CEN/CENELEC JWG 4 N55

Date: 2010-03-18

TC JWG 4 N55 WI 004001

CEN/CENELEC JWG 4 N55

Secretariat: NEN

Energy efficiency & Savings Calculation, Top-down and Bottom-up methods

Version 18 March 2010

Unedited, not for distribution or citation

ICS:

Descriptors:

Document type: European Standard
Document subtype:
Document stage: Working Document
Document language: E

Contents

Page

Foreword....3
1 Scope 5
2 Normative references 5
3 Terms and definitions 5
4 Characteristics of top-down and bottom-up methods....10
4.1 Characteristics 10
4.2 Energy efficiency improvement measure 10
4.3 Type of energy savings....11
4.4 Type of data used 13
4.5 System boundaries....14
5 Bottom-up saving calculations 14
5.1 Elaboration on the object of assessment 14
5.1.1 Elementary unit of action and unitary energy savings....14
5.1.2 Baseline options for energy efficiency improvement actions 15
5.1.3 Saving types from bottom-up calculations....16
5.2 General calculation of bottom-up energy savings....17
5.2.1 Calculation approach 17
5.2.2 Step 1: Calculation of unitary gross annual energy savings 19
5.2.3 Step 2: Calculation of total gross annual energy savings 23
5.2.4 Step 3: Calculation of total annual energy savings 25
5.2.5 Step 4: Calculation of remaining energy savings for target year 26
5.2.6 Calculation of overall bottom-up energy savings, taken into account overlap 27
Annex B (informative) Detail and harmonisation in bottom up calculations 28
B.1 Levels of detail in saving calculation....28
B.2 Harmonisation and data handling 29
Annex C (informative) Bottom up application for buildings; boiler replacement....30
Introduction....30
Potential examples for the Calculations....31
Example for category 2: Replacement of heating supply equipment in residential and tertiary buildings 31
Step 1: calculation of unitary gross annual energy savings....31
Step 1.a: Definition of the elementary unit of action....32
Step 1.b: General formula 32
Step 1.c: Baseline for unitary savings....33
Step 1.d: Normalisation....34
Step 2: total gross annual energy savings 34
Step 3: total annual energy savings 35
Step 3.a: Formula for total annual energy savings 35
Step 3.b: Correction for double counting....35
Step 4: total remaining energy savings for target year 35
Bibliography....36

Foreword

This document (TC JWG 4 N55 WI 004001) has been prepared by Technical Committee CEN/CENELEC/TC JWG 4 N55 "Energy Efficiency and Energy Savings Calculation", the secretariat of which is held by NEN.

This document is a working document.

Introduction

Due to the energy supply problems and the necessity 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 a national indicative energy savings target of 9% for 2016. This target is to be reached by way of energy services and other energy efficiency improvement measures.

The formulation of policies and targets has led to the need for harmonized monitoring and evaluation methods on energy savings at the international and 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.

CEN and CENELEC have been requested to develop one or several European standards taking into account these needs. The European standard(s) to be developed shall cover the following topics:

— the methodology and general rules of calculation,

— terminology and definitions,

— parameters and data, including data quality and data sources.

This draft concerns 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 regards the saving effect of various (policy) measures to enhance energy efficiency. For top-down the standard uses the results of earlier indicator work for the European Commission in the ODYSSEE[1)] project. For bottom-up the standard builds on the results of the EMEEES[2)] 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 EC driven ESD.

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

The 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 (section 3) and terms and definitions (section 4) the characteristics of the top-down and bottom-up methods are presented in section 5. The top-down calculation method is described in section 6 and the bottom-up calculation methods in section 7. Annex A specifies example indicators to 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) 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.

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

1 Scope

The 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.

The standard covers energy consumption in all end-use sectors, both end-use that is subject to the ESD and to the Emission Trading System for CO_2. The standard does not cover energy supply, e.g. power stations.

The standard regards savings on energy supplied to end-users; therefore renewable energy "behind-the-meter" (e.g. solar water heaters) can be included in the calculated energy savings.

The standard provides saving calculations for any period chosen. However, restrictions for concrete applications, such as short data series, can limit the period.

2 Normative references

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

CWA 15593:2007, *Saving Lifetimes of Energy Efficiency Improvement Measures in bottom-up calculations.*

EN 15603:20XX, *Energy Performance of Buildings – Overall energy use and definition of energy ratings.*

EN ab-c:199x, *General title of series of parts — Part c: Title of part.*

3 Terms and definitions

For the purposes of this European standard, the following terms and definitions apply

Terms and definitions for specific top-down and bottom-up cases are presented in the description of the specific top-down and bottom-up cases (see annex A on indicators and annex C on buildings).

3.1
adjustment factor
quantifiable parameter affecting energy consumption

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

3.2
baseline
energy consumption calculated or measured, possibly normalised, in the situation without an energy efficiency improvement action

3.3
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++, fraction of passenger transport by public modes or transport of goods by rail and water.

3.4
double counting
claiming energy savings more than once for two or more facilitating measures that focus on the same end-user action

NOTE 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.

3.5
driver
quantity that is assumed to define the development of energy use under consideration

NOTE A driver can be an activity (e.g. production) but also a state of a system (e.g. floor space).

3.6
elementary unit of action
the entity for which unitary energy savings can be defined and summed up

NOTE Generally it regards an energy using system or a participant in an energy savings programme.

3.7
end-user action
an energy efficiency improvement measure implemented at an end-user's site

3.8
energy carrier
substance or phenomenon that can be used to produce mechanical work or heat or to operate chemical or physical processes [ISO 13600:1997]

NOTE 1 The energy content of fuels is given by their gross (=lower) calorific value.

NOTE 2 Examples of energy carriers are coal, petrol, gas and electricity.

3.9
energy consumption
amount of energy used

NOTE 1 Although technically incorrect, energy consumption is a widely used term.

NOTE 2 The unit of energy consumption can be expressed related to the involved energy carrier but also in standard units as Joule, kWh or TOE.

NOTE 3 The manner or kind of application of energy is expressed as energy use.

3.10
energy efficiency
the ratio between an output of performance, service, goods or energy, and an input of energy

NOTE 1 Both input and output has to be accurately defined in quantity and quality, and be measurable.

NOTE 2 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 Commonly used meaning of energy efficiency is doing at least the same with less energy

3.11
energy efficiency improvement
increase in energy efficiency as a result of technological, behavioural and/or economic changes

3.12
energy efficiency improvement action
achievement of technological, behavioural or economical changes providing a verifiable and measurable energy efficiency improvement

3.13
energy efficiency improvement measure
action normally leading to verifiable and measurable or estimable energy efficiency improvement

NOTE The term “energy efficiency improvement measure” (EEI measure) is generally used in a context of support frameworks. In other contexts the term “energy efficiency improvement action” is preferable.

3.14
energy efficiency indicator
quantity relating energy consumption to the adjacent socio-economic driver, value indicative of the energy efficiency

NOTE 1 a driver can be physical or economic output, number of energy using systems or quantities relevant for energy use.

NOTE 2 mainly used as a metric in macroeconomic evaluation of energy efficiency.

