A new tool for evaluators: the European standard on energy savings calculations

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Abstract

During 2012 a new tool for energy savings calculations will be introduced, as it is expected that the European (CEN) standard "Introductory element, Energy Efficiency and Savings Calculation, Top-down and Bottom-up Methods Complementary element" will be published. This standard holds agreed terms and definitions, and the characteristics of the top-down and bottom-up methods. This paper presents the bottom-up calculation of CEN methods, as well as the level of detail at which bottom-up methods can be applied. It illustrates how the method is applied by use of an example case for buildings; boiler replacement.

These bottom-up calculations focus on savings of specific end-user actions using baselines for unitary savings and elementary units of actions. The preferred calculation methods should generally be composed of three main elements: a) a calculation model or formula including baselines and normalisation; b) data collection techniques, for data needed to feed the calculation model; and c) a set of reference or default values.

In order to increase transparency in savings calculations, the standard follows four steps: 1) unitary gross annual energy saving; 2) total gross annual energy savings; 3) total annual energy savings related to area, groups of end-users etc; and 4) total remaining energy savings for target year. This paper presents several elements relating to each step taking boiler replacement as a case study.

By using the standard in practise, it should make energy savings figures easier to compare, stimulate common way of documentation of energy savings calculation, and may even result in more cost-efficient evaluations.

Standard on Energy Efficiency and Savings Calculation, Top-down and Bottom-up Methods; a five year process

In March 2007 AFNOR, the French Standardisation Body organised a kick off meeting, on behalf of the European Standardisation Organisation (CEN), to "elaborate standards for common methods of calculation of energy consumption, energy efficiencies and energy savings and for a common measurement and verification of protocol and methodology for energy use indicators". Since then experts have participated in two Working Groups – one for Top-Down calculations and one for Bottom-Up calculations[1] – resulting in a draft document to create a standard by June 2010, open for comments by countries. In 2011 the draft was revised, based on comments and discussions during meeting. By April 2012 the final draft was published for formal voting by the members of CEN. This voting will take 3 months, while additional 3 months might be needed for official publication. It is thus expected that by December 2012 the standard "Introductory element, Energy Efficiency and Savings Calculation, Top-down and Bottom-up Methods Complementary element" will be officially available at CEN as a standard **EN16212:2012**.

This European standard provides a general framework for calculating energy savings and is organised as follows:

- the methodology and general rules of calculation;
- terminology and definitions;
- the characteristics of the top-down and bottom-up methods;

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1 The Bottom-Up Working Group took advantage of the work carried out in the EMEEES project and the reports produced during this project

- the top-down calculation method;
- the bottom-up calculation methods;
- 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 one bottom-up example for the building sector (boiler exchange);

This standard provides a general approach for energy efficiency and energy savings calculations with top-down and bottom-up methods, and covers final energy consumption in all end-use sectors (but not the energy supply). The general approach is applicable to energy savings in buildings, cars, appliances, industrial processes, etc. It is intended to be used for ex-post evaluations of realised savings as well as ex-ante evaluations of expected savings. It is, however, not intended to be used for calculating energy savings of individual households, companies or other end-users for e.g. audits or advice.

Experts held in-depth discussions regarding terms and definitions. Table 1 represents an example for the definition of a 'baseline' and present the final draft and text from the start of the project. For the baseline Experts needed to reach agreement on the following questions:

- should the energy consumption be normalised; and if so, for what element should the energy consumption then be adjusted?
- is a baseline a situation without any (foreseen) action to improve the energy use, or a situation before an end-use action starts?

The Experts agreed that it is preferred to normalise the energy consumption in a baseline (e.g. for normal heating degree days), but that there are situations (exceptions) when it is not required (e.g. standard package of industrial products produced). In addition it is too resource consuming if all types of adjustments (sometimes also indicated as normalisations) are to be conducted for an energy consumption of a baseline; e.g. for hospitals opening hours, number and composition of operations, number of patient days or number of beds etc.. This outcome of the discussion is included in discussion papers [2].
The Experts also agreed that it might be easier to include the impact of other actions (than the action the energy savings calculation is targeted at) already in the baseline situation instead of making a lot of additional calculations to filter the impacts of those other actions from the energy savings calculations. So the user of the standard will be free to make a choice on where to consider the impact of other actions: in the baseline or in (corrections of) the energy savings calculation.

