselines as Approach B assessing “before” consumption. But input data are different; stock/device characteristics versus (in general) energy consumption data.

When this baseline is applied, energy consumption should be adjusted using adjustment factors, if this is needed to make the “with” and “without” situations comparable (see step 1.d). If energy consumption data are not directly available, then gross energy consumption is assessed using parameters that are relevant for energy consumption (see step 1.b).

5.2.2.4 Step 1.d: Adjustment of energy consumption

Adjustment of energy consumption must ensure that the situations without and with the end-use action can be compared in a proper way when calculating the energy savings. To this end, energy consumption figures are adjusted for external factors that should not distort the energy savings calculation. Examples of such external factors are:

- weather conditions;
- occupancy levels;
- opening or operation hours for non-domestic buildings;
- installed equipment intensity (plant throughput);
- product mix;
- level of production, volume, or added value;
- relationship with other units.

The effect of each external factor is expressed in the form of adjustment factor. Each factor can be smaller or larger than 1. They are defined as an (average) value for the “without” and for the “with” situation.

The adjustment can be made only for the fraction of energy consumption that is influenced by the applicable external factors. For example in the case of weather conditions, the adjustment only relates to the part of energy consumption that is influenced by the weather. In most cases, this fraction should be estimated.

In the case where energy consumption data are available (Approach I), adjustment for external factors can take place in the form of an (aggregated) adjustment factor [see Formula (7)].

Where energy consumption data are not directly available (Approach II), energy consumption is constructed using a set of parameters [see Formula (8)]. Adjustment is in practice often achieved by choosing equal values for the parameters that take into account external factors. Depending on the case, values can be found in standards or from national reference data (e.g. for buildings: heating or cooling degree days dependent on the geographical location).

5.2.2.5 Step 1.e: Technical interaction

If there are technical interaction(s) having an influence on the unitary energy savings, this effect can be taken into account to ensure that the situation with implementation of the action can be compared to the situation without the action, when calculating the energy savings. Technical interaction can result from a relationship with other elementary units of action or with the surrounding physical system.

Where energy consumption data are available (Approach I), adjustment for technical interaction is not needed if the consumption data used for calculating unitary energy savings is derived from metering at a place which reflects all relevant technical interactions. For example, this is the case when unitary energy savings from a boiler exchange are calculated from consumption data of fuel supply to the building as a whole.

In the case where energy consumption data are not directly available (Approach II), energy consumption is constructed using a set of parameters. In this case, adjustment for technical interaction can be achieved by choosing for the case with implementation and for the baseline case different values for the parameters reflecting the interaction with the surrounding technical system or with other unitary

elements of savings. For example, when calculating the effect of insulation of the building envelope, the average yearly efficiency of the heating system is different in the case with implementation compared to the baseline case.

The problem of technical interaction can usually be avoided by calculating energy savings for a system at a “higher” level, e.g. at the level of dwellings instead of separately for insulation and boilers.

5.2.2.6 Step 1.f: Application of conversion factors

The energy consumption and savings can be expressed into various units, such as Joule, m³, litre, kWh, or toe. Often the savings case defines the appropriate unit, e.g. litre for efficient cars and kWh for efficient electrical appliances. If the savings expressed in different units have to be summed up (see step 3), the various units must be converted to a common unit, for which ISO defines the standard unit for energy consumption (e.g. MJ, GJ, or PJ). Conversion into one of the specific units, such as kWh, conceals the difference between electricity and energy in general, causing the risk of errors.

Energy consumption and savings can be expressed in primary units in order to have system-wide savings. This is mainly valid for electricity but can be applicable for distributed heat or when fuel substitution takes place at the same time when energy efficiency is improved (see 4.3.3). To this end, the electricity savings are calculated on the basis of consumption in primary units. A primary factor is used to convert final electricity consumption into primary units. The savings calculations now results in energy savings in primary units that account for avoided losses in energy supply (in power plants and the transport and distribution of electricity).

A primary factor that represents the mean efficiency in the relevant power production system should be used to convert final electricity consumption into primary units. The savings calculations now results in energy savings in primary units that account for avoided losses in energy supply (in power plants and transport and distribution of electricity).

