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Energy Efficiency and Savings Calculation, Top-down and Bottom-up Methods

National foreword

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Energy Efficiency and Savings Calculation, Top-down and Bottom-up Methods

Efficacité énergétique et calcul d'économies - Méthodes top-down (descendante) et bottom-up (ascendante)

Energieeffizienz und -einsparberechnung - Top-Down- und Bottom-Up-Methoden

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Contents

Foreword

This document (EN 16212:2012) has been prepared by Technical Committee CEN/CLC/TC JWG 4 “Energy Efficiency and Energy Savings Calculation”, the secretariat of which is held by NEN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by February 2013, and conflicting national standards shall be withdrawn at the latest by February 2013.

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Introduction

Due to uncertainties of energy supply and the need to limit the greenhouse effect, European countries have adopted policies to increase the energy efficiency and to develop the use of renewable energy sources. The amount of energy to be saved in each state separately, and overall for the European Union (EU), has been notified in international agreements. In recent years the EU has adopted several Directives as part of the efforts at EU level to improve energy efficiency. An example is the Directive 2006/32/EC on energy end-use efficiency and energy services (ESD). The ESD establishes for 2016 a national indicative energy savings target, equal to 9 % of final energy consumption in five years before 2007.This target is to be reached through energy services and other energy efficiency improvement measures.

The formulation of policies and targets has led to the need for harmonised monitoring and evaluation methods on energy savings at international level and at European level. In addition many countries that get involved in the monitoring of the energy savings achieved, or the impact of implemented policies and measures, need these calculation methods as well.

This European Standard covers the following topics:

- the methodology and general rules of calculation;
- terminology and definitions;
- parameters and data, including data quality and data sources.

This European Standard covers both top-down and bottom-up calculation methods. The top-down method is based on energy indicators (e.g. mean gas consumption per dwelling) which are often calculated from statistical data. The bottom-up method considers end-user actions and facilitating measures to enhance energy efficiency. For top-down the standard uses the results of earlier indicator work in the Odyssee project and in the framework of the ESD. For bottom-up the standard builds on the results of the EMEEES project, initially done in the framework of the ESD implementation. These results are the starting point for this standard which is general in nature and applicable to a larger category of purposes and users than the EU-driven ESD.

NOTE 1 The ODYSSEE project develops and updates energy efficiency indicators that can be used to calculate top-down energy savings for the 27 EU countries plus Norway and Croatia.

NOTE 2 The EMEEES project dealt with the definition of top-down and bottom-up calculation methods to monitor the ESD savings.

The top-down and bottom-up calculation methods are presented as two separate calculation methods. Using a combination of top-down and bottom-up methods is not part of this standard. However, the differences and application of both methods will be highlighted.

This European Standard provides a general framework for calculating energy savings. For top-down, examples of specific calculations per indicator are presented separately. For bottom-up, one specific application case, on building energy use, is presented as example.

After normative references (Clause 2) and terms and definitions (Clause 3) the characteristics of the top-down and bottom-up methods are presented in Clause 4. The top-down calculation method is described in Clause 5 and the bottom-up calculation methods in Clause 6. Annex A provides some example indicators that may be used in top-down calculations. Annex B deals with the level of detail at which bottom-up methods can be applied. Annex C describes the bottom-up example case for buildings.

1 Scope

This European Standard provides a general approach for energy efficiency and energy savings calculations with top-down and bottom-up methods. The general approach is applicable for energy savings in buildings, cars, appliances, industrial processes, etc.

This European Standard covers energy consumption in all end-use sectors. The standard does not cover energy supply, e.g. in power stations, as it considers only final energy consumption.

This European Standard deals with savings on energy supplied to end-users. Some forms of renewable energy “behind-the-meter” (e.g. from solar water heating panels) reduce supplied energy and therefore can be part of the calculated energy savings. Users of the standard should be aware that this renewable energy behind the meter can also be claimed as energy generated.

The standard is meant to be used for ex-post evaluations of realised savings as well as ex-ante evaluations of expected savings.

This European Standard provides saving calculations for any period chosen. However, short data series may limit the possible periods over which savings can be calculated.

The standard is not intended to be used for calculating energy savings of individual households, companies or other end-users.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

CWA 15693:2007, *Saving Lifetimes of Energy Efficiency Improvement Measures in bottom-up calculations*

3 Terms and definitions

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

3.1
adjustment factor
quantifiable parameter affecting energy consumption

[SOURCE: CEN/CLC/TR 16103:2010]

Note 1 to entry: Adjustment factors are mainly used in the bottom-up method.

EXAMPLE Weather conditions, behaviour related parameters (indoor temperature, light level) working hours, production throughput.

3.2
baseline
energy consumption calculated or measured, possibly normalised, in the situation without an end-use action

Note 1 to entry: The baseline provides a reference against which measurements can be taken or compared.

Note 2 to entry: The baseline can contain other actions but not the action under consideration.

3.3
bottom-up savings
energy savings calculated with bottom-up methods

3.4
bottom-up method
determination of energy savings from end-user actions using unitary savings and elementary units of actions

3.5
diffusion indicator
indicator showing the penetration of energy saving systems (e.g. efficient equipment or efficient mode of transport) with given savings per system

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

3.6
double counting
claiming energy savings more than once for two or more facilitating measures that focus on the same end-user action

Note 1 to entry: In most cases, the savings due to the combined effect of two facilitating measures will be lower than the sum of the savings from the separate effects.

Note 2 to entry: Double counting can be the result of overlap.

3.7
driver
quantity that is assumed to define the change in energy use under consideration in top-down methods

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

3.8
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.

3.9
end-use action
energy efficiency improvement measure implemented on the site of an end-user

3.10
energy carrier
substance or phenomenon that can be used to produce mechanical work or heat or to operate chemical or physical processes

[SOURCE: ISO 13600:1997]

Note 1 to entry: The energy content of energy carriers is given by their gross (=higher) calorific value.

EXAMPLE Coke, petrol, gas, district heat and electricity.

3.11
energy consumption
amount of energy used

[SOURCE: CEN/CLC/TR 16103:2010]

Note 1 to entry: Although technically incorrect, energy consumption is a widely used term.

Note 2 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.

Note 3 to entry: The manner or kind of application of energy is expressed as "energy use".

3.12
energy efficiency

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

[SOURCE: CEN/CLC/TR 16103:2010]

Note 1 to entry: It is essential that both input and output be accurately defined in quantity and quality, and be measurable.

Note 2 to entry: Energy efficiency is commonly used to mean the whole process of ensuring that energy is used in a more efficient manner, or in the most efficient manner that is economically cost-effective. This standard will only use the term in its narrower more technical sense.

Note 3 to entry: Commonly used meaning of energy efficiency is doing at least the same with less energy.

3.13
energy efficiency improvement (EEI)

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

[SOURCE: CEN/CLC/TR 16103:2010]

3.14
energy efficiency improvement measure

action normally leading to a verifiable, measurable or estimable energy efficiency improvement

[SOURCE: CEN/CLC/TR 16103:2010]

Note 1 to entry: In the ESD the term comprises both end-use actions and facilitating measures which are defined here separately.

3.15
energy efficiency indicator

value indicative of the energy efficiency

[SOURCE: CEN/CLC/TR 16103:2010]

Note 1 to entry: Mainly used as a metric in policy evaluation and in macroeconomic studies of energy efficiency.

3.16
energy end-user

entity consuming final energy

[SOURCE: CEN/CLC/TR 16103:2010]

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

Note 2 to entry: Energy end-use can be grouped using the European statistical NACE code system or a national industrial classification conforming to NACE.

3.17
energy saving

reduction of energy consumption following implementation of end-use action(s)

Note 1 to entry: The reduction is obtained by comparison against the baseline taking into account all adjustment factors.

Note 2 to entry: Energy savings can be potential following an assessment or actual after implementing action(s).

Note 3 to entry: If an intended end-use action leads to an increase in energy consumption, then the energy savings calculated will be negative.

3.18
energy use

manner or kind of application of energy

[SOURCE: CEN/CLC/TR 16103:2010]

EXAMPLE Lighting, ventilation, heating, processes, production lines.

Note 1 to entry: The quantity of the energy applied is expressed as energy consumption.

3.19
energy using system

physically defined energy using item with boundaries, energy input and output

[SOURCE: CEN/CLC/TR 16103:2010]

Note 1 to entry: An energy using system can be a building, a vehicle or a plant but also a part of it, such as equipment, a machine, a product, etc.

Note 2 to entry: Output can be energy, service, product.

3.20
estimation

process of judging one or more values that can be attributed to a quantity

[SOURCE: CEN/CLC/TR 16103:2010]

Note 1 to entry: Estimation by a suitable experienced professional can provide data of a reasonable accuracy.

3.21
facilitating measure

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

[SOURCE: CEN/CLC/TR 16103:2010]

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

3.22
final energy

energy as received by an energy using system

[SOURCE: CEN/CLC/TR 16103:2010]

3.23
free rider effect

energy savings related to a facilitating measure that would have been realised also without the measure

EXAMPLE Free riders make use of subsidy schemes but would have implemented the subsidised end-user action anyway.

3.24
gross energy saving
energy savings before correction

Note 1 to entry: Examples of corrections are technical interaction, double counting, multiplier effect and free-rider effect.

3.25
measurement
process of obtaining one or more values that can be attributed to a quantity

Note 1 to entry: Measurement implies counting and comparison of quantities.

3.26
monitoring
recording and checking of metered and other data over a period of time

[SOURCE: CEN/CLC/TR 16103:2010]

3.27
multiplier effect
ongoing effect of a facilitating measure after the measure has ended

EXAMPLE Temporary promotion of efficient devices changes the market for these devices in such a way that further penetration occurs after the end of the promotion activity.

3.28
normalisation
adjustment of energy consumption over a period for influences that are not to be accounted for in the calculation of energy savings

Note 1 to entry: The correction is done using an adjustment factor that can be smaller or larger than unity.

3.29
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

3.30
renewable energy
energy from a source that is not depleted by extraction

Note 1 to entry: In ISO 13602-1:2002, renewable resource is defined as "natural resource for which the ratio of the creation of the natural resource to the output of that resource from nature to the techno sphere is equal to or greater than one".

EXAMPLE Solar energy (thermal and photovoltaic), wind energy, water power and biomass that is replanted after harvesting.

3.31
saving lifetimes
number of years for which initial savings at implementation of end-user actions remain present

Note 1 to entry: See specified lifetimes in CWA 15693.

3.32
specific energy consumption
energy consumption per physical unit of output

[SOURCE: CEN/CLC/TR 16103:2010]

Note 1 to entry: Specific energy consumption can be defined at subsector level and relates the annual energy consumption to an annual physical production.

Note 2 to entry: In this standard it can also be defined for energy using systems and relates total energy consumption to the number of systems: it is then equivalent to mean yearly energy consumption per system.

EXAMPLE Gigajoule (GJ) per ton of steel, kWh per m^2 of dwelling, kWh per refrigerator, litre/100km for vehicles.

3.33
system boundary
physical or virtual shell around an energy using system, for which each energy transfer through this shell (in and out) is relevant in an energy efficiency and savings calculation

3.34
technical interaction
relation of the elementary unit of action to the surrounding technical system or to other elementary units of actions which influence the unitary energy savings

Note 1 to entry: In case of technical interaction between elementary units of action, the energy savings related to different action may not be simply summed up. For example the combining of thermal insulation and a new efficient boiler in a single property leads to combined savings smaller than the sum of the savings for each measure apart.

3.35
top-down savings
energy savings calculated with top-down methods

3.36
top-down method
determination of energy savings from the variation for energy consumption indicators over a period, starting with aggregate statistics at national or sector level

EXAMPLE For industry, a decrease in energy consumption per Euro of output is not only due to energy savings but also due to changes in the structure of industrial production. Therefore separate indicators are calculated for cement production, steel production, etc. The savings per targeted energy use taken together provide energy savings of industry.

3.37
unitary energy savings
calculated energy savings per elementary unit of action

Note 1 to entry: Also called “unitary gross annual energy savings bottom-up”. The word "gross" means that corrections can be made and "bottom-up" highlights its use in bottom-up calculations only.

4 Characteristics of top-down and bottom-up methods

4.1 Characteristics

This European Standard provides separate top-down and bottom-up calculation methods. Currently no attempt is made to combine the top-down and bottom-up methods into one integrated calculation system.