Table 1. Example of the changes in the definition of a baseline

	Baseline; final draft	**Baseline; one of the provisional drafts**
Definition	energy consumption calculated or measured, possibly normalised, in the situation without an end-use action	energy consumption calculated or measured, normalised by adjustment factors, as a reference before any energy efficiency improvement action
Notes	NOTE 1: The baseline provides a reference against which measurements can be taken or compared.	NOTE The definition is a combination of the definition of energy baseline (energy consumption calculated or measured over a period of time normalised by adjustment factors) and the note (baseline may be used for calculation of energy savings, as a reference before energy efficiency improvement action) in the technical report on terminology.
	NOTE 2: The baseline can contain other actions but not the action under consideration	

2 During the discussion draft versions of the standard were produced: Introductory Element – Energy Efficiency and Savings Calculation, Top-down and Bottom-up Methods – Complementary element; CEN/TC JWG4, 2011-12, NO65, NO66 and NO70. Comments were made during the meeting and in the document "Results and comments enquiry prEN 16212 'Energy efficiency and savings Calculation, top-down and Bottom-up Methods".

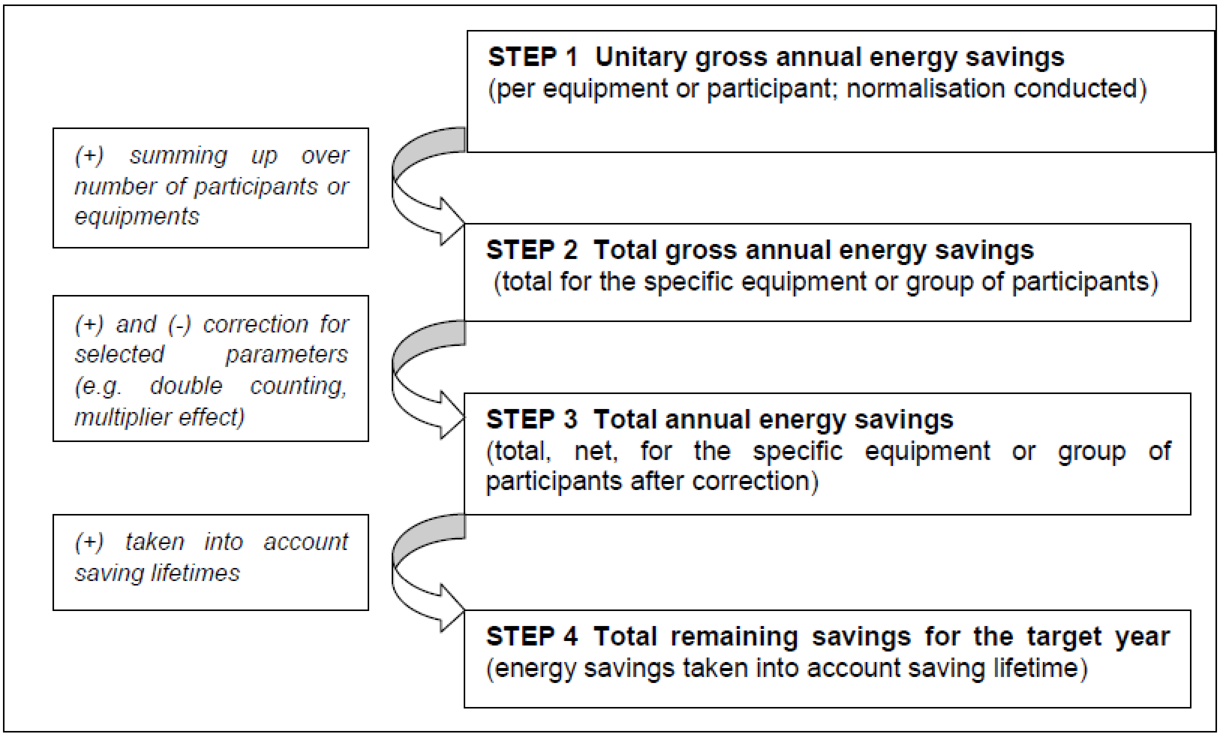
A calculation method should hold a calculation model, description of data collection techniques and a set of reference values