3.15
energy end-use
energy use, not for transformation into energy carriers to be delivered to other users

3.16
energy end-user
ultimate energy user consuming energy for final use

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

NOTE 2 Energy end-users can be grouped using the European statistical NACE code system.

3.17
energy intensity
energy consumption per financial unit of output

3.18
energy savings
gross energy savings corrected for selected parameters

NOTE Depending on the definition of energy saving used within a specific framework the gross energy savings can be corrected for elements not included in the adjustment factors. Examples of such parameters are technical interaction, double counting, multiplier effect and free-rider effect.

3.19
energy use
manner or kind of application of energy

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

NOTE The quantity of the energy applied is expressed as energy consumption.

3.20
energy using system
physically defined item with boundaries, energy input and output

NOTE 1 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 Boundaries must be clearly delimited.

NOTE 3 Output can be energy, service, and product.

3.21
estimation
process of judging one or more values that can be attributed to a quantity

3.22
facilitating measure
an energy service sold to, or an energy efficiency improvement programme offered to an energy end-user by an actor targeted to implementation of end-user actions

NOTE A facilitating measure is offered by an actor that is not the energy end-user.

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 savings
change of energy consumption following implementation of one or more energy efficiency improvement actions

NOTE 1 Change is measured against a baseline after applying adjustment factors.

NOTE 2 Energy savings can be potential following an assessment or actual after implementation of actions.

NOTE 3 If an intended energy efficiency improvement action leads to an increase in energy consumption, then the energy savings calculated will be negative.

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

NOTE 1 Measurement implies comparison of quantities and includes counting of entities.

NOTE 2 Estimation is not measurement.

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

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

NOTE Temporarily promotion of efficient devices changes the market for these devices in such a way that further penetration occurs after ending 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 The correction is done using an adjustment factor that can be smaller or larger than unity.

3.29
rebound effect
a change in energy using behaviour that yields an increased level of service and that occurs as a result of taking an energy efficiency improvement action

EXAMPLE Households on low incomes often take some of the benefits of energy efficiency improvements to their home in the form of higher internal temperatures, and so use more energy than might be calculated from the measures installed.

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

NOTE 1 Examples of renewable energy are solar energy (thermal and photovoltaic), wind, water power and renewed biomass.

NOTE 2 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".

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

NOTE See CWA15593

3.32
specific energy consumption
energy consumption per physical unit of output

NOTE Specific energy consumption can be defined at subsector level and relates the annual energy consumption to an annual physical production. It can also be defined for energy using systems and relates total energy consumption to the number of systems: it is then equivalent to an mean yearly energy use per system.

EXAMPLE Gigajoule (GJ) per ton of steel, kWh per m^2 of dwelling, kWh per refrigerator, litres/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
relations 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: In case of technical interaction between elementary units of action the energy savings related to different actions may not be simply summed up. E.g. for the combination of thermal insulation and a new efficient boiler the combined savings are 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 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 Also written as unitary gross annual energy savings bottom-up. Gross depicts that corrections can be made and bottom-up highlight the use in bottom-up calculations only.

4 Characteristics of top-down and bottom-up methods

4.1 Characteristics

The standard provides separate top-down and bottom-up calculation methods. For the moment 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 section describes the (different) characteristics of both methods as to:

— type of EEI measure;

— type of savings found;

— type of input data used;

— system boundaries.

An overview is presented in Table 1.

4.2 Energy efficiency improvement measure

An Energy Efficiency Improvement (EEI) measure can be a technical, organizational or behavioral 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 program offered to this end-user, by an actor (e.g. government or a company) not being an end-user, with the aim to support the end-user in implementing a specific technical, organizational or behavioral action.

In this standard a clear distinction is made between the two meanings of EEI measure:

— end-user action;

— facilitating measure.

End-user actions are energy efficiency improvement measure implemented at an end-user's site. 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, the end-user actions are the first focus of the calculation of energy savings. These end-user actions may be of a technical, organisational or behavioural nature.

Top-down methods use energy efficiency indicators, e.g. mean gas consumption per dwelling, to calculate energy savings. These indicators relate energy consumption at (sub)sectoral level to a "driver" that is statistically representative. E.g. 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 resultant of all end-user actions that focus on the energy use covered by the indicator (in the example roof/cavity wall insulation, double glazing and a high efficiency boiler).

End-user actions can be the result of facilitating measures but can be realised as well by other factors like high energy prices, autonomous progress, market forces or non-energy government policy. The energy indicator values incorporate the effect of all relevant facilitating measures. However, the indicators cannot show separately their combined effect, let alone the individual effect of a facilitating measure.

Some top-down indicators regard 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 stimulated end-user actions (e.g. for audits the saving measures mentioned in the audit). In case of end-user actions the saving effect can be directly calculated, and coupled to one or more facilitating measures or not.

In practice most bottom-up methods focus on aggregated end-user actions, as a result of one or more facilitating measures. E.g. the overall savings for new dwellings with insulation, high efficiency boilers, heat recovery and solar water heaters, due to energy performance standards, subsidies for solar heaters and voluntary agreements with building companies.

4.3 Type of energy savings

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, together with the effects of economic growth and structural changes, how energy use will develop (see Figure 1). Policy induced savings are important from the viewpoint of policy effectiveness, as they show what policy actually accomplishes.

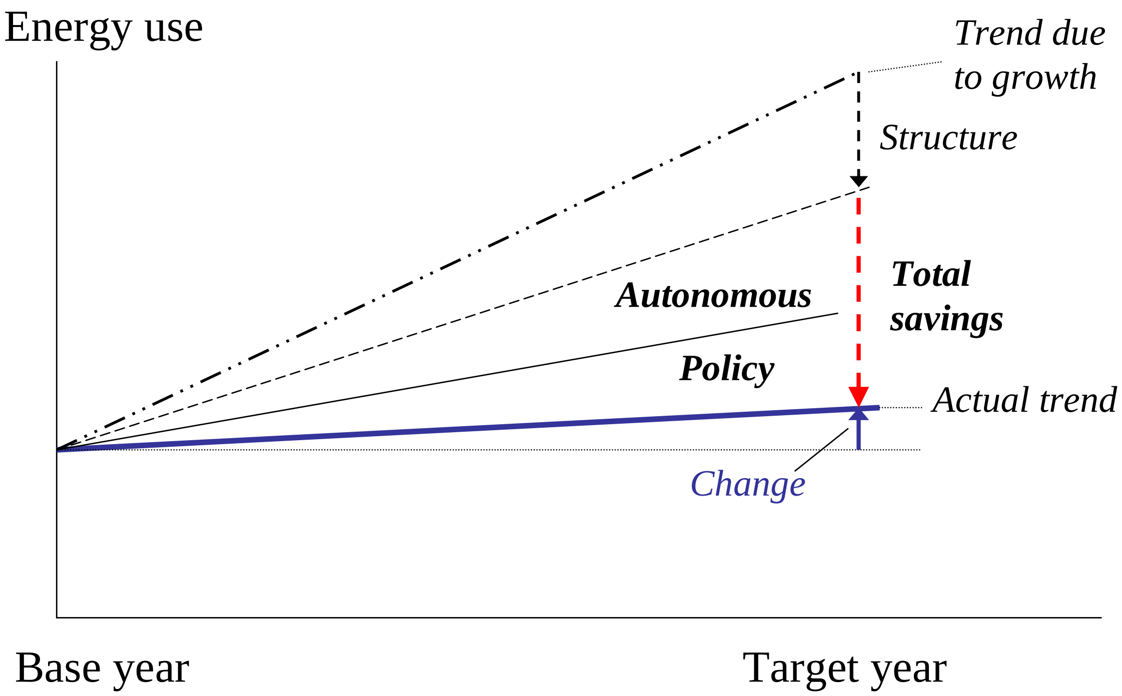


Figure 1 — Autonomous, policy induced and total energy savings

The difference between total and policy induced savings constitutes autonomous savings (see Figure 1). Autonomous savings are realized without a deliberate effort, neither from the users themselves nor by other actors, for the sake of energy savings alone. 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 will be partly dependent on high energy prices.