However, in practice there will be a need to understand how top-down and bottom-up results relate to each other. Therefore, this clause describes the (different) characteristics of both methods with regard to:

- type of EEI measure (4.2);
- type of savings found (4.3);
- type of input data used (4.4);

- system boundaries (4.5).

An overview of the characteristics is presented in Table 1.

4.2 Energy efficiency improvement measure

An Energy Efficiency Improvement (EEI) measure can be a physical, organisational or behavioural action taken at an end-user's site (or building, equipment, etc.) that improves the energy efficiency of that end-user's facilities or equipment, and thereby saves energy. But it can also be an energy service sold to, or an energy efficiency improvement programme offered to this end-user, by an actor (such as the government or a company) distinct from an end-user, with the aim of supporting the end-user in implementing a specific physical, organisational or behavioural action.

In this European Standard, a clear distinction is made between the following two meanings of EEI measure:

- end-user action;
- facilitating measure.

End-user actions are energy efficiency improvement measures implemented by an end-user. Facilitating measures, such as regulation, subsidy schemes or voluntary agreements, stimulate end-user actions.

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. The saving effect of facilitating measures becomes visible in the form of end-user actions and their effect on energy consumption. Therefore, end-user actions are the first focus of the calculation of energy savings. These end-user actions may be of a physical, organisational or behavioural nature.

Top-down methods use energy efficiency indicators such as the mean gas consumption per dwelling to calculate energy savings. These indicators relate energy consumption at a (sub)sectoral level to a “driver” that is statistically representative. For example, energy consumption for space heating is related to the number of dwellings. The change in the indicator value is used to calculate the savings (in the example a lower mean gas use per dwelling). These savings are the result of all end-user actions that focus on the energy use covered by the indicator (in the example this could include roof/cavity wall insulation, double glazing and a high efficiency boiler among other possible measures).

End-user actions can be the result of facilitating measures but they can also be caused by other factors like high energy costs, autonomous progress, market forces or non-energy government policy. The energy indicator values incorporate both the effect of facilitating measures and other factors. Normally, the indicators cannot show separately the effect of facilitating measures.

Some top-down indicators regard energy use at a (very) low aggregation level, e.g. electricity consumption of refrigerators. In that case there could be a direct relation with a specific end-user action (buying a high efficiency refrigerator) and a facilitating measure (a labelling scheme for efficient refrigerators).

Bottom-up methods focus on the saving effect of EEI measures to enhance energy efficiency. The methods can focus on the effect of a facilitating measure, e.g. the energy savings due to an audit scheme. The methods can also calculate the saving effect of an end-user action, e.g. roof insulation for existing dwellings.

In case of facilitating measures, the saving effect will be derived from the effect of the end-user actions stimulated (e.g. for audits the end-user actions recommended by the audit). In case of end-user actions, the saving effect can be directly calculated, and may or may not be linked to one or more facilitating measures.

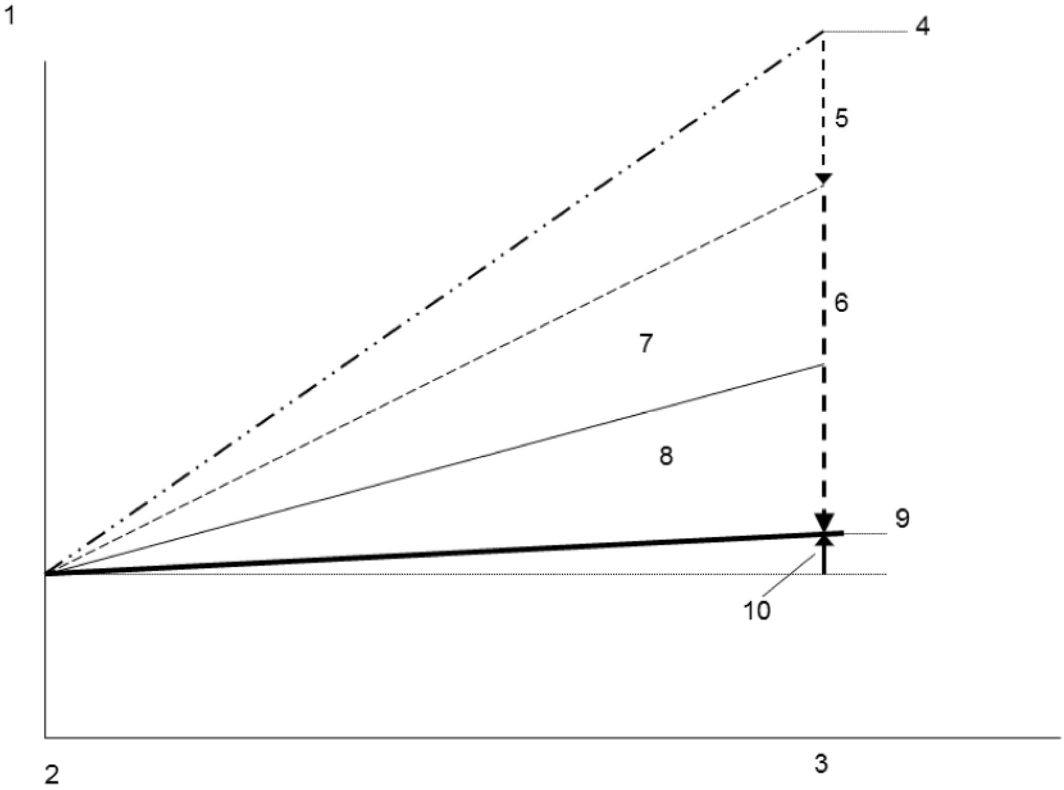
In practice, some bottom-up methods focus on aggregated end-user actions as a result of one or more facilitating measures. For example, the overall savings calculated for new dwellings may result from insulation, high efficiency boilers, heat recovery and solar water heaters, due to energy performance standards, subsidies for solar heaters and voluntary agreements with construction companies. Other bottom-up methods focus on very specific facilitating measures aiming at one end-user action, e.g. a light bulb replacement programme.

4.3 Type of energy savings

4.3.1 Total, autonomous and policy induced savings

Evaluations of energy savings can focus on total savings or policy induced savings. Total savings are important because they determine how actual energy use has changed and may develop. This is shown in Figure 1 where the upper line represents the final energy trend due to the growth in activities, number of energy using devices, etc. between a base year and a target year. Changes in the type of activities can limit the growth in energy use (see structural effect in Figure 1). However, structural effects can also stimulate energy use, e.g. longer opening hours in shops or public buildings. Total savings reduce the growth in energy use, which results in an actual energy use trend. The change in actual energy use can be upwards (see Figure 1), but with greater overall savings it could also be downwards.

A proportion of the total savings can be policy-induced savings which is important from the viewpoint of policy effectiveness, as it shows what policy has actually accomplished.

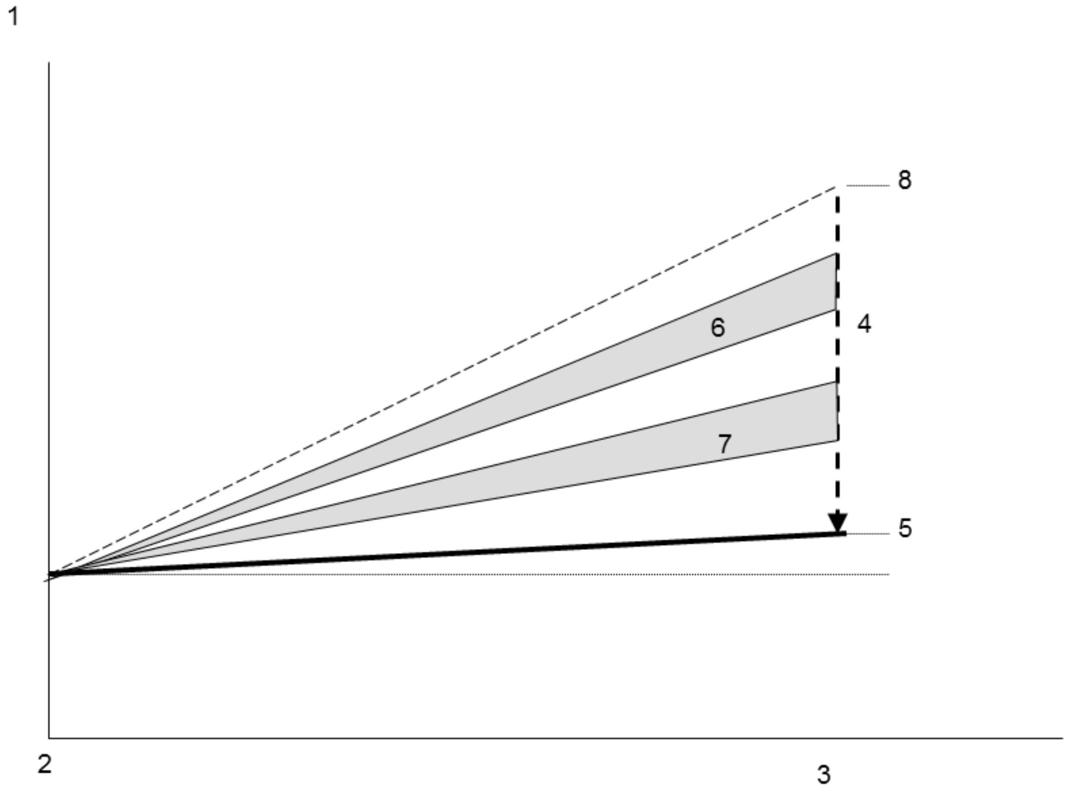


Key

1	energy use	6	total savings
2	base year	7	autonomous savings
3	target year	8	policy-induced savings
4	final energy trend due to growth	9	actual final energy trend
5	structural effect	10	change in final energy use

Figure 1 — Autonomous, policy induced and total energy savings

The difference between total and policy induced savings is known as autonomous savings (see Figure 1). Autonomous savings occur without a deliberate effort to save energy, from either the users themselves or by other actors. These savings can originate from technological progress, e.g. diesel instead of steam engines for rail transport or production of base chemicals at lower temperature when using catalysts. Often autonomous savings are driven by competitive pressure to save energy costs. Therefore autonomous savings may be partly dependent on high energy costs. In practice, the demarcation between policy induced and autonomous savings can be unclear. In Figure 2 the total savings from Figure 1 are shown separately, as the difference between the reference energy trend (due to growth and structural effects) and the actual energy trend. Top-down methods calculate the savings of end-user actions, whether they are the result of facilitating measures (e.g. policy) or due to autonomous developments (e.g. higher energy costs or technological progress). Each top-down method covers a part of energy use, e.g. energy for space heating in dwellings or electricity for industrial uses, and results in calculated energy savings. Figure 2 shows how these calculated savings (TD1 and TD2) contribute to the total savings. With all energy uses covered by top-down cases, the total savings from Figure 1 can then be determined.



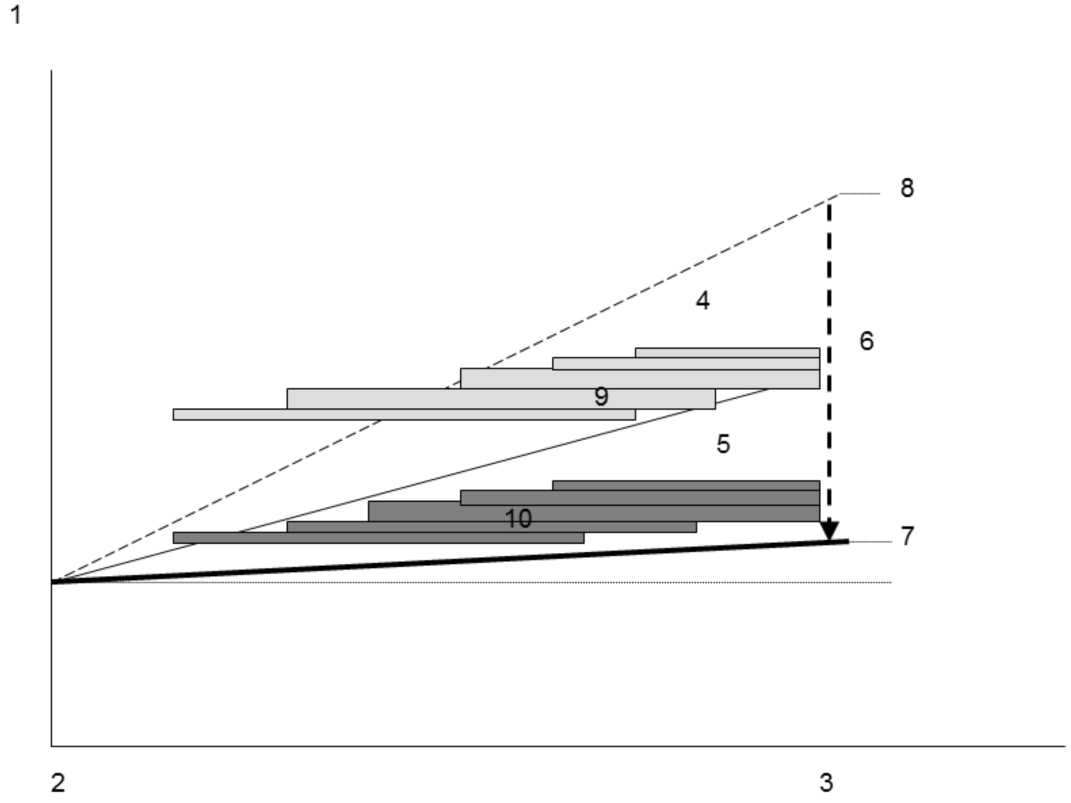
Key

1	energy use	6	case TD 1
2	base year	7	case TD 2
3	target year	8	reference final energy trend
4	total savings		
5	actual final energy trend		

Figure 2 — Total savings and calculated top-down savings

Bottom-up methods focus on savings of specific end-user actions, whether connected to facilitating measures or not. Bottom-up methods can be used to evaluate policy-induced energy savings and total savings. Depending on the choices made around baselines (see Clause 6), the calculation can result in policy-induced savings, total savings or a mix of both.