NOTE 1 If no reliable geographically based figure is available, a conversion factor of 2,5 for electricity, meaning 1 kWh = 2,5 × 3,6 = 9 MJ in primary units, is used.

NOTE 2 For a country with a high fraction of hydroelectricity or wind energy, the primary factor is lower than 2,5. A country with more coal and nuclear energy has a higher than 2,5 primary factor.

When a primary factor is used, it must be ensured that the same value is used in energy savings calculations in the before and the after situations, as well as for the baseline energy figures.

NOTE 3 If the intention is to determine changes in primary energy consumption, then an additional analysis on average electricity production efficiency will have to be performed.

5.2.3 Step 2: Calculation of total gross annual energy savings

5.2.3.1 Two sub-steps

In step 2, the unitary energy savings per elementary unit of action and number of elementary units of action are combined to calculate total gross annual energy savings.

Step 2 on total gross annual energy savings consists of the following sub-steps:

- step 2.a: calculating the number of elementary units of action;
- step 2.b: summing up the unitary gross annual energy savings.

5.2.3.2 Step 2.a: Calculation of the number of elementary units of action

The elementary units of action in this step can be (see 5.1.1):

- physical: equipment, buildings, vehicle and specific industrial processes, etc.;
- organizational: company, institute, office, shop, school, etc.;

- behavioural: employee, car driver or participant in efficiency programme.

The best way to sum up these elementary units of action depends on how the unit is observed or assessed. In general, the number of elementary units of action can be

- directly accounted for, or
- indirectly assessed.

Directly accounting for numbers is possible when the implementation of end-user actions is related to focused promotion instruments, such as subsidy schemes on specific equipment. In that case, the number of subsidized equipment can be used as the number of elementary units of action. The same is valid for vouchers or executed energy audits which are made in homogenous cases.

In other cases, the number has to be indirectly assessed through, e.g. analysis of equipment sales data, by using the results of yearly surveys on the penetration of efficient equipment, or by other analysis methods. Attention should be given to handle imperfect data collection, e.g. use of equipment sales data as a proxy for the installed equipment.

Increased numbers of elementary units of action due to end user facilitating measures can be calculated by analysing the mechanism through which these promotion instruments try to realize energy savings. For example, in an eco-driving programme the elementary unit of action is not the person who is aware of eco-driving but the person who actually and measurably changes their driving style.

5.2.3.3 Step 2.b: Summing unitary energy savings

As approaches I or II can be used in calculating unitary energy savings (in step 1.b), the summing procedure is different for these two approaches.

- Summing savings in Approach I

In approach I, with energy consumption data directly available, the elementary unit of action is often an individual company or a building or a participant. In this situation, the summing is straight forward and total gross annual energy savings are calculated according to Formula (12):

$$ES_{TGA} \text{ (individual element unit of action)} = \sum_{i=1}^n ES_{GAI}(i) \quad (12)$$

where

ES_{TGA} is total gross annual energy savings;

ES_{GAI} is gross annual energy savings for the individual elementary unit.

Formula (12) can also be used for summing the savings of elementary units of action that represent a combination of systems, entities, and participants. This is the case for an audit as elementary unit of action where the audit can focus on different end-user actions. The energy consumption before and after the audit define the unitary energy savings. The total savings for the audit programme are the sum of the savings per individual audit.

- Summing savings in Approach II

In Approach II, without directly available energy consumption data, the summing depends on the composition of the general formula for unitary savings (see step 1.b) and the type of energy baseline selected (see step 1.c). The method of calculating the number of elementary units of action (see step 2.a) also influences the summing process.

If the general formula for unitary savings results in savings for individual cases, the summing is in conformity with Formula (12).

For equipment and buildings, the energy savings are not estimated for each individual item. Here, unitary savings are defined for an average elementary unit of action. In this situation, the total gross annual energy savings are calculated according to Formula (13):

$$ES_{TGA} \text{ (average elementary unit of action)} = ES_{MU} \times N_{EUA} \quad (13)$$

where

ES_{TGA} is total gross annual energy savings;

ES_{MU} is mean unitary energy savings;

N_{EUA} is number of elementary units of action.