Top-down methods calculate the total savings of all end-user actions, whether they are the result of facilitating measures (e.g. policy) or due to autonomous developments (e.g. higher energy prices or technological progress). In Figure 2 it is shown how the calculated savings for indicators (TD1 and TD2) contribute to the total savings. With all energy used covered by indicators the total savings are found (see chapter 5).

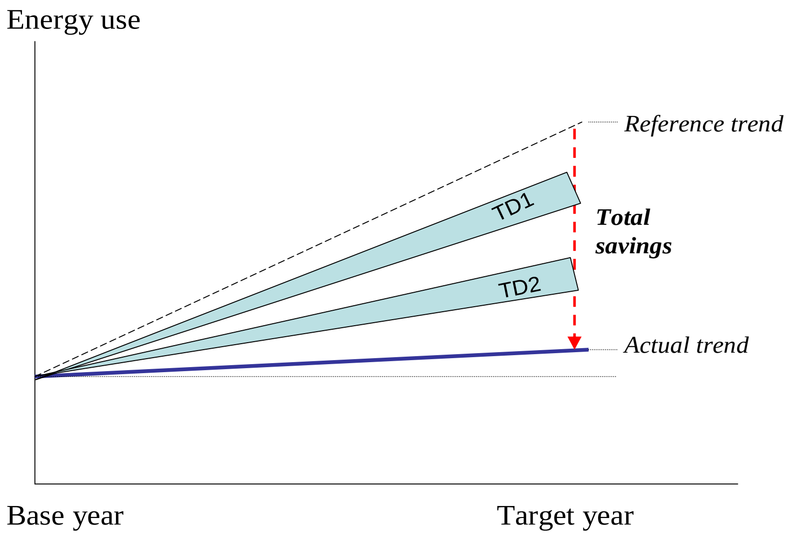


Figure 2: Total savings and calculated top-down savings

Bottom-up methods focus on savings of specific end-user actions, whether in connection to facilitating measures or not. Very often bottom-up methods are used to evaluate energy savings due to policy. Depending on the choices made as to baselines the calculation can result in policy induced savings, total savings from specific end-user actions or a mix of both.

In Figure 3 it is shown how calculated bottom-up savings from end-user actions (BU1 and BU2) contribute to policy/autonomous/total savings presented in Figure 1. The contribution is build from yearly actions that lead to savings, which will last or not up to the target year. Whether the bottom-up savings represents policy induced savings (BU2) or also autonomous savings (BU1) depends on the bottom-up methods (see chapter 6).

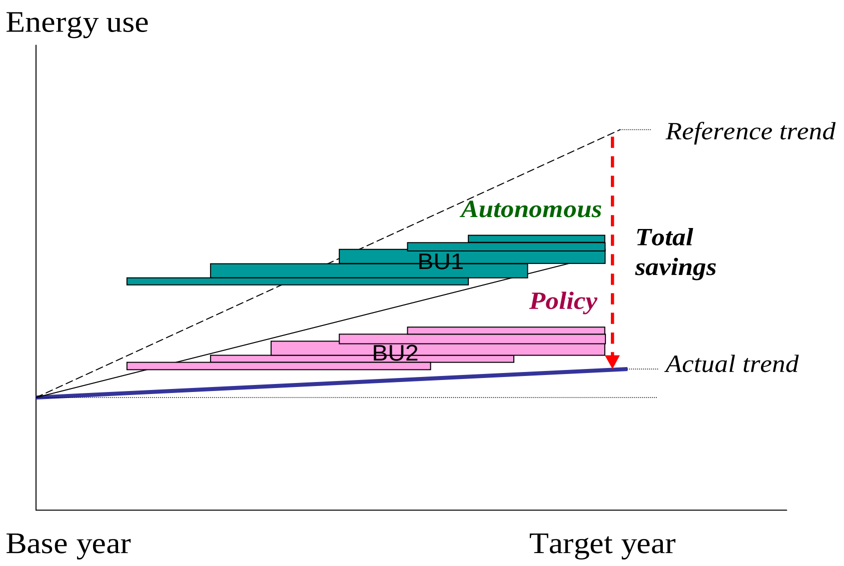


Figure 3: Policy/autonomous/total savings and calculated bottom-up savings

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 the facilitating measures. E.g. in 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 regards the reference system against which the high efficient boiler is traded, e.g. the standard boiler. The difference in energy consumption compared to the baseline represents the so-called additional savings of high efficiency boilers.

Both the normal penetration and the reference system can be ambiguous. Therefore additional savings from bottom-up calculations are highly dependent on baseline choices. With appropriate baseline choices the calculated additional savings may represent the effect of policy measures.

In top-down calculations no distinction is made as to the reason for the 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

In general top-down calculations 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 km driven with the cars.

Bottom-up calculations normally ask for detailed data, such as the number of subsidy allowances or the sold appliances per 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 show the same aggregation level as bottom-up analysis of subsidy schemes for solar heaters.

Table 1 Characteristics of top-down and bottom-up calculation methods

	Top-down	Bottom-up
Scope per method	Sector, part of sector, technology	Targeted energy use, policy measure
EEI measure	End-user actions (aggregated)	End-user actions with/without facilitating measures
Resulting energy savings	Total	Additional (policy) - Total
Data used	Statistical	Surveys, etc.
System boundary	Statistically defined	Dependent on measure

4.5 System boundaries

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

In case of electricity most of the savings are realised outside end-use, namely at the power stations where electricity is produced with considerable conversion losses. In order to capture these savings outside the system boundary, electricity savings can be expressed in primary units[3)], using a conversion factor. However, this approach is optional.

Generally when calculating energy savings the use of energy as raw materials, the so called "non energy uses"[4)] are excluded and only the savings related to a reduction in the energy used for energy purposes are considered.

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

5 Bottom-up saving calculations

5.1 Elaboration on the object of assessment

5.1.1 Elementary unit of action and unitary energy savings

Energy savings are realised by end-user actions that can be of a technical, organisational or behavioural nature. Technical actions relate to a change in physical systems, often as a result of an investment decision. Organisational actions represent changes in organisational processes that have effect on energy use. Behavioural actions regard changes in personal behaviour as to daily energy use. For organisational and behavioural actions there generally is no need for substantial investments.