Figure 3 shows separately the total-, policy- and autonomous savings from Figure1. The figure shows calculated bottom-up savings from two end-user actions, such as insulation (case BU1) and heat pumps (case BU2). The contribution is built up from yearly actions that lead to savings, which may or may not last until the target year. The bottom-up savings can represent only policy induced savings (heat pumps, BU2) or also autonomous savings (insulation, BU1), depending on the specification of the bottom-up method.



Key

1 energy use
2 base year
3 target year
4 autonomous savings
5 policy-induced savings
6 total savings
7 actual final energy trend
8 reference final energy trend
9 case BU 1
10 case BU 2

Figure 3 — Policy-induced/autonomous/total savings and calculated bottom-up savings

4.3.2 Baseline and additional savings

In bottom-up calculations, a baseline should be defined that represents the situation in the absence of end-user actions and facilitating measures. As an example, in the case of a subsidy for high efficiency boilers the baseline can be the “normal” penetration trend of these boilers without the subsidy. The baseline also considers the reference system against which the high efficiency boiler is traded, i.e. the generally installed boiler type. The difference in energy consumption compared to the baseline represents in this example the so-called additional savings of high efficiency boilers.

Both the normal penetration level and the relevant reference system can be uncertain. Therefore additional savings from bottom-up calculations are highly dependent on baseline choices.

For different cases, e.g. refurbishment of dwellings or new dwellings, different baselines are defined. With appropriate baseline choices the calculated additional savings can represent the effect of policy measures. These issues are elaborated on in Clause 6.

In top-down calculations no distinction is made as to the cause of increased penetration of high efficiency boilers. Therefore top-down methods do not need specific baselines and provide only total savings.

4.4 Type of data used

Top-down calculations generally rely on statistical figures at aggregated level, e.g. energy consumption and production in sub-sectors of industry, or total fuel use of cars and the distance driven by the cars.

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

In some cases, the difference in aggregation level between top-down and bottom-up saving calculations becomes very small. For instance, top-down diffusion indicators on solar water heaters may show the same aggregation level as bottom-up analysis of subsidy schemes for solar heaters.

4.5 System boundaries

The system boundary defines the object of assessment and the calculated energy savings. In this European Standard, the system boundary is restricted to energy use by end-users, ranging from a large group (e.g. a sector) to a specific element (e.g. washing machines).

Although end-user actions can only be carried out inside the system boundary, if those actions result in electricity savings, there will usually be extra savings in the power supply system outside the boundary. These extra savings result from lower demand, leading to lower conversion and transmission losses. In order to capture these savings resulting from the end-user action, electricity savings may be optionally expressed in primary units, using a conversion factor (see also 5.3.3.2 and 6.2.2.6).

When calculating energy savings, the use of energy as raw materials, “non-energy uses” are often excluded and only the savings related to a reduction in the energy used for purposes such as heat, light or power are considered.

NOTE Examples of non-energy uses are: petrochemical feedstocks, asphalt, lubricants.

In general, with top-down methods the system boundaries are determined by the statistical definition of the energy consumption figures used (see Annex A). For bottom-up methods, the system boundaries can vary considerably, ranging from almost all end-use when calculating the saving results of a comprehensive audit scheme, to the energy use of a single appliance type in households when calculating the savings of a subsidy scheme for that particular appliance.

Table 1 — Overview of characteristics of top-down and bottom-up calculation methods

	Top-down	**Bottom-up**
Scope per method	Sector, final energy end-use, equipment	Targeted energy use, facilitating measure
EEI measure	End-user actions (aggregated)	End-user actions with/without facilitating measures
Resulting energy savings	Total	Additional (policy) - Total
Data used	Representative statistics at the level of analysis	Monitoring, surveys, test results on equipment, etc.
System boundary	Statistically defined	Dependent on measure

5 Top-down saving calculations

5.1 Energy efficiency indicators

5.1.1 General

Energy efficiency indicators relate energy consumption to a driver, preferably a physical output or the number of energy using systems. The change in the indicator value over a period of time is used to calculate top-down energy savings. Subclauses 5.1.2 and 5.1.3 consider the applicability of indicators for top-down energy savings calculations.

5.1.2 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. 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 eliminate the so-called structure effects due to structural changes is by disaggregation of activities. For instance, instead of analysing the ratio between energy consumption and drivers 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, provided that reliable data is available. Indicators at a lower aggregation level are distorted less by structure effects in the calculation of energy savings.

The indicator can also be corrected for factors that mask actual energy savings. For instance, energy use for space heating may be corrected for the shift from room heating to central heating which will lead 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 will typically provide positive energy savings.

Due to restricted data availability it is not always possible to correct for factors that are considered structure effects. Statistically based indicators represent aggregated changes in consumption for groups of end-users, measuring either their total energy consumption or parts thereof. As well as applying at the national level, indicators can cover smaller geographical units, such as regions or cities, if statistical data is available.

5.1.3 Indicator choice and savings definition

Some factors influencing the indicator value can be regarded as a structure effect but also as part of the energy savings. For instance, the mean fuel use per passenger-km for cars is not only dependent on the efficiency of the engine but also on the weight of the car, changes in the use of air-conditioning, driving patterns (e.g. due to congestion) and the number of passengers in the car.

If the focus is on technical efficiency, corrections should be made for all factors except the engine and transmission efficiency because the other factors constitute structure effects. If the focus is on the overall efficiency of the car, only a correction for traffic conditions and occupants per car is necessary. And if the focus is on the efficiency of transport by car no corrections are needed at all.

Depending on the definition of savings a choice can be made between different indicators. In the car example a choice is possible between “litre/passenger-km” and “litre/km”. If the focus is also on limiting car use (e.g. encouraging the use of bicycles or public transport), the indicator “litre/car/year” is a more appropriate indicator.

In the following general calculation of top-down savings no choices are made as to the appropriate indicator. The user of the standard shall decide what type of indicator fits best to the focus and preferred scope of energy savings. Depending on this choice, corrections shall 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, such as the energy consumption of all non-electric fuels 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 accuracy of the calculated savings.

5.2 General calculation of top-down energy savings

5.2.1 Calculation approach

Calculation methods are generally composed of two main elements:

1) a calculation model or formula, including normalisation;

2) data collection and parameters to be used (Annex A).

In the following clause, subject I, the general top-down calculation model, is described. Subject II, data collection and parameters, is part of the calculations for specific top-down indicators. Therefore, it is not treated here, but in Annex A.

The calculation steps are as follows:

- definition of indicator types (5.2.2);
- calculation of indicator values (5.2.3);
- calculation of energy savings per indicator (5.2.4).

Other issues related to the steps of the calculation of top-down energy savings are described in 5.3.

5.2.2 Definition of indicator types

For top-down energy savings calculations, the following indicator types can be used.

5.2.2.1 Indicator type A.

Type A, specific energy consumption at sub-sector level, relates energy consumption to physical production (e.g. MJ/tonne of steel) for a given period, usually a year. At the sector level, such as the whole industry, where physical production is not of a uniform nature, no such indicator can be defined due to the diversity of production. Therefore specific energy consumption is generally 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 in constant prices. This driver acts as a proxy for physical output.

5.2.2.2 Indicator type B.

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 use per system: (e.g. GJ/dwelling, kWh/refrigerator or litres of petrol per car). If size is used, a typical indicator would be GJ/m^2 of building floor space.

5.2.2.3 Indicator type C.

Type C, diffusion indicators that show the penetration of energy saving systems, is sometimes used where annual energy consumption data is 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.

EXAMPLE Examples of diffusion indicators are the number of energy efficient cars or appliances.

Specific energy consumption indicator types A and B differ as to the type of driver (5.2.3.2), i.e. the item which energy consumption is related to. However, the same calculation method is used to calculate savings with these types of indicators. Diffusion indicators form a special category for which alternative calculation rules apply.

5.2.3 Calculation of indicator values

5.2.3.1 Normalisation of climate dependent energy consumption

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).

Annual energy consumption figures may be normalised, i.e. corrected for yearly deviations from average climate that influence energy consumption (see Formula 1). Normalisation may take into account space heating and space cooling. Normalisation is necessary for sectors with significant use of energy for heating or cooling (e.g. mainly residential and tertiary sectors).

$$NEC(t) = EC(t) \times SHC(t) \times AF + EC(t) \times [1 - SHC(t)] \qquad (1)$$

where

- *NEC* is normalised energy consumption;
- *EC* is annual energy consumption from statistics;
- *SHC* is fraction of yearly consumption dependent on climate;
- *AF* is adjustment factor for climate (larger or smaller than unity);
- *t* is year of calculation.

For heating, the normalisation is based on the number of degree-days, representing the number of degrees that the mean temperature over the day is below a given threshold value during the heating season. This may vary between countries: for example in France a threshold temperature of 18 °C is applied, but in the UK 15,5 °C is used instead. The adjustment factor is usually defined as 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. For example Eurostat calculates the long-term mean on a period of 25 years.

NOTE 1 Some countries have 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 change the period (moving reference period), which means that the number of normal degree-days varies from year to year.

The correction is only applied to the part of energy consumption that is climate dependent. For households the fraction SHC covers space heating but not energy use for hot water or cooking. If no data is available the fraction can be estimated. The correction can be further restricted to a certain fraction of the space heating consumption (e.g. 90 %), to account for the fact that energy consumption proves not to be entirely dependent on degree-days. If degree-days differ substantially between regions of a country, the national data should be weighted with reference to population.

NOTE 2 For example in ODYSSEE only 90 % of space heating energy consumption is corrected. Some countries require other fractions to be used for normalisation.

For cooling, the approach is similar and uses a number of cooling degree-days, i.e. the number of summer days with a temperature above a given level, which is usually several degrees higher than the base used for heating degree-days.

Normalisation does not comprise corrections for other adjustment factors, such as occupation rate for buildings or production level. In the aggregated top-down calculations occupation rate is not dealt with. The adjustment factor for changes in production level is already covered when the indicator type A relates energy consumption to production.

5.2.3.2 Definition of driver types

Energy consumption per subsector or 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 production

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

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 or index of production for a factory producing multiple products.

- 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 is needed as energy savings are directly calculated from the savings per system and the number of systems. Therefore no driver is needed.

5.2.3.3 Calculated indicator values

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

$$IND(t) = \frac{NEC(t)}{DV(t)} \tag{2}$$

where

IND	is indicator value;
NEC	is normalised energy consumption;
DV	is quantity for driver;
t	is year of evaluation.

5.2.3.4 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. the proportion of dwellings equipped with solar water heaters or percentage of commuters using public transport.

5.2.4 Calculation of energy savings per indicator

5.2.4.1 Change in indicator value

For specific energy consumption indicators (i.e. all 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.

$$CIND = IND(t_0) - IND(t) \tag{3}$$

where

$CIND$	is change in indicator value;
IND	is indicator value;
t_0	is base year;
t	is year of evaluation.