In general a bottom-up calculation method should be composed of the following three main elements:

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

The Calculation Model

The standard uses a straight forward and simple calculation model that is summarised below. The model (see figure 1) starts with unitary savings. In the first step bottom-up calculations focus on savings of specific end-user actions using baselines for unitary savings and elementary units of actions. The elementary “unit of action” - the entity for which unitary energy savings can be defined and summed up- generally relates to an energy using system or a participant in an energy savings programme. As a next step the savings of all units are summed up and after (in step 3) conducting adjustments for ensuring net energy savings, the total annual energy savings results. An optional fourth steps deals with energy savings over a longer time period, e.g. the savings lifetimes for equipments or accountable as programme impacts.



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

Figure 1. Four steps in the bottom-up calculation model, as included in prEN16212:2012

The baseline situation

In order to calculate energy savings for given end-user actions, the energy use situation must be compared to a baseline situation, i.e. the situation without that action. The chosen baseline influences, via the unitary savings, the calculated energy savings of an end-use action. For physical end-use actions different baseline situations can be relevant:

- 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.

The standard takes two general approaches for selecting the baseline situation:
a. reference situation; for this the two most used ones are:

1. the stock situation; based on a the existing overall situation for the product or systems;
2. the market situation; based on those products or systems currently available in the market;

This approach (a) is applicable to add-ons, replacements and new systems.
b. the “before” situation.
This approach (b) is applicable to add-ons and replacement cases, but not to new systems. For new systems there is no actual “before” situation; it does not replace another, existing one. When approach 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. As the existing system continues to be in place, but in the “after situation” with an add-on, this differs with the replacement case. In this latter the technical device in the before situation is replaced by another one.
For new systems, a virtual baseline situation has to be defined/created, e.g. for new dwellings with higher standards this could be an equivalent dwelling constructed to the existing standard. A new piece of equipment could also be compared with other options, such as the market average or existing stock average of equipment serving the same function.

Data Collection Techniques

For data needed to feed the calculation model, a number of data collection techniques can be used. The standard refers to the three levels of evaluation efforts related to details in data handling:

- a minimum level of efforts: using already available data often in combination with existing (international) default values;
- an intermediate level of efforts: using well know techniques for data collection additional to already available data and national default values or deemed savings (available and/or adjusted); and
- a level of enhanced efforts: using data collections best fitted for the specific calculations/evaluation and action specific values for the parameters and additional some default values

This 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. It makes the choices evaluators are faced with more transparent. In addition it provides guidance to the data processing and documentation (see figure 2).

	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

Figure 2. Three levels of harmonisation and data handling, as included in the Annex in prEN16212:2012

Reference or Default Values

The standard does not hold a set of reference or default values as these can only be specified for specific bottom-up cases. Examples of sources of such default values are CEN /CLC CW 15693:2007, Saving Lifetimes of Energy Efficiency Improvement Measures in bottom-up calculations; Recommendations on measurement and verification methods in the framework of Directive 2006/32/EC on energy end-use efficiency and energy services; Italian and France White Certificate schemes,

A Four step Calculation Process

The standard also organises elements for calculating unitary gross annual savings in step 1 and those for gross to net in step 3 (see figure 3). Several elements within each of the four steps will now be presented using the example of boiler replacement.

Step 1: calculation of unitary gross annual energy savings

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

The example deals only with a boiler.