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

---

3) Consumption of end-users expressed in primary units must not be confused with primary energy consumption at the supply side of the energy system

4) E.g. petrochemical feedstocks, asphalt , lubricants

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

— technical: 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:

— technical: kWh savings for a label A refrigerator, m^3 of gas savings for a new dwelling with stricter standard, lower l/km for a new car, decrease in toe per ton of cement for a factory;

— organisational: lower energy use of schools with good housekeeping system or company with 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.

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

1) the overall system, such as a building, production process, road transportation of persons, an organisation, a region or a service;

2) the subsystem, such as heating/cooling/ventilation, building envelope, lighting, car, communication, compressed air;

3) individual components, such as boilers, air-conditioners, appliances, internal combustion engine of a car, electric motors, etc.

5.1.2 Baseline options for energy efficiency improvement actions

In order to calculate energy savings for given end-user actions the energy use situation must be compared to a baseline situation, i.e. the situation without the energy efficiency improvement action. Baselines should be defined for the unitary energy savings. The chosen baseline influences, via the unitary savings, the calculated energy savings of an energy efficiency improvement action[5].

For technical energy efficiency improvement actions different baselines 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 technical features added to an existing technical system to improve energy efficiency while maintaining its original function.

— replacement; replacing a technical system with one with the same function but with better energy efficiency.

— new system; meaning an energy using system for which no previous system is in use.

[5] 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 instance, the autonomous penetration of efficient electric motors needs to be taken into account when determining the extra penetration due to a subsidy scheme.

There are two approaches for selecting the baseline situation:

a. a reference situation; for this the two most used one are:

   1. based on a stock situation

   2. based on a market situation

b. the before situation.

Option a is applicable to add-ons, replacements and new systems. Equation 9 and 10 in section 6.2.2.3 elaborates these options a.1 and a.2. Option b is applicable to add-ons and replacements cases. This option b is not applicable for new systems (that do not replace another one) because there is no concrete 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 replaced technical device.

For new systems, a virtual baseline situation has to be defined/created, e.g. for new dwellings with stricter standards this could be the dwelling according to one of the existing standards. The new device could also be compared with other options, such as the market average or stock average of the device.

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

For technical, organisational or behavioural actions it is possible to distinguish between estimated or measured energy efficiency improvements, these are called Approach I and II and elaborated in section 6.2.2.3.

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

5.1.3 Saving types from bottom-up calculations

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

Total savings encompass the savings that result from:

- ongoing technological development;
- end-user actions driven by (higher) energy prices;
- technical, organisational or behavioural actions due to policy (facilitating measures);
- other technical, organisational or behavioural actions.

If the baselines are chosen in such a way that they incorporate autonomous (technological and price driven) savings, the calculated energy savings are due to policy or actions of other parties. Other actions from non-governmental organisations could be campaigns in the field of nature protection by environmental organisations or actions by public housing corporations, labour unions or social responsible companies.

The user of the standard can also define such baselines that the policy induced savings (almost) equal total savings, including autonomous and price driven savings. E.g. in case of defining the replaced system as the baseline and counting every replacement irrespective of the cause, the result will represent total savings.

5.2 General calculation of bottom-up energy savings

5.2.1 Calculation approach

Calculation methods generally are 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 sections the calculation model is described in detail. These calculations can be done at different levels of detail regarding data needs and reference values. Per step the level of detail can be chosen. The calculation level in relation to data collection and quality of saving figures is treated in Annex B. The data collection techniques and reference/default values are not described here as they can only be specified for concrete bottom-up cases. For the building case an example is given in Annex C.

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

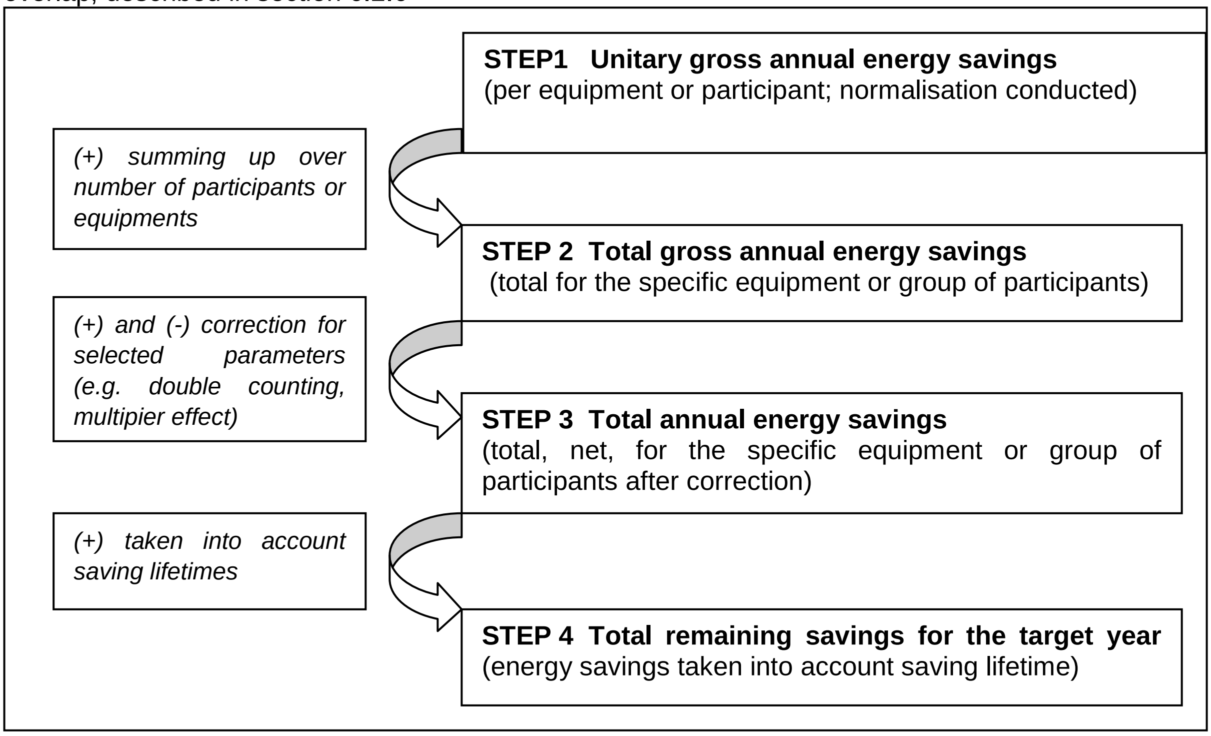
Step 1: unitary gross annual energy saving;

Step 2: total gross annual energy savings;

Step 3: total annual energy savings related to area, groups of end-user etc;

Step 4: total remaining energy savings for target year.

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



Source: EMEEES, general bottom up data collection page 11

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

NOTE Note: in step 2 the unitary saving are summed over all participants or equipment, in practise this could also be the multiplication of the saving by the number of participants or equipments Unitary savings times the number of elementary units (participants, equipments) provides gross annual savings. After correction for factors, to be chosen, annual savings result. The remaining part of these savings in the target year is 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 section 6.2.7).