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

$$CDIND = DIND(t) - DIND(t_0) \tag{4}$$

where

$CDIND$	is change in diffusion indicator value;
$DIND$	is diffusion indicator (number or fraction) of saving systems;
t_0	is base year;

t is year of evaluation.

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 proportion, e.g. for solar boilers the proportion of dwellings equipped with such a boiler, the change in the proportion shall be multiplied by the number of dwellings.

5.2.4.2 Energy savings per indicator

For top-down indicators except diffusion indicators (type C), the energy savings per indicator are calculated from the change in indicator value times the driver quantity in the year of evaluation (see Formula 5).

$$ESPI = [IND(t_0) - IND(t)] \times DV(t) \qquad (5)$$

where

$ESPI$ is energy savings per indicator;

IND is indicator value;

DV is quantity for driver;

t_0 is base year;

t is year of evaluation.

For example, the energy savings for cement production at year t are derived from the decrease 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, energy savings are calculated as follows (see Formula 6).

$$ESDI = [DIND(t) - DIND(t_0)] \times DS(t) \qquad (6)$$

where

$ESDI$ is energy savings per diffusion indicator;

$DIND$ is diffusion indicator value;

DS is deemed savings;

t_0 is base year;

t is year of evaluation.

The calculation of deemed (estimated) energy savings is part of the description of specific indicators (Annex A).

The calculated energy savings per indicator represent savings for:

- a given sector or sub-sector or targeted end-use (type A);
- an energy-using system (type B or type C).

5.3 Other issues in the calculation of top-down savings

5.3.1 General

The calculation of top-down savings raises the following technical issues associated with the steps in the preceding clauses.

5.3.2 Calculation alternatives

5.3.2.1 Smoothed indicator values

Annual indicator values sometimes show large fluctuations, even after normalisation for climate. Apart from imperfect data, other factors, such as short-term business cycles, can cause these effects. Deviations for the first and last year (which determine the total effect over a period) are to be particularly avoided. For that reason, it is recommended to use three year moving average values instead of annual values for the indicators

NOTE The method traditionally used in statistics to calculate the three years moving average is to take for year *t* the average of t_{-1}, t and t_{+1}. However, data for the last observed year cannot be obtained, using years t_{-2}, t_{-1} and *t* allows rolling saving figures to be calculated, possibly at the cost of some accuracy.

5.3.2.2 Moving base year calculation

Top-down 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 may depend on the 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.

EXAMPLE 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 preferred for top-down savings calculations.

5.3.2.3 Driver quantity for base year or for year of evaluation

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

The results applying base year or evaluation year will be different, depending on the magnitude of variation for the driver quantity, as shown in the following example:

EXAMPLE The average 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 evaluation 2008, electricity savings are (400 – 300) x 1 000 000 = 100 GWh. With the driver quantity for the base year the savings are (400 – 300) x 600 000 = 60 GWh.

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 5.3.2.2).

5.3.3 Energy consumption units

5.3.3.1 Unit of consumption

Energy consumption and savings can be expressed in various units, such as Joule, m^3 for gas, litre for motor fuels, kWh for electricity or toe (for historical reasons). Monitoring bodies can express the energy savings in the most appropriate unit, e.g. litre of motor fuel for energy savings in cars. However, in calculations according to this European Standard, these figures should be converted into the SI unit for energy consumption Joule (MJ, GJ or PJ).

5.3.3.2 Energy savings in primary units

National statistical offices and Eurostat provide energy consumption data in final energy terms. 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. Electricity is more efficient than gas, oil, coal or biomass in end-use heating because no conversion losses are incurred. However, the production of electricity causes substantial conversion losses elsewhere.
- Underestimation of the total savings generated by electricity savings because the avoided conversion losses in power stations are not accounted for.

For this reason, the electricity savings may be calculated on the basis of energy consumption in primary units. 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 will show 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, the Energy Services Directive (ESD) mentions a conversion factor of 2,5 for electricity, meaning that 1 kWh is equivalent to $2,5 \times 3,6 = 9$ MJ in primary units.

NOTE 2 For a country with a high fraction of hydroelectricity or wind, the primary factor will be lower than 2,5; with much coal and nuclear the factor will be higher.

For heat delivered to end-users by a district heating system, a primary units approach can also be applied. In the standard calculation method for district heat uses an energy content basis. But compared to fuel use no conversion losses are incurred at the end-user. 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 electricpower 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 heat

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

into primary units with a primary factor smaller than unity. The lower energy consumption in primary units will lead 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 greater than unity can be used to convert heat consumption into primary units.

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.

5.3.4 Miscellaneous

5.3.4.1 Indicators resulting in negative savings

For energy consumption indicators, such as those presented in Annex A, it is usual for a decreasing indicator value to be found over time, which means that energy savings have been realised. However, in some cases the observed indicator trend shows an increase, resulting in negative energy savings.

This result can correspond to a real decrease in energy efficiency or it may 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 can be decided not to account for these negative savings in the calculation of energy savings.

5.3.4.2 Rating the quality of top-down energy saving figures

The quality of the calculated saving figures can be rated by determining the uncertainty margin for the resulting figures. However, this is rarely done due to the complexity of the procedure. Therefore this European Standard does not provide guidelines for rating the quality of the saving figures.

5.3.4.3 Overall top-down energy savings

Energy saving calculations, using a set of indicators, result in overall top-down energy savings that may be representative of all savings in a sector or country. The total savings are calculated by summing all energy savings derived from each of the indicators that cover 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 top-down energy savings.

6 Bottom-up saving calculations

6.1 Elaboration on the object of assessment

6.1.1 Elementary unit of action and unitary energy savings

Energy savings are realised by end-user actions that can be of a physical, organisational or behavioural nature. Physical actions relate to a change in equipment or systems, often as a result of an investment decision. Organisational actions represent changes in organisational processes that have an effect on energy use. One type of behavioural action is change in personal behaviour concerning daily energy use. For organisational 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:

- physical: all kinds of equipment, buildings as physical unit, vehicle types, specific industrial processes;

- organisational: company, institute, office, shop, school;
- behavioural: appliance user, occupant of dwelling, employee, car driver, participant in efficiency programme.

Examples of unitary energy savings are:

- physical: kWh savings for an “A” labelled refrigerator, m^3 of gas savings for a higher standard new dwelling, lower l/km for a new car, decrease in toe per tonne of cement for a factory;
- organisational: lower energy use of schools with good housekeeping system or companies with an energy management system in place;
- behavioural: lower l/km for participants in eco-driving schemes, decrease in kWh use per household receiving information on actual energy use from an eco monitor.

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

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

6.1.2 Baseline options for end-use actions

In order to calculate energy savings for given end-user actions, the energy use situation shall 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, via the unitary savings, the calculated energy savings of an end-use action.

NOTE 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 saving 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 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; meaning 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; meaning an energy using system for which no previous system has been in use.

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

a) reference situation; for this the two most used ones are:

   1) based on a the existing of the product or systems (the "stock situation");
   2) based on those products or systems currently available in the market (the "market situation").

b) the “before” situation.

Option a) is applicable to add-ons, replacements and new systems. Formulae 9 and 10 in 6.2.2.3 elaborate options a).1) and a).2). 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 case is the technical device that has been replaced.

For new systems, a virtual baseline situation shall 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 existing stock average of equipment serving the same function.

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

For physical, organisational 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 is directly available and in Approach II energy consumption is assessed using parameters, as explained in 6.2.2.2.

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.

6.1.3 Saving types from bottom-up calculations

Bottom-up calculations focus on savings of specific end-user actions using baselines for unitary savings and elementary units of actions. Depending on the choices made about baselines, the calculation can result in policy induced savings, total savings from specific end-user actions or a mixture of both.

Total savings encompass the savings that result from:

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

If the baselines are chosen in such a way that they incorporate autonomous (technological and costdriven) savings, the calculated energy savings are due to policy or actions of other parties. Examples of actions from other parties include environmental campaigns by non-governmental organisations or actions by public housing corporations, labour unions or socially responsible companies.

Baselines can also be defined in such way that the policy induced savings (almost) equal total savings, including autonomous and cost driven savings. For example, when defining the replaced system as the baseline, and counting every replacement irrespective of the cause, the result will represent total savings.

6.2 General calculation of bottom-up energy savings

6.2.1 Calculation approach

Calculation methods are generally composed of three main elements:

- a calculation model or formula including baselines and normalisation;

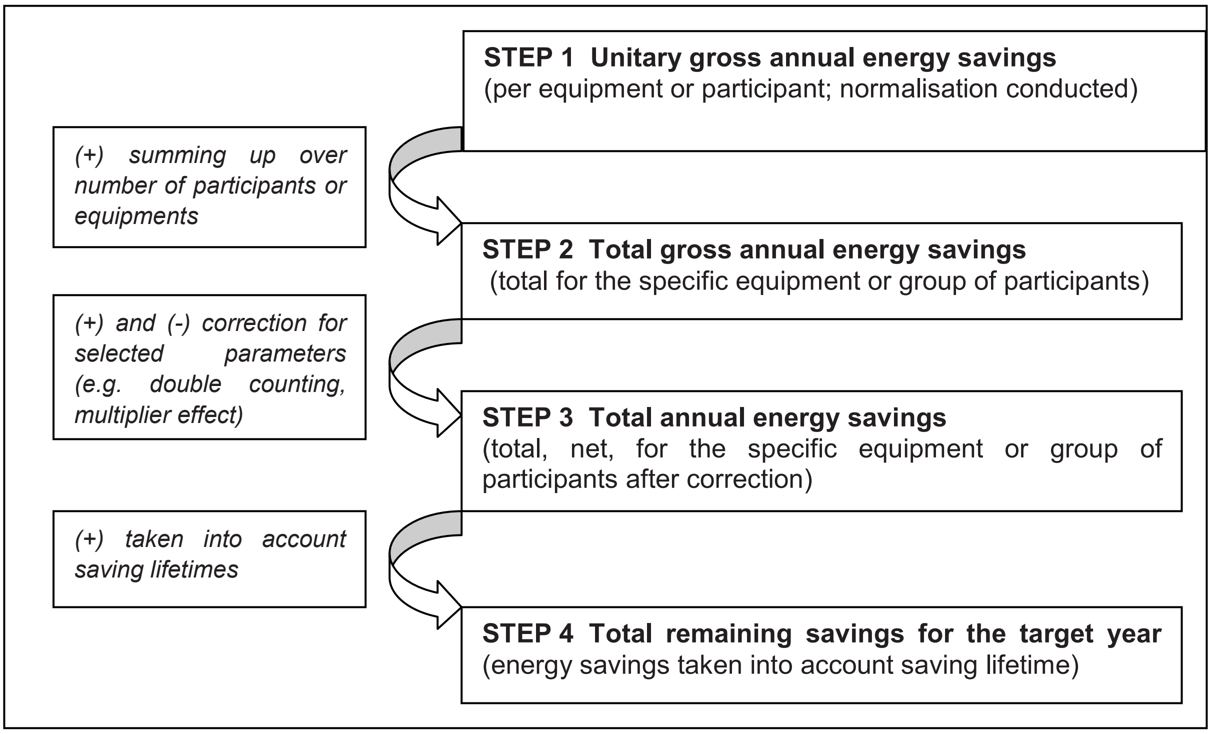
- data collection techniques, for data needed to feed the calculation model;
- a set of reference or default values.

In the following sub-clauses the calculation model is described in detail. These calculations can be done at different levels of detail taking into account data availability and reference values. The level of detail can be chosen at each step in the calculation. Three possible levels in relation to data collection and quality of savings are described in Annex B. Data collection techniques and reference or default values are not described here as they are specific to each individual bottom-up case. An example is given in Annex C for the case of buildings.

The bottom-up calculation of energy savings per end-user action consists of the following steps:

- Step 1: unitary gross annual energy saving;
- 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 target year.

These steps are illustrated in Figure 4 and described in 6.2.2 to 6.2.5. The results from end-user actions can be summed to find the overall bottom-up energy savings for a set of actions, taking into account any overlap, as described in 6.2.6.



NOTE Based on Vreuls et al 2008 [6]; Figure 1: a four steps calculation process.

Figure 4 — Four steps in the calculation of bottom-up energy savings

NOTE 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 multiplied by the number of elementary units (participant, equipment) provides gross annual savings. After correction for factors, to be chosen, annual savings result. Any remaining from prior year actions savings in the target year can be determined using saving lifetimes.

The results per EEI measure are summed up to find the overall bottom-up energy savings. However, if the scope of the two EEI measures overlaps, account should be taken of this overlap (see 6.2.6).

