Comparable energy savings: how to ensure that singers form a harmonious chorus?

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Abstract

There are numerous ways in which energy savings are conducted: from top-down to bottom-up, from simple calculations with standard values to complex formulas and corrections and adjustments, from energy savings for an individual household to energy management systems etc. During the last decades, a number of actions has been started to make energy savings more comparable; e.g. IPMVP (EVO), California Evaluations guidebooks, EMEEES, EM&V Forum (NEEP), CEN. This paper presents the results of an IEA project dealing with harmonisation of global energy savings calculations. Based on case applications for five technologies as well as existing knowledge of evaluations from six countries over the world, the expert team involved in this project agreed to a template for presenting the information used for energy savings calculations. The results for the application of this template in case applications show that although calculated energy savings are different, they can be made comparable to each other. Also the use of metered value is compared with default values and show that the calculation rules are more important for the energy savings than the data collection method. The paper concludes with next steps: a parallel development of case applications providing data in a comparable way and a global agreement on the main elements and definitions in the ISO.

Harmonisation of energy savings calculation, a project within the IEA DSM programme

This paper presents the results of an IEA project dealing with harmonization of global energy savings calculations. The IEA Demand Side Management Agreement is a co-operation between 16 countries to work together in the field of energy savings on the end-user (demand) side. It has been operating since the early 1990s over 20 different projects in the field of changing energy use and electricity load. From 2002 to 2004 this agreement managed a project to develop an evaluation guidebook for governmental and non-governmental Energy Efficiency Programmes and also for (utility) DSM programmes targeted towards energy end-users. Based on the experiences from this project and increased attention for (inter)national energy savings and green house gas reductions, in 2006 the IEA DSM Agreement started a project to research options to harmonise energy savings calculations, to contribute to more simplified internationally comparable energy savings and to define subsequent actions for future standardisation of energy savings calculations.

The overall aim of this project is to identify basic concepts, calculation rules and systems for Energy Savings Calculations standards. Both energy savings and emissions avoidance calculation methods and standards will be evaluated for efficiency activities. The actual research work was carried out by a combination of country experts from Norway, France, Spain, Switzerland, The Netherlands, USA and the Republic of Korea[1] and the project manager. In 2012 the project will produce the final reports on results for the research up to 2011. Some highlights are included in this paper, while information on other topics such as Demand Response projects and energy savings as well as the reports are available free of charge via the website www.ieadsm.org in the sections Publications and Tasks & Projects (Task 21).

1 The author thanks all the experts that participates in this project for their efforts and (country) reports as well as the organisations that financed the project.

A template with the key elements for energy savings calculations

Based on case applications (examples of energy efficiency projects) for five technologies - lighting, air conditioning, variable speed drive motors, heat pumps and insulation - as well as existing knowledge on evaluations from the six participating countries and a worldwide team of experts, an agreement was reached on a template for presenting the key information for energy savings calculations and related green house gas emissions. This template has four sections: 1) summary of the program; 2) formula for calculation of annual energy savings; 3) input data and calculations; and 4) GHG savings. Additional information is presented (in an annex) and in line with a proper documentation, there are references and definitions. Table 1 presents this template.

Table 1. Template to present key information on energy savings calculations and green house gas reductions

1 Summary of the program
- 1.1 Short description of the program
  - 1.1.1 Purpose or goal of the program
  - 1.1.2 Type of instrument(s) used
- 1.2 General and specific user category
- 1.3 Technologie(s) involved
- 1.4 Status of the evaluation and energy savings calculations
- 1.5 Relevant as a Demand Response measure

2 Formula for calculation of Annual Energy Savings
- 2.1 Formula used for the calculation of annual energy savings. specify if the formula
- 2.2 Specification of the parameters in the calculation
- 2.3 Specification of the unit for the calculation
- 2.4 Baseline issues
- 2.5 Normalisation
- 2.6 Energy savings corrections
  - 2.6.1 Gross-net corrections
  - 2.6.2 Corrections due to data collection problem

3 Input data and calculations
- 3.1 Parameter operationalisation
- 3.2 Calculation of the annual savings as applied
- 3.3 Total savings over lifetime
  - 3.3.1 Savings lifetime of the measure or technique selected
  - 3.3.2 Lifetime savings calculation of the measure or technique