The elementary unit should be chosen in a way that no major technical interaction with other elementary units is to be expected. If this condition cannot be fulfilled technical interaction has to be taken into account

- by identifying, documenting and qualifying the potential technical interactions with the elementary unit of savings and their influence on the unitary energy savings;
- by quantifying the influence of technical interactions on the unitary savings;
- and – if necessary – by adjusting unitary gross annual energy savings due to changing technical interactions for the situation without EEI action and the situation with EEI action (see step 1d Normalisation of energy consumption).

Each of these four steps holds several sub-steps in those specific calculations are conducted. The process of calculating bottom-up energy savings is presented in Table 2.

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	

Table 2: Steps and sub-steps in the calculation of bottom-up energy savings

5.2.2 Step 1: Calculation of unitary gross annual energy savings

Step 1 comprises calculation methods which are mainly related to the type of end-user actions considered. It can be split into the following sub-steps:

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)

5.2.2.1 Step 1.a: Definition of the elementary unit

Unitary savings are coupled to the chosen elementary unit of action, e.g. a new dwelling or a refrigerator. For a new dwelling the unitary energy savings represent a diminished energy use for space heating, while for a refrigerator unitary energy savings regard lower electricity use. In order to calculate unitary energy savings the first step must be the definition of the elementary unit, including system boundaries.

The elementary unit can be defined at different aggregation levels, e.g. the housing sector, detached houses, the heating system, the boiler and even the pump of the boiler.

If there are substantial changes in the properties of an elementary unit, e.g. for the elementary unit “TV” the shift from black-and-white to colour, two different elementary units can be defined.

Next to technical systems the elementary unit can also represent an organisational entity or a participant (see examples in section 6.1.1).

The elementary unit should be chosen in a way that no major technical interaction with other elementary units is to be expected. If this condition cannot be fulfilled technical interaction has to be taken into account

1) by identifying, documenting and qualifying the potential technical interactions with the elementary unit of savings 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 END-USER action and the situation with END-USER action (see step 1f technical interaction).

5.2.2.2 Step 1.b: General formula

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 with consumption data available;

— approach II for cases with consumption data to be constructed.

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). Gross annual energy consumption (GAEC) for the situations without (0) and with (1) are directly known from energy bills or meter readings or energy end-use measurement in case that the without action is equal to the situation before. The general calculation formula is given in the following equation.

Equation 7:

unitary gross annual energy savings = $[GAEC]_0 * AF_0 - [GAEC]_1 * AF_1$

Where:

GAEC is gross annual energy consumption;
AF is adjustment factor
0 is situation without action [baseline];
1 is situation with action.

The normalisation is intended to adjust the energy consumption for influences that are not to be accounted for in the calculation of energy savings (e.g. weather condition). See step 1.d.

Approach II: energy consumption data not directly available

The “before” and “after” gross energy consumption is assessed using parameters that are relevant for energy consumption and for which data are available or can be estimated. The general calculation formula is:

Equation 8:

unitary gross annual energy savings = function $(P_{00}, p_{01} \ldots P_{0n}) * AF_0$ - *function* $(P_{10}, P1_1 .. P_{1n}) * AF_1$

Where:

$P_1 \ldots P_n$ is parameters
AF is adjustment factor
0 is before
1 is after
Function an algorithm defining gross annual energy use.

In practise in most cases the adjustment factor AF is not used because normalisation is achieved here mostly by means of dedicated modifiable parameters in the equation (see step 1.d).

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

— parameter M: electrical power absorbed by the standard lamps [W]

— parameter F: number of operating hours (h)

The formula for the gross annual energy use is M * F and the formula for unitary gross annual energy savings is $M_0 * F - M_1 * F$.

For replacement of a 60 W lamp by a 12 W lamp which has 2500 operating hours annual unitary energy savings are 60W x 2.500h – 12W x 2.500h =120 kWh. It is assumed that there is no change in the area lighted and thus no need for normalisation

The calculation formula offers much 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) National accepted formula;

3) Literature sources;

4) Self developed and documented.

Preference 1 constitutes e.g. other standards or EU Directives.

5.2.2.3 Step 1.c: Baselines and specific formulas

Baseline is handled differently in Approaches I (before energy consumption data are available) and II (before consumption data are not directly available)

A) Baseline in Approach I

In approach I it is assumed that before energy consumption data are 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 has to be normalised using adjustment factors, provided that this is needed to make the with and without situations comparable (see step 1.d).

B) Baseline in Approach II

In approach II it is assumed that before consumption data are not directly available. This can be the case in technical, organisational and behavioural actions. The baseline situation corresponds to energy consumption without these energy efficiency improvement actions. The baseline situation when energy consumption is not measured, estimated or assessed it is derived from a chosen reference device, such as new equipment, new cars or new buildings. The following two reference cases can be identified (equations 9 and 10).

In equation 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 e.g. be EU or domestic market. The unitary energy savings are calculated according to the specific formula:

Equation 9:

"market" unitary energy savings of devices = [energy consumption for present/reference market] – [energy consumption for new/efficient]

In equation 10 stock modelling[6)] instead of market modelling is applied to define the reference device**.** The before situation is based on (average) existing devices. The reference stock is primarily the domestic stock or the stock in a comparable country. The energy savings are calculated according to the following specific formula:

Equation 10:

*"stock" unitary energy savings of devices = [energy consumption for **average** / **existing stock**] – [energy consumption for new/efficient]*

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

---

6) In fact, stock modelling will lead to similar baselines than first approach assessing "before" consumption. But input data are different; in the first approach input data are in general energy consumption data

5.2.2.4 Step 1.d: Normalisation of energy consumption

Normalisation of energy consumption must ensure that the situations without and with 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 enter the energy savings calculation. Examples of such external factors are:

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

The effect of each external factor is expressed in the form of adjustment factor. The 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 influences by the applicable external factors. E.g. in case of weather conditions the adjustment only relates to the part of energy consumption that is influenced by the weather. In most cases this fraction will be estimated.

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

In case energy consumption data are not directly available (Approach II) energy consumption is constructed using a set of parameters (see equation 8). Normalisation is in practise often achieved by choosing equal values for the parameters that regard external factors. Depending on the case, values can be found in standards (e.g. for buildings: heating or cooling degree days conditional on the geographical location).

5.2.2.5 Step 1.e: Technical interaction

If there exist technical interaction(s) having an influence on the unitary energy savings this effect shall be taken into account by ways of ensuring that the situations with implementation of the action can can be compared to the situation without the action when calculating the energy savings. Technical interaction may relate to relationship with other elementary units or to relationship with the surrounding technical system.

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

In case energy consumption data are not directly available (Approach II) energy consumption is constructed using a set of parameters. In this case adjustment for technical interaction can be achieved by choosing for the case with implementation and for the baseline case *different* values for the parameters reflecting the interaction with the surrounding technical system or with other unitary elements of savings. E.g. 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 be avoided by calculating energy savings for a system a ‘higher’ level, e.g. at the level of dwellings instead of separately for insulation and boilers.