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

Step 1: Calculation of unitary gross annual energy savings

Step 1.a: Definition of elementary unit
Step 1.b: General formula / calculation model
Step 1.c: Baselines and specific formulas
Step 1.d: Normalisation of energy consumption
Step 1.e: Technical interaction
Step 1.f: Application of conversion factors (when relevant)

Step 2: Calculation of total gross annual energy savings

Step 2.a: Calculating the number of elementary units of action
Step 2.b: Summing up the unitary gross annual energy savings

Step 3: Calculation of total annual energy savings

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

Step 4: Calculation of remaining energy savings for target year

Figure 5 — Steps and sub-steps in the calculation of bottom-up energy savings

6.2.2 Step 1: Calculation of unitary gross annual energy savings

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

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

The elementary unit of action can be defined at different aggregation levels, such as 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 this should be taken into consideration. For example for the elementary unit of action “television” the shift from black-and-white to colour, two different elementary units of action can be defined.

Apart from physical systems the elementary unit of action can also represent an organisational entity or a participant (see examples in 6.1.1).

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. If this condition cannot be fulfilled technical interaction shall be taken into account:

1) by identifying, documenting and qualifying the potential technical interactions with the elementary unit of action and their influence on the unitary energy savings;

2) by quantifying the influence of technical interactions on the unitary savings;

3) 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).

6.2.2.2 Step 1.b: General formula

6.2.2.2.1 Two approaches

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

- Approach I for cases where consumption data is available;

- Approach II for cases where consumption data needs to be constructed.

6.2.2.2.2 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 the following formula.

$$UGAES = [GAEC]_0 \times AF_0 - [GAEC]_1 \times AF_1 \tag{7}$$

where

$UGAES$ is unitary gross annual energy savings;

$[GAEC]_0$ is gross annual energy consumption situation without action [baseline];

$[GAEC]_1$ is gross annual energy consumption situation with action;

AF_0 is adjustment factor without action [baseline];

AF_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 (6.2.2.4).

6.2.2.2.3 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 is available or can be estimated. The general calculation formula is:

$$UGAES = function(P_{00,}P_{01}...P_{0n}) \times AF_0 - function(P_{10,}P_{11}...P_{1n}) \times AF_1 \tag{8}$$

where

UGAES	is unitary gross annual energy savings;
$P_{00} \ldots P_{0n}$	are parameters;
AF	is adjustment factor;
$_0$	is the variable without the action (baseline);
$_1$	is the same variable with the action;
function	an algorithm defining gross annual energy use.

In practice in most cases the adjustment factor *AF* does not need to be used as normalisation is achieved by means of modifiable parameters in the formula (see step 1.d).

EXAMPLE: The replacement of a lighting system. For this the relevant parameters are:

- parameter P_{00}: electrical power absorbed by the standard lamps [W];
- parameter F : number of operating hours (h).

The formula for the unitary gross annual energy savings is $P_{00} \times F - P_{10} \times F$

In the replacement of a 60W lamp by a 12W compact fluorescent lamp which both have 2500 operating hours annually, unitary energy savings are 60W x 2500h – 12W x 2500h =120 kWh. It is assumed that there is no change in the area illuminated and thus no need for normalisation.

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:

1) internationally accepted formula;
2) nationally accepted formula;
3) literature sources;
4) self developed and documented.

Preference 1 would typically be from other EN or ISO standards or EU Directives.

Attention should be given to how imperfect datacollection is handled. For example if it is not possible to research directly when whether CFLs are installed. For such a case sales data is used, and the number might be too high as some CFLs are kept in stock in the house (as spare lamps) or replace an older CFL or are not used in the private house but in a small and medium enterprise.

6.2.2.3 Step 1.c: Baselines and specific formulas

6.2.2.3.1 Two approaches

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

6.2.2.3.2 Baseline approach A

A reference situation is selected for the baseline situation. This can be the case for physical, organisational and behavioural actions. The energy consumption is derived from a chosen reference device, such as new equipment, new cars or new buildings. The following two reference cases can be identified (Formulae 9 and 10).

In Formula 9, 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 domestic market or the entire European Union. The unitary energy savings are calculated according to the specific formula:

$$\text{"}market\text{"}\ unitary\ energy\ of\ devices = [energy\ consumption\ for\ present/reference\ market] - [energy\ consumption\ for\ new/efficient] \qquad (9)$$

In Formula 10, stock modelling[2] instead of market modelling is applied to define the reference device**.** The before situation 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 the following specific formula:

$$\text{"}stock\text{"}\ unitary\ energy\ savings\ of\ devices = [energy\ consumption\ for\ average/existing\ stock] - [energy\ consumption\ for\ new/efficient] \qquad (10)$$

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

6.2.2.3.3 Baseline approach B

It is assumed that the “before” situation is a good reference. Often energy consumption data is available, from measured or estimated data (e.g. using energy bills and/or control groups), 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. When this baseline is applied, energy consumption should be normalised using adjustment factors, if this is needed to make the with and without situations comparable (see step 1.d). If energy consumption data is not directly available then gross energy consumption is assessed using parameters that are relevant for energy consumption (see step 1.b)

6.2.2.4 Step 1.d: Normalisation of energy consumption

Normalisation of energy consumption shall be used to ensure comparablility 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 normalised 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;
- level of use of installed equipment (plant throughput) or changes to product mix;
- level of production, volume or added value;

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[2] Stock modelling will lead to similar baselines to the first approach assessing "before" consumption. But input data is different; in the first approach input data is in general energy consumption data.

- schedules for installation and vehicles;
- relationship with other units.

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

The normalisation shall 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, such as space heating for a building. In most cases this fraction will need to be estimated.

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

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

6.2.2.5 Step 1.e: Technical interaction

If there are technical interaction(s) having an influence on the unitary energy savings, this effect shall 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 may result from a relationship with other elementary units of action or with the surrounding physical system.

Where energy consumption data is 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 the unitary energy savings from a boiler exchange can be calculated from consumption data of fuel supply to the building as a whole.

In the case where energy consumption data is 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 will be 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.

6.2.2.6 Step 1.f: Application of conversion factors

The energy consumption and savings can be expressed into various units, such as Joule, m^3, litre, kWh or toe. Often the measure 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 shall be converted to Joule, which is the standard unit for energy consumption (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 may be applicable for distributed heat or when fuel substitution takes place at the same time when energy efficiency is improved (see 5.3.3). To this end the electricity savings are calculated on the basis of consumption in primary units.

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 results in energy savings in primary units that account for avoided losses in energy supply (in power plants and transport and distribution of electricity).

When a primary factor is used, the same value shall be used in energy savings calculations in the before and the after situation as well as for the baseline energy figures.

NOTE If the intention is to determine changes in primary energy use, an additional analysis will be necessary.

6.2.3 Step 2: Calculation of total gross annual energy savings

6.2.3.1 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.

6.2.3.2 Step 2.a Calculation of the number of elementary units of action

The elementary units of action in this step can be (see 6.1.1):

- physical entities or processes: equipment, buildings, vehicle and specific industrial processes etc.;
- organisational entities: company, institute, office, shop, school etc.;
- behavioural entities: employee, car driver or participant in efficiency programme, etc

The best way to sum up these elementary units of action will depend on how the unit is observed or assessed. In general the number of elementary units of action may 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, such as subsidy schemes on specific equipment. In that case, the number of items of equipment subsidised can be used as the number of elementary units of action.

NOTE The same method can be used for voucher schemes (for example, where vouchers are distributed to end users entitling them to obtain energy saving equipment free or at a subsidized rate), or for energy audits, but only where audits are carried out in sufficiently large numbers across sites or other units sharing similar characteristics so that average savings may justifiably be used.

In other cases the number shall 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 how 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 realise energy savings. For example, in an eco-driving programme the elementary unit of action is not the person that is aware of eco-driving but the person that actually and measurably changes their driving style.

6.2.3.3 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 will be 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, building or participant. In this situation, the summing is straight forward and total gross annual energy savings are calculated according to the formula:

$$TGAES\ (individual\ elementary\ unit\ of\ action) = \sum_{i=1}^{n} GAESI(i) \tag{11}$$

where

TGAES is total gross annual energy savings;

GAESI is gross annual energy savings for the individual elementary unit.

The formula can also be used for summing the savings of elementary units of action that regard 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 measures. 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.

- 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 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 11.

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 the following formula:

$$\begin{aligned} &total\ energy\ savings\ (average\ elementary\ unit\ of\ action) = mean\ unitary\ energy\ savings \times \\ &number\ of\ elementary\ units\ of\ action \end{aligned} \tag{12}$$

The mean value shall 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, the formula should be calculated for each version separately where possible and then summed up in accordance with Formula 11.

6.2.4 Step 3: Calculation of total annual energy savings

6.2.4.1 General

In step 3 the total gross annual energy savings are corrected, if necessary. 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.

6.2.4.2 Step 3.a, calculation of total annual energy savings.

Total annual energy savings are calculated according to the formula:

$$TAES = f(DC) \times f(MP) \times f(FR) \times f(RE) \times TGAES \qquad (13)$$

where

TAES	is total annual energy savings;
TGAES	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;
f	is factor.

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

The decision whether or not to take into account factors shall be consistent with the 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.

6.2.4.3 Step 3.b, correction for double counting

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

Double counting cannot be done for one facilitating measure in isolation as it shall be known which other facilitating measures are present. Thus, double counting shall be assessed for each specific situation and expressed as 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. where using both labels and subsidies leads to greater installation of energy efficient equipment than would have occurred from the total of the two actions had they been undertaken in isolation. Therefore, the double counting factor may be larger than unity.

6.2.4.4 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. The promotion of efficient appliances may be so succesful that after some time shops only offer efficient appliances to customers. Accordingly energy savings will be realised after the promotion period. 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 will be larger than unity but is often very difficult to estimate.

6.2.4.5 Step 3d, 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 will be 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 will be smaller than unity.

6.2.4.6 Step 3e, 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 use. 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.

6.2.5 Step 4: Calculation of remaining energy savings for target year

The calculations described in the preceding steps provide energy savings for a certain year in an evaluation period. 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.

CWA 15693:2007 defines the development of energy savings over time. 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:

1) the initial energy savings;

2) the saving period;

3) the divergence from initial energy savings during the saving period.

In defining the saving period for elementary units of actions, the harmonised or calculated saving lifetimes according to CWA 15693:2007 can be used. 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 a certain target year is less than or equal to its lifetime, it counts for the energy savings in this target year and otherwise it does not count at all.

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

- 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 saving 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 is available for each year of the savings lifetime of the end-user action. In other cases – i.e. if energy consumption data is only available for the initial year or if energy consumption data is not available at all – deterioration and the maintenance regime can be reflected by plausible parameters expressing the influence of these factors on energy consumption.

6.2.6 Calculation of overall bottom-up energy savings, taking into account overlap

Elementary units of action can be defined at very different aggregation levels, from overall system, via subsystems to individual components (see 6.1.1).

The choice of aggregation level in savings calculations depends on a number of issues:

- data availability: energy consumption data is 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 items of equipment may be quite straightforward;
- 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 shall be summed to find the overall bottom-up 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 will depend on the type of end-user action. If it relates to two end-user actions, such as cross-sector efficient electric motors and savings on industrial electricity use, the correction follows from the common scope, i.e. the savings for electric motors in industry that are also covered in industrial electricity savings. 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 bottom-up energy savings (taking the overlap factor into account) are calculated according to the formula:

$$OBUES = \sum_{i=1}^{n} \left[ESEUA\,(i) \times overlap\ \ factor\,(i,\,j) \right] \tag{14}$$

where

OBUES	is the overall bottom-up energy savings;
ESEUA	is the energy savings end use action;
overlap factor (i, j)	is the 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.

Annex A
(informative)

Examples of energy efficiency indicators

A.1 Introduction

The top-down savings calculations make use of energy indicators. In order to highlight the application possibilities of the general calculation method, an overview is provided of commonly used energy indicators. These indicators originate from the Odyssee project, financed through the Intelligent Energy Europe programme of the EC, and/or have been proposed by EC to the EDMC (Energy Demand Management Committee).

A.2 Sectors and indicators

A.2.1 Sectors covered

The sectors covered are industry, transport, residential (households) and services (tertiary sector). Agriculture, forestry and fishery are not included as they generally constitute small sectors in terms of energy use. For countries with substantial energy use in greenhouses, a similar approach as in the service sector can be used. The same is true for forestry where an approach similar to industry can be applied.