The mean value must be valid for the stock for which the number is calculated. If large differences in energy savings occur, e.g. due to different versions, types, or models for the elementary unit, Formula (13) should be calculated for each version separately where possible.

5.2.4 Step 3: Calculation of total (net) annual energy savings

5.2.4.1 General

In step 3, the total annual energy savings are corrected, if necessary and possible given the data needed. This is usually done in order to provide energy savings in line with a defined target for energy savings. Step 3 consists of the following sub-steps:

- step 3.a: calculation of total annual energy savings;
- step 3.b: correction for double counting;
- step 3.c: correction for the multiplier effect;
- step 3.d: correction for the free-rider effect;
- step 3.e: correction for the rebound effect.

The need for, and way to define, the corrections is very dependent on the specific case for which measure-based savings are calculated. Therefore, no guidelines can be given on when to apply corrections or not, and how to calculate the value of the correction factor. The sections on corrections only provide a general description of the correction.

5.2.4.2 Step 3.a: Calculation of total annual energy savings

Total annual energy savings are calculated according to Formula (14):

$$ES_{TA} = f_{DC} \times f_{MP} \times f_{FR} \times f_{RE} \times ES_{TGA} \quad (14)$$

where

- ES_{TA} is total annual energy savings;
- f is the multiplication factor;
- ES_{TGA} is total gross annual energy savings;
- DC is double counting;
- MP is the multiplier effect;
- FR is the free rider effect;
- RE is the rebound effect.

The factors constitute a positive value without dimension. Most factors are smaller than unity but the multiplier factor is larger than unity. If a factor is not required, its value will be one.

The decision whether or not to take into account factors must be consistent with the energy baseline choices in step 1.c.

In many cases, the evaluation of the effect of a factor is cumbersome or almost impossible due to data constraints. If it can be argued that the possible effect on the reported savings is negligible, the factor can be ignored.

The decision not to use a factor should be explained (see also guidance in ISO 17743).

5.2.4.3 Step 3.b: Correction for double counting

Double counting can occur where there are two or more facilitating measures that focus on the same end-user action, e.g. a label system and a subsidy scheme, both promoting the purchase of efficient appliances. For each facilitating measure, the savings effect can be calculated but the combined savings can be lower than the sum of both individual saving effects.

Double counting cannot be done for one facilitating measure in isolation as it must be known which other facilitating measures are present. Thus, double counting has to be assessed for each specific situation and expressed in a factor in the formula for energy savings.

In rare cases, the combined effect can be larger than the sum of separate effects, e.g. in the example of labels and subsidies. Therefore, the double counting factor may be larger than unity.

5.2.4.4 Step 3.c: Correction for multiplier effect

The multiplier or spill-over effect enhances the initial effect of promotion measures to stimulate end-user actions. For instance, the promotion of efficient appliances can be so successful that after some time shops only offer efficient appliances to customers. Accordingly, energy savings is realized after the promotion period. The multiplier effect can also consider a transfer of the saving effect to another field than originally focused on.

The savings due to this market transformation can be added to the direct energy savings due to the promotion measure. The multiplier effect is taken into account by the factor in the formula for energy savings. The factor is larger than unity but is often very difficult to estimate.

5.2.4.5 Step 3.d: Correction for free rider effect

Facilitating measures are designed to stimulate end-use actions by energy users, e.g. a subsidy for insulation of the dwelling is intended to increase the numbers of end users installing insulation. Free riders are participants or consumers who would have implemented the end-use action also in absence of the facilitating measure(s) being evaluated. The factor is smaller than unity.

5.2.4.6 Step 3.e: Correction for rebound effect

The rebound (or take back) effect decreases the energy savings, because part of the initial gain is offset by behaviour that increases energy consumption. For example, after insulation of dwellings the occupants might set the thermostat at a higher temperature, because heating proves to be less costly than before. The rebound factor is smaller than unity.

5.2.5 Step 4: Calculation of remaining energy savings for the calculation year

The calculations described in the preceding steps provide energy savings for a certain year. If this calculation is done for the initial year, i.e. for the first year with the end-user action implemented, the initial energy savings are calculated.