5.2.2.6 Step 1.f: Application of conversion factors

The energy consumption and savings can be expressed into various units, such as Joule, m^3, litre, kWh or toe. Often the measure defines the appropriate unit, e.g. litre for efficient cars and kWh for efficient appliances. If the savings expressed in different units have to be summed up (see step3) the various units must 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 (see section 6.2.5). To this end the electricity savings are calculated on the basis of consumption in primary units. A primary factor is used to convert final electricity consumption into primary units. The savings calculations now results in energy savings in primary units that account for avoided losses in energy supply (in power plants and transport and distribution of electricity).

Users of the standard can apply a primary factor that represents the mean efficiency in the relevant power production system. In the ESD a default value of 2.5 is proposed for the primary factor of electricity, meaning that 1 kWh is equal to 2.5 * 3.6 = 9 MJ primary units.

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

5.2.3 Step 2: Calculation of total gross annual energy savings

In step 2 the unitary energy savings per elementary unit 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

Step 2.a: Calculating the number of elementary units of action

The elementary units can regard (see section 7.1.1):

- technical entities: 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 will depend on how the unit is observed or assessed. In general the number of elementary units may be:

- directly accounted for;
- indirectly assessed.

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

In other cases the number has to be indirectly assessed through analysis of equipment sales data, by using the results of yearly surveys on the penetration of efficient equipment or by other analysis methods.

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. E.g. for an eco-driving programme the elementary unit is not the person that is aware of eco-driving but the person that actually and measurably changed the driving style.

Step 2.b: Summing up unitary energy savings

As approaches I or II can be used in calculating unitary energy savings, the summing up will be different for these two approaches.

Summing up in Approach I

In approach I, with energy consumption data directly available, the elementary unit 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:

Equation 11:

Total gross annual energy savings (individual elementary unit) =

$$\sum_{i=1}^{n}[\text{gross annual energy savings for the individual elementary unit(i)}]$$

The equation can also be used for summing up the savings of elementary units regarding a combination of systems, entities and participants, e.g. as part of an audit or permit. The elementary unit is the energy user with the audit or permit and energy savings per elementary unit will differ. The energy consumption before and after the audit or permit define the unitary energy savings.

Summing up in Approach II

In approach II, without available energy consumption data, the summing up depends on the composition of the general formula for unitary savings (see step 1.b) and the type of baseline selected. The accounting for the number of elementary units of action (see step 2b) also influences the summing up.

If the general formula for unitary savings results in savings for individual cases, the summing is in conformity with equation 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. In this situation the total gross annual energy savings are calculated according to the formula:

Equation 12:

*total energy savings (average elementary unit) = mean unitary energy savings * number of elementary units*

The mean value must be valid for the stock for which the number is calculated. If large differences in energy savings occur, e.g. due to different versions, the equation should be calculated for each version separately where possible.

The elementary unit can also regard a combination of systems, entities and participants, e.g. as part of an audit or permit. If it has to do with standard cases the average unitary energy savings can be estimated and te total savings calcualtd with the equation.

5.2.4 Step 3: Calculation of total annual energy savings

In step 3 the total gross annual energy savings are corrected, if needed, for one or more factors in order to provide energy savings according to the definition of the target for energy savings. Step 3 on total annual energy savings 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 multiplier effect;

Step 3.d: correction for free-rider effect;

Step 3.e: correction for rebound effect.

Step 3.a: Calculation of total annual energy savings

Total annual energy savings are calculated according to the formula:

Equation 13:

*total annual energy savings = factor(DC) * factor(MP) * factor(FR) * factor(RE)* total gross annual energy savings*

Where:

Factor DC is double counting;
Factor MP is multiplier effect;
Factor FR is ree rider effect;
Factor RE is rebound effect.

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 be taken into account, the value will be unity.

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

In some cases the evaluation of the effect of a factor is cumbersome or almost imposible due to data constraints. If it can be argued that the possible effect on the reported savings is negigible the factor can be ignored. The choice of not using a factor has to be explained

Step 3.b: Correction for double counting

Double counting regards two facilitating measures that both focus on the same end-user action. E.g. a label system and a subsidy scheme, both promoting the purchase of efficient appliances. For each facilitating measure the saving effect can be calculated but the combined effect may be lower than the sum of both effects.

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

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

In practice the assessment of double counting is often cumbersome due to data constraints.

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 is taken into account by the factor in the formula for energy savings. The factor will be larger than unity.

Step 3.d: Correction for free rider effect

Facilitating measures stimulate end-use actions of energy users, e.g. a subsidy for insulation of the dwelling. 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.

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. E.g. after insulation of dwellings the occupants set the thermostat at a higher temperature because heating it is less costly than before. The rebound factor is smaller than unity.

5.2.5 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. Usually 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-15593 defines the development of energy savings over time (see figure *xy; include figure 1 of the CWA*). 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:

- the initial energy savings
- the saving period
- the divergence from initial energy savings during the saving period

In defining the saving periods for elementary units of actions the harmonised or calculated saving lifetimes according to CWA-15593 shall 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 or not: If the age of an end-user action in a certain target year is smaller or equal to its lifetime, it counts for the energy savings this target year and otherwise it does not count at all.

In addition to the “binary” decision of saving lifetimes the calculation of remaining energy savings for target year can take into account the divergence of energy savings over time as a result from:

- Deterioration: For technical systems deterioration of the saving 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 technical 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 a technical 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.

Only if energy consumption data is directly available for each year of the savings lifetime of the end-user action the influence of deterioration and maintenance region needs not to be taken into account additional. 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 maintenance regime can be reflected by plausible parameters expressing the influence of these factors on energy consumption.

5.2.6 Calculation of overall bottom-up energy savings, taken into account overlap

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

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

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

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

If the end-user actions at different aggregation level 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 up.

In case of overlap a correction should be made for overlap in scope which will depend on the type of end-user action. If it regards two end-user actions, such as cross-sector efficient electric motors and savings on industrial electricity use, the correction follows from the common scope, the savings for electric motors in industry that are also covered in industrial electricy savings. If it regards two facilitating measures, e.g. an energy tax on all end-use and a voluntary agreement for retail shops, the overlap should already be dealt with when correcting for double counting. Note that overlap differs from the correction for technical interaction which regard effects for individual end-user action.

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

Overall bottom-up energy savings are calculated according to the formula:

Equation 14:

Overall bottom-up energy savings = $\sum_{i=1}^{n} [\text{energy savings end - user action(i)} * \text{overlap factor(ij)}]$

where:

overlap factor (i,j) is matrix of overlap fractions between action i and action j

In case no overlap exists all factors are equal to unity and overall energy savings are the sum over all end-user actions.

Annex B
(informative)

Detail and harmonisation in bottom up calculations

B.1 Levels of detail in saving calculation

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.