Energy transformation (central power and heat generation, refineries) is not covered here.

A.2.2 Choice of indicators on energy savings

General criteria for the selection of indicators are:

- Type of savings that need to be measured (definition of energy savings);
- Amount of savings provable with the indicator;
- The need to correct for structure effects;
- The availability and quality of data.

The definition of energy savings depends on the types of drivers behind the changes in energy consumption: economic, technical or behavioural factors. In the first case any reduction in the energy required per unit of economic output (e.g. kWh/€) will be considered as energy saving even if there is no energy saving from a technical viewpoint. To assess technical efficiency, usually the specific energy consumption per physical unit is calculated.

Energy savings can also arise from behavioural changes. In transport, energy savings may result from modal shift, e.g. from car to rail, because transport by train uses less energy per passenger km than by car. Savings for cars may come from an increase in the load factor, possibly due to carpooling. Depending on the type of saving to be measured, a different indicator may be considered. For instance for cars, the indicator litre/vehicle-km is suitable for measuring the technical savings, the indicator litre/passenger–km measures both technical and non-technical energy savings (occupancy rate) and the indicator yearly litre/car also measures savings due to a reduction in mobility by car (e.g. by modal shift to bus, train or cycle).

The second criterion is important if overall energy savings need to be calculated with limited resources with regard to data gathering and analysis. Often 80 % of all savings to be proved come from 20 % of the indicators to be defined.

Indicators on energy savings often include changes in energy consumption that influence the indicator value but are not regarded as part of energy efficiency. These so-called hidden structure effects distort the calculation of the energy savings. For instance, savings calculated from the reduction in the specific energy consumption per dwelling include the effect of larger dwellings. Doing the calculation of savings with the alternative indicator MJ/m^2 will correct for this effect. Another example is the diffusion of central heating which increases energy consumption per dwelling. The technical savings will be underestimated if they are not corrected for the shift from local to central heating, by using an indicator with dwellings “normalised” for the heating system.

Structure effects are connected to the definition of top-down savings that in turn defines the choice of indicators. The chosen indicator defines also what can be regarded as hidden structure effect (see 6.1). If in the examples the policy focus is on lower energy consumption per dwelling, the hidden structure effects mentioned earlier should not be corrected for.

The availability of data defines to a large extent at which aggregation level indicators are defined, and how many indicators can be calculated. Alternative indicators to the “best” indicators are often necessary to cope with possible data gaps. Indicators may therefore be split into preferred indicators and “minimum” indicators. For instance, for countries without data on space heating, the minimum indicator total consumption of fuels per dwelling can be used. However, there is a trade-off between the quality of the calculated savings and the effort put into data collection.

In the following sub-clause, possible indicators are described that can be used in most countries. The calculation of these indicators will be standardised at a later stage. The indicators are grouped to the end-use sectors:

- residential;
- service sectors;
- transportation;
- industry.

A.3 Indicators for the residential sector

A.3.1 General

In the residential sector, energy efficiency indicators can be calculated for:

- space heating;
- water heating;
- large electrical appliances;
- lighting;
- total electricity consumption;
- total non-electricity consumption.

The first four indicators can be calculated if enough data is available. In other cases the calculation of energy savings can be based on the overall indicators for electricity and other energy use.

Large appliances consist of refrigerators, freezers, washing machine, dishwashers, dryers, TV and air-conditioning. If enough data is available, indicators can also be calculated for cooking and for the many smaller electrical appliances (e.g. ICT, coffee machines, and DVD players and digital decoders) that are responsible for an increasing share of household electricity consumption.

A.3.2 Space heating

The indicator represents mean energy consumption for space heating per m^2 of floor space of (occupied) dwellings. The building volume in m^3 or the heated volume can be used as an alternative to m^2 but data on volume are more difficult to be collected.

The calculation encompasses:

- energy consumption for space heating;
- number of occupied dwellings;
- floor space per dwelling or building volume in m^3;
- corrections.

Energy consumption for space heating mainly comprises fuels, such as natural gas, heating oil, some coal and occasionally wood or peat. Delivered heat from a district heating system shall also be taken into account. In some countries, electricity is widely used for space heating. This electricity needs to be subtracted from total electricity consumption and added to energy consumption for space heating.

Energy consumption shall be adjusted to normal climate in order to correct for climate variations from one year to the other, using degree days (see 5.2.3).

The stock of dwellings may be counted at the middle of the year, or taken as the mean of the number by 1 January and by 31 December.

Energy consumption is dependent on the occupation of dwellings,as – for example – summer homes and houses waiting for a new buyer or renter will show quite different energy use patterns. Therefore only dwellings occupied through the year should be considered: the so-called permanently occupied dwellings. The number of permanently occupied dwellings is usually given in the statistics. If information on the number of permanently occupied dwellings is not available, the number of households may be the best proxy (see A.3.7).

The mean floor space per dwelling comprises all living space and usually excludes cellars and attics, which normally are not heated. Therefore it is equal to the heated floor space. For countries in which floor area statistics include attic and/or cellar or other non-heated areas, a correction factor corresponding to the fraction of heated floor space can be introduced.

Depending on data availability and influence on the indicator value, further corrections can be made for:

- the type of heating (central heating, room heating);
- the type of dwellings (detached, in a row or multi-family house/apartment);
- the fuel used: electricity, gas, oil, coal, district heat or biomass.

Room heating generally consumes less energy for heating than central heating as all the rooms are not heated (only some rooms are heated with stoves). In order to enable a correction for central heating, a distinction is made between centrally heated dwellings and dwellings with room heating in the formula of calculation of the total heated area.

NOTE Central heating, as defined by Eurostat, includes district heating, block heating, individual boiler heating and electric heating (if there are convectors in each room).

Detached dwellings have a relatively large shell surface compared to floor surface; for multi-family buildings such as flats or apartments the opposite is true. Therefore energy consumption will differ independently from the differences in floor surface (which have already been dealt with). A correction for type of dwellings may be applied to the normalised energy consumption. However such a correction is only meaningful if the energy savings have to be calculated over a long period as the composition of the dwelling stock only changes slowly.

Fuel substitution, e.g. from coal or oil to gas, leads to a lower energy consumption due to the higher conversion efficiency for gas. Often this lower energy consumption is regarded as energy savings. However, the increased use of biomass (wood) for reduction of greenhouse gas emissions leads to higher energy consumption. Therefore, a correction for fuel switch may be needed.

A.3.3 Water heating

The energy savings are calculated using an indicator on specific energy consumption for water heating per person in a household.

The indicator can incorporate “renewables behind the meter”, e.g. from solar water heaters that will lead to lower fuel or electricity use for hot water. The savings linked to the penetration of solar water heaters can be calculated separately, using a diffusion indicator.

If needed, the overall savings can be split into a contribution of renewable energy sources (e.g. a solar hot water panel) and ”real” energy savings, i.e. more efficiency regardless of the energy source used.

A.3.4 Large appliances

For large electrical appliances the indicator shows electricity consumption per appliance: refrigerators, freezers, washing machines, clothes dryers, dish washers and televisions. The specific consumption can be corrected for the size of the appliances (e.g. small or large refrigerators, expressed in litre of storing capacity) or the intensity of use (e.g. kg of clothes washed and dried per cycle and number of cycles).

A.3.5 Lighting and other appliances

Lighting is combined with other appliances because electricity use for lighting consumption is not known for some EU countries. For other electrical appliances and lighting, the indicator represents electricity consumption per household. An adjustment can be made for the diffusion of more lamps or appliances. However, because lighting has become the most energy consuming “appliance group” in households, it should be encouraged to handle it separately from any other appliances if data is available.

A.3.6 Total electricity consumption

The indicator is defined as total electricity consumption per household. If relevant and possible, substantial consumption of electricity for space heating can be subtracted from total electricity consumption. If no correction is made for increased appliance ownership, the indicator value will increase for most countries and no savings will be found.

A.3.7 Total non-electricity consumption

The indicator represents total energy consumption excluding electricity that is related to the number of households, number of dwellings or income. Normally the number of (continuously occupied) dwellings resembles the number of households.

This indicator can be used to estimate the energy savings for space heating if the earlier presented indicator cannot be calculated due to data constraints. In that case substantial electricity use for space heating should be added to energy consumption (see also A.3.6)

A.4 Indicators for the service sector

A.4.1 General

The service sector comprises public and commercial services. Commercial services include wholesale trade, retail shops, hotels/restaurants, banks, insurance, repair, communication, etc. Public services comprise education (schools, universities), care (hospitals, old-age facilities), culture & sport facilities and government (ministries, municipalities) although in some countries many of these functions may also be provided by the commercial sector.

In the service sector, energy savings should (preferably) be calculated by subsector so as to correct for structural changes in the composition of branches. Following the NACE Rev 2 classification, up to seven subsectors can be considered: administration or public sector, wholesale/retail trade, private offices, hotels/restaurants, education/research and health/social action. It should also be recognised that according to Council Directive 1893/2006/EC, member countries can implement either NACE Rev.2 classification or a corresponding national application which has a similar structure with regard to the general classification.

Energy efficiency indicators can be calculated for:

- Total energy consumption;
- Total electricity;
- Total non-electricity consumption;
- Fuels and delivered heat for heating;
- Electricity for heating for countries with a significant penetration of electric heating;
- Electricity for lighting;
- Electricity for air-conditioning;
- Electricity for ICT and other equipment.

The last four indicators can only be calculated from detailed data. If these data are not available, energy savings can be calculated on the basis of the first three overall indicators.

A.4.2 Total energy consumption

Energy savings can be calculated by relating total energy consumption to the number of employees or the turnover in Euro or national currencies.

When calculating energy savings by branch, energy consumption can be related to branch-specific indicators of activity such as:

- NACE Rev 2 classification;
- wholesale/retail trade: turnover;
- accommodation and food services: number of person-nights;
- education/research: number of pupils/students;
- human health/social work activities number of beds;
- others (public administration or private offices): number of employees.

A.4.3 Total electricity consumption

Total electricity consumption can be related to the number of employees. However, the indicator kWh/employee often shows an increasing trend due to more ICT applications or a higher quality of the indoor environment (air-conditioning).

As an alternative indicator, kWh/Euro can be used. This indicator relates consumption to an output (value added or turnover) instead of an input (employees).

If possible, subsector electricity consumption can be related to the branch-specific activity level. Here as well negative savings can result due to all kind of structural changes that increase specific electricity use.

A.4.4 Total non-electricity consumption

Total energy consumption excluding electricity consists of different fuels and district heating which are mainly connected to space heating. The consumption can be related to number of employees, m^2 of floor space or turnover in Euro. Data on turnover and, to a lesser extent, employees is normally available but the meaning of calculated indicator trends is not clear. For subsectors with many offices, consumption can best be related to floor space, in order to calculate energy savings for space heating.

A.4.5 Fuels and delivered heat for space heating

Buildings in the service sectors can be heated with fuels or with heat from district heating systems.

For heating, a distinction can be made between office buildings for administrative activities and buildings for visitors. For the first type of buildings, energy consumption for space heating should preferably be associated with m^2 of floor space. For visitor-buildings, e.g. shops, restaurants, schools and hospitals, the pattern of energy use can be quite specific. Instead of m^2 floor space the branch-specific activity level can be used.

A.4.6 Electricity for lighting or air-conditioning

This part of electricity consumption is related to m^2 floor space as floor space is the most relevant driver for lighting or air-conditioning. Electricity consumption for air-conditioning can be corrected for yearly variations in the number of warm and hot summer days using cooling degree days.

A.4.7 Electricity for ICT and other equipment

Energy savings may be measured from the specific electricity consumption per employee. For such electricity uses, including cooking and water heating, calculations will usually not show savings because of the growing use of ICT applications. Corrections for increased penetration of ICT devices per employee are needed to show savings.

A.5 Indicators for the transportation sector

A.5.1 General

In transportation there are two ways of saving energy

- improved efficiency of vehicles and driving patterns;
- shifts between transport modes (e.g. from car to public transport).

It is recommended to use the following breakdown by main mode:

- road transport: cars, trucks, vans, motorcycles, buses;

- rail transport: goods or passengers;
- domestic air transport;
- water transport (barges).

For each main mode of transport, an indicator relates the energy consumption to the transport performance. For passenger modes, the performance is generally measured in passenger-km and for goods in ton-km.

For road transport, a further split can be made between types of vehicle: cars, trucks, vans, buses and motorcycles. For rail, a further split between passengers and goods can be made.