4 GHG savings
- 4.1 Annual GHG-savings
  - 4.1.1 Emission factor for energy source
  - 4.1.2 Annual GHG-savings calculation as applied
- 4.2 GHG lifetime savings
  - 4.2.1 Emission factor
  - 4.2.2 GHG lifetime savings as applied

Within the first section, most elements are easy to understand, apart from ‘1.4 the status’. Under status, three different topics are handled. Together they should give a good indication of the quality level of the calculation. The first one is to indicate how official the calculation is. This can range from legal to under research; it is assumed that a legal or official stamped calculation as such has a higher quality than a calculation that is use in practise or is under research. On the other hand, it will be more difficult to change such an official calculation in a process of international harmonisation. Additional information to indicate the quality must show whether the energy savings calculations are used in an evaluation report and whether the energy savings calculations themselves have been evaluated.

Within the second section, four most commonly used types of baseline (under section 2.4) are suggested to refer to:

a. before situation; evaluate the measurement against the technique used before
b. stock average; evaluate the measurement against the average stock technique
c. market average; evaluate the measurement against the average technique on the market
d. common practice; evaluate the measurement against the most commonly used technique.

Normalisation (under section 2.5) not only deals with normalisation for e.g. heating degree days, but can also be used for other types of normalisations such as opening hours for shops. While the gross-to-net correction is well known, in most cases less attention is given to corrections due to data collection problems (section 2.6.2), while during the project this topic showed up in the experts' discussion for a number of case applications. This type of correction could be applied to handle imperfect data collections e.g. using sales data as a proxy for installation data or using a secondary data source for a bigger region than the region a programme is implemented.

Within the third section under '3.1 parameter operationalisation' it is advised not only to present the information on how the data for the parameters in the formula are obtained (both for the actual and for the reference situation), but also to indicate the type of values. For this the four most common types are: deemed (rough approximations, expert opinions, etc.); calculated (for example using survey data); measured (for example real measurements taken, billing information, etc.); combination of these. The most important section is section '3.2 Calculation of the annual savings as applied'. In this section the conducted calculation with the formula from section 2.1 and the values used is presented. It is advised to present the data in several steps as this improves transparency and understanding.

In the fourth section the calculation of green house gases reductions related to the annual and the lifetime energy savings are presented.

Key elements for energy savings calculations for a selection of case applications

The results for the application of this template in case applications show that although calculated energy savings are different, they can be made comparable to each other. The best example for this is **lighting in households**. The first draft of the case applications which the experts presented for this selected technology seems to hold very different approaches to calculated energy savings. During the discussion it was concluded that all use the same components in the formula:

1. the situation before: the old lamp;
2. the situation after: the new lamp;
3. the average burning hours of the lamp;
4. possible normalisations;
5. correction factor(s).

In practise all formulas could be based on the same formula:

$$\text{Annual energy savings: } ES = 1/1000 \sum^{Units} (P_{old} - P_{new}) \times t$$

Where[2]

- *relevant units: installed and operating units*
- *ES: annual energy savings in kWh*
- *1/1000: conversion from W to kW*
- P_{old}*: power old lamp in Watt*

2 The symbols "P" and "t" in the formula follow those as provided by (international) standards such as ISO80000-7, 2008 and NEN-EN 12665. Both use t for time. Like many other norms, NEN-EN 12665 uses P for Power.

- *P_{new}: power new lamp in Watt*
- *t: time period for the energy consumption in hours per year ("burning hours")*

The key parameter Delta Watt *($P_{old} – P_{new}$)* is derived in two ways:

a. An (average) value of the old as well as the new lamp; In this case the averages are depending on CFLs, lamp wattage and the relevant baseline
b. An average value for Delta Watt. This is applied in situations of replacement by multiple CFLs having different wattages.

The key parameter annual burning hours is also derived in two ways:

a. an average annual value
b. An average daily value multiplied by 365 (days).

The most common parameter is the burning hours being based on all households and on all rooms in a house. They are assumed not to change after replacement.

The baseline (or reference situation) for lighting in households is the replacement by the same type of lamp[3]. In all case applications this is the reference situation in which conventional bulbs are being replaced by conventional bulbs, with the exception of Korea where the unit of analysis is a fluorescent lamp.