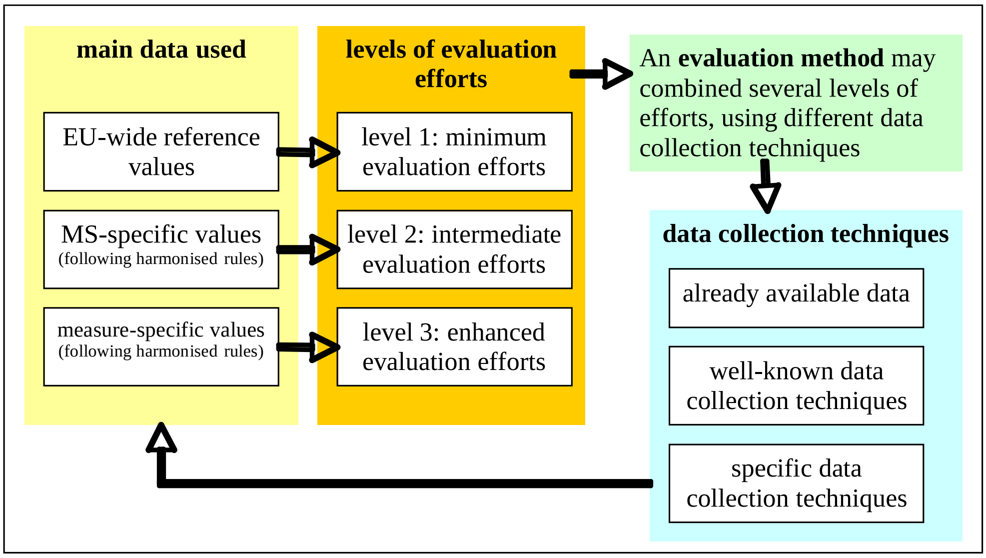
The data used can be already available, gathered by well known methods or specific data that need tailored collection techniques.

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 section 7. E.g. the use of an EU-default value (level 1) for the unitary savings (in step 1) and specific values per member state (level 2) for the number of participants (in step2).

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.

Figure B-1*: Three levels of calculation and harmonisation*



Source: EMEEES, The development process, page 30

B.2 Harmonisation and data handling

If the standard on savings calculations is to be 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 as to the three levels of effort described earlier and summarised in Figure B-2.

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 exist only a few data about this measure (e.g. number of participants) and calculations are conducted using general (European) default values (= level 1 evaluation) ;
- One can evaluate the energy savings 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) ;
- One can evaluate the energy savings 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).

Figure B-2*: 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: Emeees final report page 29

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 also applicable at a more detailed level while also other evaluation tools may be needed (e.g. measurement campaigns, enhanced engineering analysis).

Annex C
(informative)

Bottom up application for buildings; boiler replacement

Introduction

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

The EPBD standards give the possibility to calculate the energy use of a building and the saving of energy by changing the conditions and/or the equipment. The calculation results are fit together in EN 15603. An overview of the EPBD standards is given in TR 15615.

Terms and definitions are those presented in TR15615. 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 object of the assessment of the energy saving calculation can be very different. To structure the objects a system approach is chosen. This makes it possible to organise the objects into four separate areas, being arranged from 'broad' to specific:

1. the origin 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 arranged: heating and cooling, ventilation, building envelope, lighting, communication appliances, food and drinks appliances, cleaning appliances.
4. the individual component. An individual component is a product. Examples are boilers, air-conditioners, fans, insulation material, bulbs, computers, TVs, fridges and washing machines.

It is of vital importance to **define the system boundaries** for correctly attributing energy efficiency results to the system by which they have been generated. When defining the system boundary it must encompass the sub systems 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: energy saving for improvement of the insulation of the building envelope shall 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 up the savings. The first is to sum over the components. The other is to add the different component savings within the subsystem together and sum over the subsystems.

Example: energy savings for changeover of a boiler can be restricted to the component 'boiler' or seen as a change in the subsystem heating.

Example: generation energy savings for changeover of a boiler in combination with a change is the water temperature, the radiators or the pipe system is a change in the subsystem heating.

If a part of a technical 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 explicitly.

Potential examples for the Calculations

The building approach consists of 3 main categories of energy efficiency improvement actions. These categories are defined below:

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

- refurbishment measures in existing residential and tertiary buildings (building envelope and heating system)
- insulation refurbishment measures applied to building shell in existing residential and tertiary buildings (walls, roofs, windows)
- lighting in residential buildings (lamp)
- lighting in tertiary buildings (system or components)
- set of the controller (e.g. set of the correct design temperature, the correct heating curve or the correct using time)

Category 2 (replacement):

- replacement of heating supply equipment in residential and tertiary buildings
- replacement of water heating equipment in residential and tertiary buildings
- replacement of air-conditioning split systems (< 2kW) in residential and tertiary buildings
- replacement of household appliance (cold appliances, washing machines, dishwashers, televisions, etc.) in residential buildings
- replacement of office equipment in tertiary buildings
- replacement of lighting in residential buildings (lamp)
- replacement of lighting in tertiary buildings (system or component)

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

- new building constructed according to building codes in new residential and tertiary sectors
- new office equipment in tertiary buildings
- installation of new air-conditioning split systems (< 12 kW) in residential and tertiary buildings
- new installation of heating supply in residential and tertiary buildings
- solar water heating in residential and tertiary buildings
- new lighting in residential buildings (lamp)
- new lighting in tertiary buildings (system or component)

We present the four steps of calculating energy savings by the replacement of heating supply equipment in residential and tertiary buildings (example only from the category 2). This example is based on the EMEEES bottom-up case application 4, residential condensing boilers

Example for category 2: Replacement of heating supply equipment in residential and tertiary buildings

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). 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 formulas, because of diverging variables per unit/system and subunit/system. Here below the relevant formulas will be assessed, 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 (UGAES), by means of which the total energy savings per participant can be calculated, will be addressed.

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

The example deals only with a boiler.

Step 1.b: General formula

For all components, so also for a boiler, there are in almost all cases no data on energy consumption for heating supply or lighting available, so *Approach II, energy consumption data are not directly available,* is used.

Level 1 calculation (related to Appendix B)

unitary gross annual energy savings = $\left(\frac{1}{N_0} - \frac{1}{N_1}\right) * SHD * A[kWh/unit * year]$

Where:
N_0 = Mean annual Energy efficiency of the heating supply equipment before the replacement action (seasonal)
N_1 = Mean annual Energy efficiency of the new heating supply equipment (seasonal)
SHD = Specific Heating Demand {kWh/unit*yr]
A = Average area of the space heated by the heating supply equipment (household, office, etc.) [m^2]
0 = situation without action [baseline];
1 = situation with action.

The formula is only applicable when only the boiler is changed and the other conditions are not changed. If more actions are taken, technical interaction (see step 1e) 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 get the values for N_0 in the equation. For the baseline situation, the options are related to the selection of a baseline (see step 1.c)

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

a. *An EU average, e.g. on average 86 kWh/m^2 (ecoboiler study, part 3, page 58).*
b. *A national average*
c. *A building specific value*

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

a. *An Eu average, that could be more specific e.g. for type of building*
b. *A national average, that could be more specific e.g. for type of building*
c. *A building specific value*

Level 2 and 3 calculation

The formula for the level 1 calculation is also applicable for the level 2 and level 3 calculations. For example, 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:

Efficiency of replaced or adjused heating system = efficiency of replaced boiler * efficiency of replaced emitter

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

Efficiency of the more efficient or adjused heating system = efficiency of the efficient boiler * efficiency of the efficient emitter * efficiency of the efficient distribution network * efficiency of the efficient controller.