If data is not available by type of road vehicle, savings will be directly calculated for road transport as a whole. However, the aggregate indicator trend will incorporate structure effects, such as shifts between vehicle types.

NOTE Reduction of transportation activity (e.g. by working at home) can be a source of energy savings, but it is difficult to capture with indicators that relate energy consumption with a transport performance, such as km driven. To calculate savings from less transport, one needs to define a common performance quantity for the transportation case and the non-transportation case. For working at home the common performance could be “doing the task of the job” but this already raises many questions about the comparability of the “performance”. Thus due to the lack of data and its still low contribution, this type of savings is not considered here. A bottom up approach is therefore much appropriate to evaluate savings for this type of analysis.

A.5.2 Fuel use in cars

The larger part of fuel consumption for transportation is used in cars. Therefore it is important to apply a calculation method that is as detailed as possible. Total savings for cars can be broken down into several different types:

- savings linked to improvement in the technology of cars (less l/km for a standard driving cycle);
- savings from buying cars that are smaller or less powerful;
- savings due to changes in driving behaviour (e.g. lower speed or eco-driving);
- savings from increased car occupancy (e.g. due to car pooling).

To measure these savings separately, the following indicators are necessary:

a) Mean fuel use of new cars (in litre/100km) captures both the technological savings and the savings resulting from a shift to smaller or less powerful cars. These last savings can be calculated as the difference between the detailed calculation per type of new car (e.g. by class of efficiency) and the fleet average calculation.

b) Mean specific fuel use of the total car stock (in litre/100km) which shows the combined effect of technological improvements and changes in driving behaviours. Savings due to driving behaviour are equal to savings calculated with indicator b minus savings calculated with indicator a.

c) Mean fuel use of car transport (in litre/passenger-km) will capture all types of savings; it incorporates in addition changes in the car occupancy rate (number of persons in the car). Energy savings coming from car pooling are equal to the total savings minus savings calculated with indicator b.

To measure the savings linked to fuel substitution between different fuels, the savings can be separately calculated for km driven for each fuel type and then summed. The difference with the result for a calculation on the total stock of cars (i.e. all fuels together) indicates the effect of fuel substitution, which can be a positive saving or a negative saving.

In the future, with electric cars and cars on alternative fuels, litre/km should be replaced by a more common unit, such as MJ/km or ktoe/km.

A.5.3 Fuel use in road freight transport

Another large part of fuel use is for freight transport by road. This includes lorries, trucks and vans (light vehicles). The following indicators can be calculated:

- mean vehicle fuel consumption (litre/100 km);
- mean transport fuel consumption per unit of traffic (litre/tonne-km).

The first indicator shows technological savings for new vehicles but also the effects of driving more slowly and eco-driving. However, the calculated savings also incorporate the effect of congestion.

The second indicator also shows managerial energy savings from a smarter use of the vehicle fleet, such as a higher load factor, reduced empty trips and capacity increase (larger maximum load per vehicle).This indicator will provide total savings. The difference compared to the savings from the first indicator represents logistic efficiency savings.

A.5.4 Energy use for other modes

For the other modes, the following indicators can be defined to calculate energy savings:

- buses: fuel per passenger-km;
- motorcycles: fuel consumption per vehicle;
- domestic air transport: fuel consumption per passenger-km;
- rail transport of passengers: energy consumption per passenger-km;
- rail transport of goods: energy consumption per tonne-km;
- water transport of goods: fuel consumption per tonne-km.

For rail and air transport of persons, the indicator will normally be energy consumption per passenger-km as the consumption per vehicle differs too much due to their very different capacity.

A.6 Indicators for the Industry sector

A.6.1 General

For industry, energy savings can be calculated by industrial branch, taking account of the amount of energy consumption per branch. The breakdown corresponds to the two or three-digits levels according to the NACE REV 2 classification [3], i.e.:

- mining;
- construction;

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[3] Ref : EUROSTAT 2008 Statistical classification of economic activities in the European communities NACE Rev 2; ISSN 19977-0375

- food & beverages;
- textiles & leather;
- pulp & paper and printing;
- chemicals;
- transformation of rubber & plastics;
- non metallic minerals (building materials);
- steel;
- non ferrous metals;
- fabricated metals;
- machinery;
- transport vehicles;
- other.

A.6.2 Energy-intensive industry

Energy intensive industries are split further in order to have an output of a homogeneous nature. For example the base metal industry can be split into iron & steel and non-ferrous (aluminium, zinc, etc.) and building materials can be split into cement, bricks, etc. This enables indicators to be defined based on the physical output, e.g. tonnes of steel or cement.

For these energy intensive branches, the specific energy consumption is calculated as the ratio between the final energy consumption of the branch and the production measured in physical units (e.g. kilotonne).

For countries with a large energy consumption for some energy intensive products, such as cement, steel, petrochemicals, a further breakdown by type of product or process could be made to measure savings linked to changes in the process mix, provided that the data is available. In that case, energy savings can be separated into two components: savings linked to changes in process mix (e.g. from oxygen to electric steel, or from wet process to dry process for cement) and savings from energy efficiency improvements within each process (e.g. better housekeeping, heat recovery, preheating).

For countries with significant structural changes within some subsectors (e.g. in the chemical industry, from heavy chemicals to cosmetics or pharmaceuticals) a further breakdown is needed to correct the calculated savings for these structural changes.

A.6.3 Other industrial branches

Where no physical production can be defined, the energy consumption can be related to the turnover or added value in Euro.

Annex B
(informative)

Level of detail and data handling in bottom up calculations

B.1 Levels of detail in savings calculations

Calculations can be done at three levels of evaluation efforts (see Figure B.1). These levels represent minimum, intermediate or enhanced efforts.

These levels also define:

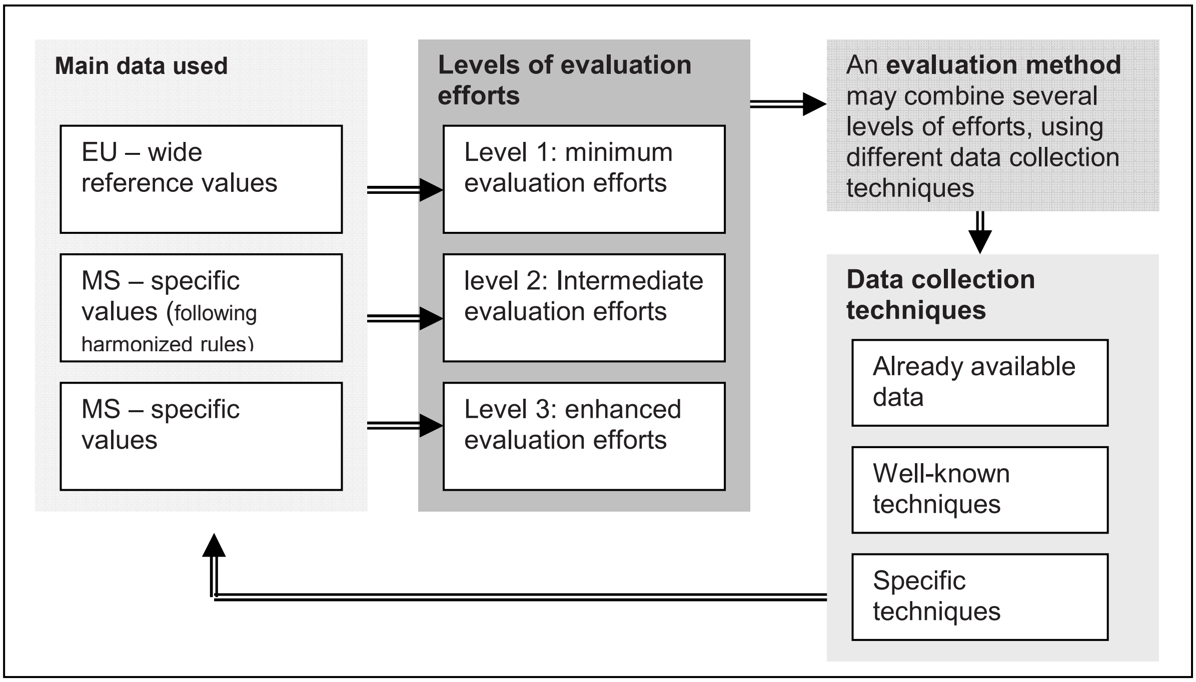
- the type of data used;
- the amount of harmonisation between EU countries.

The data used can be already available, gathered by well known methods or it can be specific data that requires tailored collection techniques.

Reference values, such as deemed savings, constitute EU values at level 1, values per country at level 2 and values per measure at level 3.

The level of detail can be chosen per calculation step as defined in Clause 6, e.g. the use of an EU-default value (level 1) for the unitary savings (in step 1) and specific values per country state (level 2) for the number of participants (in step 2).

The three level approach leads to an optimal trade-off between evaluation costs and accuracy, i.e. between the effort on calculation and data gathering and the quality of the resulting saving figures. The trade-off can be dependent on the situation in various countries.



[SOURCE: Broc et al [13]; modified. Figure 3 levels of evaluation efforts related to data collection techniques,]

Figure B.1 - Three levels of calculation and harmonisation

B.2 Harmonisation and data handling

When the standard on savings calculations is applied to concrete cases there is a need for harmonisation of parameters applied in the different European countries. The possible harmonised reporting on the bottom up evaluation is structured according to the three levels of effort described earlier and summarised in the EMEEES final report (see Table B.1).

The three levels correspond to the situations that may occur when one wants to evaluate the energy savings related to a given EEI measure:

- there is only limited data about this measure (e.g. number of participants) and calculations are conducted using general (European) default values (= level 1 evaluation);
- energy savings can be evaluated by using mainly data available at national level (e.g. national statistics or surveys); additional documentation on the quality of data and data collections is conducted and general accepted rules are applied (= level 2 evaluation);
- energy savings can be evaluated by using mainly (detailed) data specific to the evaluated measure (e.g. registry of participants' data); at least standard reports for all major data sources are prepared (= level 3 evaluation).

Table B.1 — Three levels of harmonisation and data handling

	Data scale	Main data sources	Data processing and documenting
Level 1	European default values	existing/available European regulation, studies and statistics	Reliability coefficient according to the data basis for the default value
Level 2	National representative values	up-to-date national statistics, surveys, samples, registries	requirements = minimum set of data and justifications to be reported
Level 3	Programme- or Participant-specific	specific monitoring systems, registries, surveys, measurements	requirements to report on the specific data and justifications in detail (standard report at least available)

[SOURCE: Vreuls et al 2008 (6);Figure 2: three levels of harmonisation]

Default values at level 1 could to be set to a conservative level to reduce the chance of overestimation of savings.

General guidelines at level 2 can comprise guidelines (evaluation toolbox) and minimum requirements (thresholds or quality criteria to ensure a minimum quality level, e.g. minimum size of samples) etc.

At level 3 the same guidelines and minimum requirements are present, but they are applicable at a more detailed level and other evaluation tools may also be needed (e.g. measurement campaigns, enhanced engineering analysis).

Annex C
(informative)

Bottom up application for buildings; boiler replacement

C.1 Introduction

This annex holds the application of the standard to buildings and presents options for more detailed calculation methods at effort level 2 and 3, as presented in Annex B.

The annex holds that elements can be included in calculations, but holds no minimum level or minimum requirements of elements that shall be included;

Standards in the Energy Performance of Buildings Directive (EPBD) give the possibility of calculating the energy use of a building and the saving of energy by changing the conditions and/or the equipment. The calculation results are collected together in EN 15603:2008. An overview of the EPBD standards is given in CEN/TR 15615.

Terms and definitions are those presented in CEN/TR 15615. No additional terms and definitions are needed for the example on energy savings from replacement of heating supply equipment in residential and tertiary buildings.

The entity for which the energy savings are calculated can be very different. A systematic approach is chosen to organise the objects into four separate areas, arranged from ‘broad’ to 'specific':

1) The source of the change: an external action;

2) The system, this is perceived as the central element and could be a building (house, commercial building, school, etc), an organisation (service centre, government, etc), a region (city area, town, region, etc) or a service (energy management);

3) The subsystem. Among the subsystems, the following items could be selected: heating and cooling, ventilation, building envelope, lighting, group of communication appliances, group of food and drinks appliances, group of cleaning appliances;

4) The individual component. An individual component is a product. Examples are boilers, air-conditioners, fans, insulation material, light bulbs, computers, TVs, fridges and washing machines.