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 3*, is used in the formula:

3 Approach I is used when energy consumption data are directly available

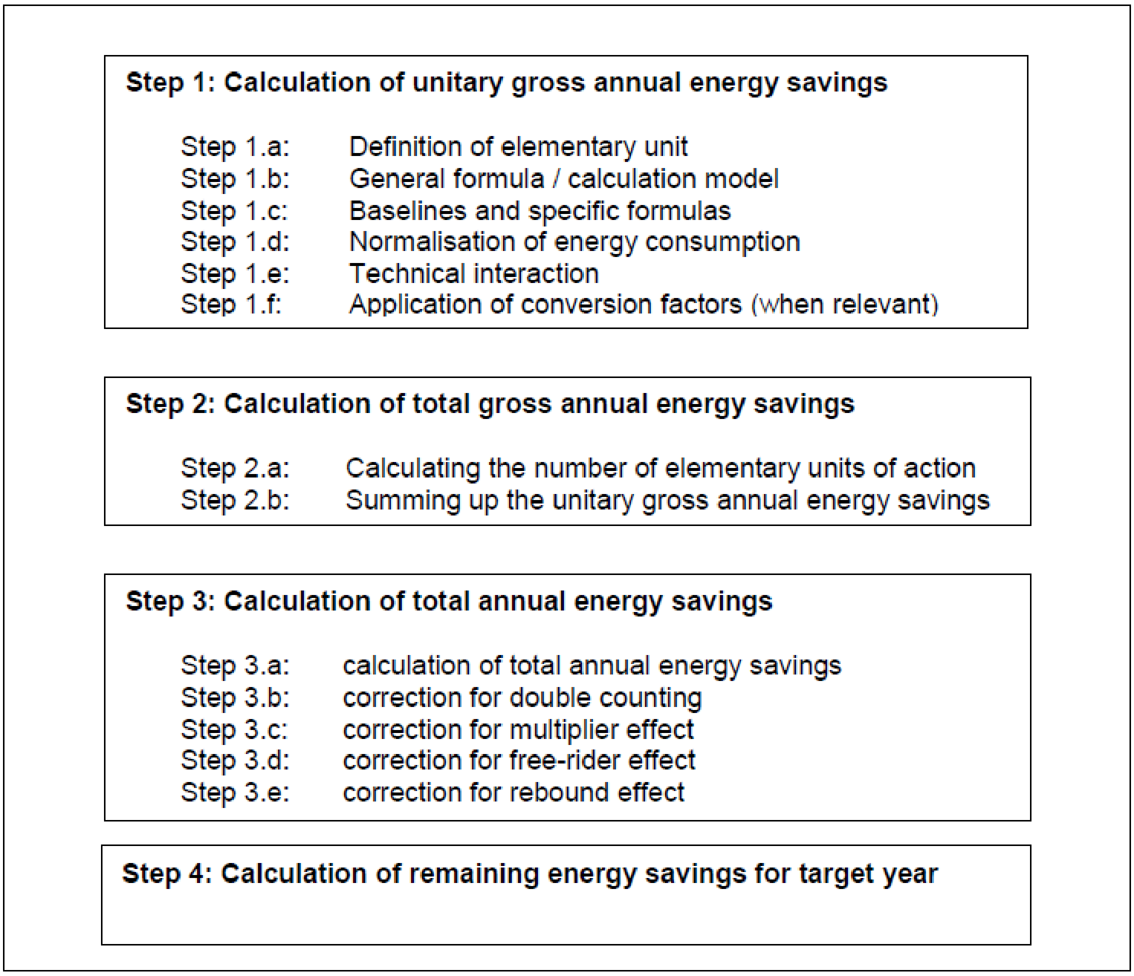


Figure 3. Steps and sub-steps in the calculation of bottom-up energy savings as included in prEN16212:2012

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

Where:
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 is specific Heating Demand {kWh/unit*yr}
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 just the boiler is changed and the other conditions remain the same. If more actions are taken, technical interaction (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 (step 1.c)
For the SHD and for A (Average area of the space heated) there are three options for a (standard) value: an EU average, a national average or building specific value

Example: For the EU average of 86kWh/m^2 Specific Heating Demand (*SHD*) and an EU average area of the space heated of 90 m^2 the formula will be:

Unitary gross annual energy savings (UGAES) $= (1/N_0 - 1/N_1) * 86 * 90$ *kWh*

Step 1.c: Baseline for unitary savings

In the baseline approach with a reference situation (Approach A) 4 one can use two options: market or stock. The reference market for each could be e.g. the domestic market or the entire European Union. The reference could be specified for a) non condensing boilers or for b) condensing boilers. The choice results in different values of N_0 in the formula and in different unitary gross annual energy savings. While both approaches are acceptable, the unitary gross savings differs by roughly a factor 4:

> Example:
> A1a: N_0 is mean annual energy efficiency of the average **non-condensing** boiler on the *market,* having a mean efficiency of 89%. Assuming that the new boiler has an efficiency of 96%, then
>
> *UGAES* = (1/0.89 –1/ 0.96)* *86* 90= 634 kWh*
>
> A1b: N_0 is mean annual energy efficiency of the average **condensing** boiler on the *market,* having a mean efficiency of 94%. Assuming that the new boiler has an efficiency of 96%, then
>
> *UGAES* = (1/0.94 –1/ 0.96)* *86* 90= 172 kWh*

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.

Step 1.e: Technical Interaction

Technical interaction is applicable in case the building code holds standards for *separate* efficiency measures. As more than one measure is implemented at the same time, the calculation for one measure should take the change in situation into consideration. E.g. boiler replacement in combination with improved insulation results in lower heat demand and so in a lower energy use for the boiler compared to only boiler replacement. The EU Energy Performance of Building Directive (EPBD) methodological framework deals with this technical interaction. As the calculation method for this example conforms with the EPBD, interaction effects are already incorporated in the calculation method therefore this step does not need to be conducted.

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, m3 gas and m3 wood have to be converted into an equivalent in Joule.

Step 2: Total gross annual energy savings

4 Approach B has the 'before' situation as the baseline situation

The total gross annual energy savings are the result of adding up the gross unitary energy savings for the individual boilers. E.g. for the example below dealing with an EU stock for non-condensing boiler baseline (option A2a), where the unitary gross annual energy savings is 1377 kWh, and a number of 20000 boiler replacements, the total gross annual energy savings will be

$$TGAES = 20\ 000 * 1\ 377 = 27540\ kWh$$

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:

$$f(DC) * f(MP) * f(FR) * (RE) * \text{total gross annual energy savings}$$

Where:

f *(DC)* is double counting;
f (MP) is the multiplier effect;
f (FR) is the free rider effect;
f (RE) is the 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 promotional 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. E.g. some 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. Then the rebound factor is relevant.

Step 4: total remaining energy savings for target year (optional)

Only those end-use actions that have not reached the end of their energy saving lifetime in the target year will be counted. E.g. the EU default/harmonised energy saving lifetime for small boilers in the CWA-15693:2007 holds: 17 years. This means that the maximum number of annual savings to be accounted for in the target year is 17.

Conclusions

The Directive on Energy End-use Efficiency and Energy Services (ESD) led to research on harmonisation of energy savings calculations in the period 2007-2009, and was an important driver for the European standardisation organisation CEN to start the work in this field. This paper is restricted to the bottom-up energy savings calculations, and present the framework consisting of 4 steps and creating a structure for energy savings calculations. The (draft) European standard prEN 16212 provides evaluators with a tool to make the calculations more transparent and helps other evaluators to get a quick overview on the choice made during the calculation process. As the standard becomes more widely used it can make future evaluations more efficient, as experiences from conducted calculations will be better documented and easier to be (re)used.

As the standard provides the evaluator with a structure to highlight the choices for baselines and for the use of default values and/or parameter values from program specific data collections, it will stimulate future development of more and improved accurate deemed savings. This will result in more cost-efficient evaluations.

The Annex to the standard only includes one example at the moment, the boiler replacement, which is also used in this paper to illustrate the calculation steps and sub-steps. Increasing the number of examples by including energy savings calculations for the industry, residential and non-residential buildings as well as for appliances and energy technologies like lighting will stimulate future use of the standard.

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