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

Step 1.c: Baseline for unitary savings

In approach I it is assumed that before energy consumption data are 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 can be the case if the only use of an energy carrier (e.g. natural gas or LNG) is for the boiler. When this baseline is applied (before and after), energy consumption has to be normalised using adjustment factors (see step 1.d).

unitary gross annual energy savings = $\left(\frac{1}{N_0}-\frac{1}{N_1}\right) * SHD * A[kWh / unit * year]$

Where:

N_0 = Mean annual Energy efficiency of the *old* boiler before the replacement action

N_1 = Mean annual Energy efficiency of the installed high efficient *new* boiler after the replacement action

Example: for the EU market of existing boilers, eficiency is choosen of 82% (value from the EMEEES case application 4) and of 97% for the new boiler , the formula will be:

unitary gross annual energy savings = (1/0,82 – 1/0.96) SHD* A[kWh/unit*year]*

In approach II it is assumed that before consumption data are not directly available. This is the case when energy consumption is not measured, estimated or assessed but it is derived from a chosen reference device, such as stock or market averages

In equation 2, the choice of reference device is based on market modelling, i.e. tha average high efficienct boiler available in the market..The reference market could e.g. be EU or domestic market. The unitary energy savings are calculated according to the specific formula:

unitary gross annual energy savings = $\left(\frac{1}{N_0}-\frac{1}{N_1}\right) * SHD * A[kWh / unit * year]$

Where:

N_0 = Mean annual Energy efficiency of the *average boiler on the market*

N_1 = Mean annual Energy efficiency of the installed high efficient new boiler

Example: for the EU market of boilers, one can choose a market value of non-efficient new boilers of boiler efficiency of 89% or that of efficient one of 94%, (value from the EMEEES case application 4) the formula will be for the efficient boilers in the baseline:

unitary gross annual energy savings = (1/0.94 –1/ 0.96) SHD* A[kWh/unit*year]*

In equation 3 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:

unitary gross annual energy savings = $\left(\frac{1}{N_0}-\frac{1}{N_1}\right) * SHD * A[kWh / unit * year]$

Where:

N_0 = Mean annual Energy efficiency of the *average boiler in the stock*
N_1 = Mean annual Energy efficiency of the installed high efficient *new* boiler

Example: for the EU stock of boilers, one can choose a stock value of boilers of 84% (value from the EMEEES case application 4) the formula will be for the efficient stock boilers in the baseline:

unitary gross annual energy savings = (1/0.84 –1/ 0.96) SHD* A[kWh/unit*year]*

In all formulas the same SHD and A parameter is used.

Example: For the EU stock of boilers and for the average area of the space heated (A) an EU average of 90 m^2, the formula will be

unitary gross annual energy savings = (1/0.84 –1/ 0.96) SHD* 90[kWh/unit*year]*

Step 1.d: Normalisation

There is no need for normalisation in this example is already includes in the situation of the specific heating demand (SHD), which is calculated according to the EPD (EN13790) and thus already normalised.

Example: For the EU stock of boilers and for the Specific Heating Demand (SHD) an EU average of 86kWh/m2 (ecoboiler study, part 3, page 58), the formula will be

unitary gross annual energy savings = (1/0.84 –1/ 0.96) 86* 90[kWh/unit*year]= 1151.8 kWh for one boiler*

Step 1.e: Technical interaction

Applicable when the building code involves standards for separate efficiency measures. The calculation method is in conformity with the EPBD methodological framework. Therefore interaction effects are already incorporated in the calculation method.

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

The conversion factor is relevant in the situation that the change of the boiler is combined with a change of energy carrier. E.g. the old boiler was fired by oil, while the new boiler is fired by gas or by wood.

Step 2: total gross annual energy savings

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

$$\text{Total Gross Annual Energy Savings} = \sum_{i=1}^{c} \text{UGAES}$$

Where:
UGAES = unitary gross annual energy savings
n = The number of units

Example: For the EU stock of boilers, EU average for the Specific Heating Demand (SHD) and an EU average of area and a number of 20.000 boiler replacements, the formula will be

*Total Gross Annual Energy Savings = 20,000 * 1151.8 = 230 357.1 kWh*

Step 3: total annual energy savings

Step 3.a: Formula for total annual energy savings

Total annual energy savings are calculated according to the formula:

Equation 4

*total annual energy savings = factor(DC) * factor(MP) * factor(FR) * factor(RE)* total gross annual energy savings*

Where:
Factor DC is double counting;
Factor MP is multiplier effect;
Factor FR is ree rider effect;
Factor RE is rebound effect.

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 succesful 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.

Example: There is some research indicating a multiplier effect around 2 in a country in the 90's.

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 any measure. 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. This factor is not relevant in the case of the boiler as occupants don't feel the difference generated by a new boiler and won't change their behaviour at home. But is specific situation it could happen that the occupants set the thermostat at a higher temperature because heating it is less costly than before. Then the rebound factor is relevant.

Step 4: total remaining energy savings for target year

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

The EU default/harmonised energy saving lifetime for boilers in the CWA-15593 holds the same value for small and large boilers: 17 years. For small boilers it as a harmonised values, while the value for large boilers is a default one.

Bibliography

[1] EC Directive of the European Parliament and of the Council of 5 April 2006 on energy end-use efficiency and energy services, 2006/32/EC, Official Journal L 114 of 27/04/2006 (ESD)

[2] Top down evaluation methods of energy savings - Summary report, B. Lapillonne (Enerdata), D. Bosseboeuf (ADEME) and S. Thomsa (WI), WP5, EIE-06-128 EMEEES, March 2009

[3] Annex to the summary report on top-down evaluation methods - Odyssee and ODEX indicators that can be used in top-down evaluation of energy savings, B. Lapillonne (Enerdata), WP5, EIE-06-128 EMEEES, March 2009

[4] www. odyssee-indicators.org, definitions of energy efficiency indicators

[5] Directive of the European Parliament and of the Council of 16 December 2002 on the Energy Performance of Buildings, 2002/91 EC (EPBD)

[6] General bottom-up data collection, monitoring and calculation methods – Summary report, H. Vreuls (SN), S. Thomas (WI) and J-S. Broc (Armines), WP5, EIE-06-128 EMEEES, September 2008

[7] CWA-15593: 2007, Saving lifetimes of Energy Efficiency Improvement Measures in bottom-up calculations

[8] Evaluation and monitoring of energy efficiency in the EU 25, EIE project ODYSSEE/MURE; 2007

[9] Technical Report Energy management and Energy efficiency - Glossary of terms, SFEM WG TEMEE, CEN, July 2009

[10] Evaluating energy efficiency policy measures & DSM programmes - volume I: evaluation guidebook, H. Vreuls, W. de Groote, P. Bach, R. Schalburg et al.. Report for the IEA-DSM task IX, October 2005.

[11] Harmonised calculation of energy savings for the ESD – development, assessment and a combined top-down and bottom-up approach. P.G.M. Boonekamp (ECN) & S. Thomas (WI), WP 61, EIE-06-128 EMEEES, April 2009

[12] Umbrella document EN 15603 Energy Performance Directive –Overall energy use and definition of energy ratings

[13] CEN/TR 15615 Explanation of the general relationship between various European Standards and the Energy Performance Directive (EPDB)

[14] ISO/FDIS 23045 Building environment design- guidelines to assess energy efficiency of new buildings