It is of vital importance to define the system boundaries correctly for attributing energy efficiency results to the system by which they have been generated. The definition of the system boundary shall encompass the subsystems and components that interact with the object of assessment.

One option is to consider the system as a black box. In that case it is not important in what subsystem or component the changes occur. The energy saving is the difference between the (measured) energy use at the system level without and with the action.

EXAMPLE 1 Energy saving for improvement of the insulation of the building envelope can consider the building as physical boundaries. There is no need to know whether the change was in the roof, wall or floor insulation or in replacement of windows or glass. The metered energy use attributed to heating for the building is the start of the energy savings calculation.

Another option is to measure or estimate/calculate energy consumption for a subsystem or a component. In this case there are two ways for summing the savings. The first is to sum each of the components' savings. The other is to add the different component savings within the subsystem together and sum the subsystems.

EXAMPLE 2 Energy savings for changeover of a boiler can be restricted to the component 'boiler' or seen as a change in the subsystem heating.

EXAMPLE 3 Energy savings from changing a boiler can be measured in combination with a change in the water temperature, the radiators or the insulation of the pipework, and can collectively be considered as a change to the subsystem "heating".

If a part of a building system (e.g. boiler, chiller, cooling tower, etc.) is located outside the building envelope but forms part of the building services assessed, it is considered to be inside the system boundary, and its system losses are therefore taken into account.

C.2 Potential examples of calculations

The building approach consists of three main categories of end-use actions: retrofitting, replacement and new. Each category has elements in the bottom up energy savings calculation that differ from the others (e.g. selected baseline, directly availability of energy consumption data). Examples are presented for these categories below.

In future bottom-up applications, the following examples on energy savings calculation for each category could be developed.

a) Category 1 (retrofitting and operational improvements; add-ons):

   1) refurbishment measures in existing residential and tertiary buildings (building envelope and heating system);

   2) insulation refurbishment measures applied to building shell in existing residential and tertiary buildings (walls, roofs, windows);

   3) lighting in tertiary buildings (system or components);

   4) setting of the controller (e.g. setting of the correct design temperature, the correct heating curve or the correct using time).

b) Category 2 (replacement):

   1) replacement of heating supply equipment in residential and tertiary buildings;

   2) replacement of water heating equipment in residential and tertiary buildings;

   3) replacement of air-conditioning split systems in residential and tertiary buildings;

   4) replacement of household appliance (cold appliances, washing machines, dishwashers, televisions, etc.) in residential buildings;

   5) replacement of office equipment in tertiary buildings;

   6) replacement of lighting in residential buildings (lamps);

   7) replacement of lighting in tertiary buildings (lamps).

c) Category 3 (additional new energy efficient equipment or construction of new energy efficient buildings*):*

   1) new building constructed according to building codes in new residential and tertiary sectors;

   2) new office equipment in tertiary buildings;

   3) installation of new air-conditioning split systems in residential and tertiary buildings;

4) new installation of heating supply in residential and tertiary buildings;

5) solar water heating in residential and tertiary buildings;

6) new lighting in residential buildings (lamps);

7) new lighting in tertiary buildings (system or component).

C.3 Example for category 2: Replacement of heating supply equipment in residential and tertiary buildings[4]

C.3.1 Step 1: calculation of unitary gross annual energy savings

Unitary savings are dependent on the definition of the elementary unit of action (participant or technical system). The calculation is dependent on the level of evaluation effort (see Annex B). At level 1 the energy consumption is equal to the purchased (= measured) energy for the elementary unit. In level 2 the delivered energy from one participant/technical system to another external participant/technical system (not an energy distribution company) is taken into account. Level 3 gives possibilities to include special items for energy savings, like energy savings in the entire product life cycle.

The calculation of the energy savings can be done on the level of the participants, systems and subsystems. The calculation of energy savings within systems and subsystems in buildings requires different formulae, because of diverging variables per unit/system and subunit/system. The relevant formulae are shown below, starting with the calculation of the unitary annual energy saving per unit relevant for each of the energy efficiency improvement measures or programmes. Afterwards the bottom-up formula for calculating the unitary gross annual energy savings, by means of which the total energy savings per participant can be calculated, will be addressed.

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

The example deals only with a boiler.

b) Step 1.b: General formula

Most components, including boilers, are not separately metered or monitored, so there will be no data on energy consumption available. Therefore *Approach II, energy consumption data is not directly available,* is used.

$$UGAES = \left(\frac{1}{N_0} - \frac{1}{N_1} \right) \times SHD_i \times A \quad [kWh/unit \times year] \tag{C.1}$$

where

UGAES is unitary gross annual energy savings;

N_0 is mean annual energy efficiency of the heating supply equipment before the replacement action (seasonal);

N_1 is mean annual energy efficiency of the new heating supply equipment (seasonal);

SHD_i is Specific Heating Demand [kWh/unit x yr];

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[4] This example is based on the EMEEES bottom-up case application 4, residential condensing boilers [14].

A	is average area of the space heated by the heating supply equipment (household, office, etc.) [m^2];
0	is situation without action [baseline];
1	is situation with action.

The formula is only applicable when only the boiler is changed and the other conditions remain the same. If more actions are taken, technical interaction (see step 1.e) should be considered.

There is no need for an adjustment factor as the specific heating demand (SHD) is already normalised.

There are several options to obtain the values for N_0 in the formula. For the baseline situation, the options are related to the selection of a baseline (see step 1.c).

For the SHD there are three options for a (standard) value:

1) an EU average;

2) a national average;

3) a building specific value.

For the average area of the space heated *A*, there are the three options for a (standard) value:

4) an EU average, that could be more specific e.g. for type of building;

5) a national average, that could be more specific e.g. for type of building;

6) a building specific value.

The calculations for a minimum level of effort (level 1) will use the EU average for *SHD* and heated surface *A*.

EXAMPLE For the EU average of 3207 Specific Heating Demand (*SHD*), an EU average area of the space heated of 86kWh/m^2 (values from [15] Table 3 page 17 and Table 4 page 18) the formula will be

$UGAES = (1/N_0 - 1/N_1) \times 86 \times 90$ kWh

The calculation for intermediate and enhanced level of effort (level 2 and 3) will use national or building specific values for *SHD* and *A*.

For the level 2 and level 3 calculations, in case of using the standard EU average efficiency of equipment, the efficiency of the replaced or adjusted heating system can be determined by means of the following formula:

$$\begin{aligned}&Efficiency\ of\ replaced\ or\ adjusted\ heating\ system =\\&efficieny\ of\ replaced\ boiler \times efficiency\ of\ replaced\ emitter\end{aligned} \tag{C.2}$$

The formula for calculating the energy efficiency of the more efficient or adjusted heating system is as follows:

$$\begin{aligned}&Efficiency\ of\ the\ more\ efficient\ or\ adjusted\ heating\ system = efficiency\ of\ the\\&efficient\ boiler \times efficiency\ of\ the\ efficient\ emitter \times efficiency\ of\ the\ efficient\\&distributi on\ network \times efficiency\ of\ the\ efficient\ controller\end{aligned} \tag{C.3}$$

At least one of the components in the latter formula shall be more efficient than before. The existing efficiency of the remaining components can then be used to complete the formula for determining the efficiency of the adjusted heating system.

c) Step 1.c: Baseline for unitary savings

In the baseline approach with a reference situation (Approach A), one can use two options: market or stock. The reference market for each could be the domestic market or the entire European Union. The reference could be specified for non-condensing boilers or for condensing boilers. The choice results in different values of N_0 in the formula and in different unitary gross annual energy savings.

In approach A1 market modelling is for (non)condensing boilers:

1) A1a: N_0 is mean annual energy efficiency of the average non-condensing boiler on the market

EXAMPLE For the EU market for non-condending boilers, the mean efficiency of 89 % is chosen (value from [14], Table 1, page 14). Assuming that the new boiler has an efficiency of 96 %, then

$UGAES$ = (1/0,89 –1/ 0,96) × 86 × 90= 634 kWh

2) A1b: N_0 is mean annual energy efficiency of the average condensing boiler on the *market*

EXAMPLE For the EU market for condensing boilers the mean efficiency of 94 % is chosen (value from [14], Table 1, page 14). Assuming that the new boiler has an efficiency of 96 %, then

$UGAES$ = (1/0,94 –1/ 0,96) × 86 × 90= 172 kWh

In approach A2 stock modelling instead of market modelling is applied to define the reference device. The before situation is based on (average) existing boilers. The reference stock could be on a selected regional level (EU, national, region). The energy savings are calculated according to the following specific formula:

3) A2a: N_0 is mean annual energy efficiency of the average non-condensing boiler in the *stock*

EXAMPLE For the EU stock for non-condending boiler the mean efficiency of 82 % is chosen (value from [14] Table 2 page 16). Assuming that the new boiler has an efficiency of 96 %, then

$UGAES$ = (1/0,82 –1/ 0,96) × 86 × 90= 1377 kWh

4) A2b: N_0 is mean annual energy efficiency of the average condensing boiler in the *stock*

EXAMPLE For the EU stock for condensing boiler the mean efficiency of 93 % is chosen (value from [14] Table 1 page 14). Assuming the the new boiler has an efficiency of 96 %, then

$UGAES$ = (1/0,93 –1/ 0,96) × 86 × 90= 260 kWh

In approach B, the calcualtion proceeds as follows:

N_0 is mean annual Energy efficiency of the old boiler (in the *before* situation)

EXAMPLE Assuming that old boiler has an efficiency of 80 % and the new boiler 96 %, then

$UGAES$ = (1/0,80 –1/ 0,96) × 86 × 90 = 1612 kWh

d) Step 1.d: Normalisation

There is no need for normalisation here as the specific heating demand (*SHD*), which is calculated according to ISO 13790, is already normalised.

e) Step 1.e: Technical interaction

Technical interaction is applicable in case the building code holds standards for *separate* efficiency measures: boiler replacement in combination with insulation results in lower energy use for the boiler. As the calculation method is in conformity with the EPBD methodological framework in this example, interaction effects are already incorporated in the calculation method.

f) Step 1.f: Application of conversion factors (when relevant)

The conversion factor is relevant in situations where the replacement of the boiler is combined with a change in energy carrier (fuel). For example the old boiler might have used oil, while the new boiler is fired by gas or by wood, the litre oils, m^3 gas and m^3 wood need to be converted into an equivalent into Joule.

C.3.2 Step 2: total gross annual energy savings

The total gross annual energy savings are the result of adding up the gross unitary energy savings for the individual boilers. The total gross annual energy savings are now calculated as:

$$TGAES = \sum_{i=1}^{c} UGAES \tag{C.4}$$

where

TGAES is total gross annual energy savings;

UGAES is unitary gross annual energy savings;

C is the number of units.

EXAMPLE For baseline option A2a (EU stock for non-condensing boiler), where the unitary gross annual energy savings is 1377 kWh, and a number of 20000 boiler replacements, the formula will be

$TGAES = 20,000 \times 1151,8 = 27540$ kWh

C.3.3 Step 3: total annual energy savings

Step 3.a: Formula for total annual energy savings

Total annual energy savings are calculated according to the following formula:

$$TAES = f(DC) \times f(MP) \times f(FR) \times f(RE) \times TGAES \tag{C.5}$$

where

TAES is total annual energy savings;

TGAES 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;

f is factor.

Step 3.b: Correction for double counting

Double counting is important when more than one facilitating measure is stimulating the replacement of the boiler, e.g. a local energy plan and a national subsidy scheme both promoting replacement by high efficient boilers.

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. The promotion of the boiler may be so successful that after the facilitating period, the less efficient one will no longer be on the market and a market transformation is realised. This can be added to the direct energy savings due to the promotion measure.

Step 3.d: correction for free-rider effect

Free riders are participants or consumers who would have implemented the end-use action also in absence of the facilitating measure(s) being evaluated.

EXAMPLE There is research estimating an EU average of 20 % of purchasers that would have selected a condensing boiler without facilitating measures as subsidies. But this value may be much higher in countries where high efficient boilers already have a high market share.

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 use. It could happen that the occupants set the thermostat at a higher temperature because heating proves to be less costly than before. In this case the rebound factor is relevant.

C.3.4 Step 4: total remaining energy savings for target year

Only those end-use actions that have not reached the end of their energy saving lifetime in the target year will be counted.

EXAMPLE The EU default/harmonised energy saving lifetime for small boilers in the CWA 15693:2007 holds: 17 years. Therefore the maximum number of annual savings to be accounted for in the target year is 17.

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