Normalisation should be conducted when the estimation of burning hours is based on measurements during a period shorter than a year. Of all case applications only in the case of California normalisation is applied.

A correction could be applied to the situation of a new lamp replacing an existing CFL (the situation before (Pold). In two case applications this is taken into consideration, but not as a correction to the situation before but as a correction of the gross energy savings. Concerning the new situation (Pnew), all case applications deal with data collection methods that are based on sales data and assumptions are made on the amount of the installed lamps. Only in the case application of California are corrections made for not installed lamps and 'gross-to-net'.

All countries have data to calculate savings over lifetime. But the use in practise differs widely over the countries. The used lifetime is often the technical burning hours of the CFL divided by the annual burning hours.

In the case applications for **insulation of houses**, the formulas for calculating the annual energy savings as used in the four countries' case applications are developed from rather different views: The French and the Norwegian cases are based on energy savings per m^2 of insulation materials/windows; while the Dutch one is based on the estimated heat demand calculated using a model approach for meeting the heat demand. The Spanish formula is based on a model for the building performance. In the USA case billing analysis with two models is used to calculate energy savings. The formulas, even after harmonisation of parameters, are very different.

This is also illustrated by the differences in baselines. In the France case application, the baseline insulation coefficient used for external wall is U_o=3.3 W/m^2K (this corresponds to a non insulated wall). For other insulation measures the baseline used for the energy savings calculations is the stock average. In the Dutch case application, the baseline situation is the energy usage per year corresponding with the energy label for the house before any energy savings measurements are taken. This baseline is different for each specific dwelling depending on the way the dwelling was built and which techniques where used. In the Norwegian case application it is assumed that the program only triggers an improved retrofit and not a replacement of the windows as such. For this reason the U value of 1.6 for the old window is used. In the Spanish case application, a model is used to calculate the average energy use per type of dwelling and size class and these results of the model are used as baselines. In the USA case application, the energy use from the billing prior to the installation of insulation was used as the baseline.

3 These baselines will in the future no longer be valid for European countries as the European Commission is banning conventional bulbs. On 1 September 2009, the 100W incandescent light bulbs and other energy inefficient lamps, a year later the 75W, two year later the 60W and by 1 September 2012 40W and 25W.

Also for **air conditioning in commercial building/offices** the approaches to calculate the annual energy savings are rather different. We here present two case applications: the Spanish and the Dutch. In the Spanish case the programme was targeted to a replacement of an existing air conditioner (R22 machines) with water condensed chillier system (electric). So in the Spanish case application, the energy savings are based on calculations for that specific system to meet the cooling demand. In the Dutch case all types of air conditioners and different energy sources (electricity, gas or heat) are included for the savings calculation. So in the Dutch case application, the energy savings are based on calculations for the efficiency of several systems that are in use for meeting the cooling demand. Table 2 lists the formulas in a summarised fashion; the country reports contain more details.

Table 2. Issued formulas in the case application for air conditioners in office buildings

Country	Formulas
The Netherlands	*Annual energy savings:* $ES = \sum^{Units} (\frac{Q_{cool,yr}}{\eta_{gen}})ref - (\frac{Q_{cool,yr}}{\eta_{gen}})sel$ *Unit = number of air conditioning systems installed* $Q_{cool,yr}$ *= yearly cooling demand* η_{gen} *= efficiency of the air conditioner* *ref = reference air conditioner* *se = selected air conditioner*
Spain	*Annual electricity savings:* $ES = \sum^{Units} discount\ factor * load * t * P_{nominal} \left(\frac{1}{COPold} - \frac{1}{COPnew}\right)$ Unit = number of (new) air conditioning systems installed Discount factor= annual performance reduction Load = annual cooling load profile t = time of use (in hours) $P_{nominal}$ = Nominal power COP = Coefficient of Performance Old = existing air conditioner New = new installed air conditioner

The yearly cooling demand as well as the annual cooling load profile is, in both cases, a sum of demands or loads in a short time period: monthly cooling demand or 10% load in combination with hours per year. In the Spanish case application, the annual electricity savings are discounted by 2.5% over the theoretical performance. In the Dutch case application, the parameters on the dimensions of the building are in line which those specified in ISSO 75.1.