Energy savings accumulate from implementation of the elementary unit of action until the moment when the action stops performing. The cumulative savings are thus defined by three elements:

- a) the initial energy savings;
- b) the saving period;
- c) the divergence from initial energy savings during the saving period.

Harmonized or calculated saving lifetimes can be used to define the saving period for elementary units of actions (see Reference [8] for example). With help of these lifetimes, it can be decided whether the total energy savings are still accountable for after a number of years. If the age of an end-user action in the calculation year is less than or equal to its lifetime, it counts for the energy savings in this year and otherwise it does not count at all.

In addition to saving lifetimes, the calculation of energy savings for the calculation year can take into account the divergence (usually a reduction) of energy savings over time that result from the following.

- Deterioration: For physical systems, deterioration of the savings effect means that the initial savings erode due to aging, e.g. due to fouling of the burner of a boiler. For behavioural end-user actions deterioration represents of change (mostly a loss) in savings performance for the group of participants.
- Maintenance regime: For many physical end-user actions, the quality of maintenance strongly influences the level of energy savings achieved over time. The maximum influence on the level of savings is equal to the difference in savings achieved for that end-user action without maintenance compared to an action with optimal maintenance. Maintenance could compensate to a certain extent for the loss in yearly energy savings due to deterioration.

The influence of deterioration and the maintenance regime can be taken into account if energy consumption data are available for each year of the savings lifetime of the end-user action. In other cases, i.e. if energy consumption data are only available for the initial year or if energy consumption data are not available at all, deterioration and the maintenance regime can be reflected by plausible parameters expressing the influence of these factors on energy consumption of the more efficient boiler (compared to the fouling effect of the standard boiler).

5.2.6 Calculation of overall measure-based energy savings, taken into account overlap

Elementary units of action can be defined at very different aggregation levels, from overall system, through subsystems to individual components (see 5.1.1).

The choice of aggregation level in savings calculations depends on

- data availability: energy consumption data are often more easily available at the overall system level than at the subsystem or component level,
- simple calculation of savings: for components, the calculation based on unitary savings and number of equipment can be quite straightforward, and
- potential interaction between energy savings for various end-user actions, occurring mainly at component and subsystem level. At the overall system level interaction is automatically taken into account in the overall results.

The preceding steps showed the calculation of total savings for one end-user action. The results per end-user action must be summed to find the overall measure-based energy savings for the full set of end-user actions.

If the end-user actions at different aggregation levels have a hierarchical relationship, the energy savings at a higher level are the sum of savings at a lower aggregation level. If end-user actions are defined such that their targeted energy use, or scope, does not overlap, their energy savings can be summed.

In case of an overlap, a correction should be made for the overlap in scope which depends on the type of end-user action. If it relates to two end-user actions, such as installing efficient electric motors and upgrading compressed air systems, then the correction will be determined by the overlap, i.e. the motors used within the improved compressed air systems. In case of two facilitating measures, e.g. an energy tax on all end-use and a voluntary agreement to improve energy efficiency in a specific sector, the interaction between the effects of the two measures should already be dealt with when correcting for double counting.

Note that overlap differs from the correction for technical interaction which considers effects for individual end-user action.

It is assumed that the scope of each end-user action is known and that the overlap in energy use with all other end-user actions can be determined. For the first end-user action, the overlap with following measures is expressed as a fraction of the energy use covered by the first end-user action. The same is done for the second end-user action and so on. In this way, the overlap is only accounted for once.

Overall measure-based energy savings (taking the overlap factor into account) are calculated according to Formula (15):

$$ES_{OMB} = \sum_{i=1}^n [ES_{EUA}(i) \times OF(i, j)] \quad (15)$$

where

ES_{OMB} is overall measure-based energy savings;

ES_{EUA} is energy savings end-user action;

$OF(i, j)$ is matrix of overlap fractions between action i and action j .

Where no overlap exists, all factors are equal to unity and overall energy savings are the sum of all end-user actions.

5.3 Reliability of calculated savings

The reliability of the calculated savings figures can only be determined for concrete cases, where the data sources with their reliability can be assessed.

For this general standard, the following general requirements can be made.