For the baseline in the Spanish case application is this the efficiency of the exiting cooling system with the existing R22 machines, while in the Dutch case application this is a reference situation with another air conditioning system or another air conditioner.

Normalisation is not conducted in the Spanish case application; while in the Dutch case the yearly cooling demand is calculated using average monthly values for a standardised year. In both case no corrections are conducted.

In the Spanish case application, the annual electricity savings are discounted with 2.5% over the theoretical performance. So at the 10^{th} year of the savings, (the expected lifetime of a chiller is assumed to be around ten years), the annual savings are discounted by a factor of 0,825.

Choices within the calculations have more impact on the calculated energy savings than the data collection method

All case applications describe the method to estimate the key parameters. In France, the parameters are used within the system of White Certificates and for that reason they are published through Ministerial Decrees. The values are set after a process of consultation. Table 2 presents the values for the old and new lamp and for the burning hours. The values for the Republic of Korea are used for a program that facilitates the replacements of fluorescent lamps by 32W types. The value of the old lamp is based on data collected during the design stage of the programme (to estimate the stock average).

Table 3. Key parameters in the case application lighting in houses per country

Country	Key parameters
France	• *Method is focused on CFL units;* • *Deals with an average 80 W for incandescent bulbs and 18 W for new CFLs. Delta Watt is therefore 62W;* • *Burning hour t is assumed to be 800. This amount is based on the living room and* an assumed utilisation of 2 hours and 10 minutes per day on average*. Burning hours t do not change after the replacement.*
Korea	• *Method is focused on fluorescent lamps;* • *Deals with old fluorescent lamps of 40W and new fluorescent lamps of 32W. Delta is 8W;* • *Burning hour t is assumed to be: 2771. This amount is based on all rooms in a building.*
The Netherlands	• *Method is focused on CLF-units;* • *Average power old lamp is 55,8W and average power new lamp is 12,4W. Delta is 33,4W;* • *Burning hour t is assumed to be 482. This amount is based on all households and on all rooms in a house. Burning hours do not change after the replacement.*
Spain	• *Method is focused on LED-units;* • *Assumed power old lamp is 40W and assumed average power new lamp is 4W. Delta is 36W.* • *Burning hour t is assumed to be around 700. This amount is based on energy auditing experiences. Burning hours do not change after the replacement.*
United States case area California	• *Method is focused on CLF;* • *Overall delta watts 44.5 W. This value depends on CFLs, lamp wattage and the relevant baseline;* • *Burning hours t are approximately 657 hour annually (1.8 daily time 365 and are determined via monitoring e.g. retrieving information on operating hours of installed measures.). This is done as a function of dwelling unit characteristics, room type, fixture type, lamp type, and region.*

Source: the individual case applications as included in the country report

In the Spanish case application, the burning hours are based on experiences in energy auditing, while the lamp Wattage is taken as an example for the calculation. The Dutch values are based on market research in the year 2000 and are for CFLs Wattage and burning hours an average for all rooms/areas in a house. It is assumed that a CFL lamp replaces a light bulb of 4.5 times it Wattage. In the California case, the data is based on residential lighting inventory and data for the lamps and hours are based on models using metered time of burning in a sample. Table 3 holds the information on the key parameters. It shows that almost all options for data collections are covered by the case applications.

France calculates the energy savings for the CFL replacement programme with a delta W of 62 and 800 burning hours (see table 3). Applying the general formula this results in an annual energy saving of 49 kWh per CFL. In table 4 we present the energy savings calculation for four states, using the country specific burning hours and delta W in the shadowed cells. In the columns we present the annual energy savings per lamp, using each of the country's *burning hours*, but by applying the differences in Watts for each of other three countries as well. E.g. using in the France case the delta W of California, the energy savings would be 35.6 kWh; so the energy saving would be 28% less. When using the average Dutch value, even 46% lower. On the other hand, if we would use the France value in the Dutch case, this would result in 65 % higher savings and when using the California value, 30% higher.

Table 4. Energy savings per land, using same **burning** hours

	Values France			Values Netherlands			Values Spain			Values California		
	delta P	t	kWh	delta P	t	kWh	delta P	t	kWh	delta P	t	kWh
	to CFL			to CFL			to LED			to CFL		
	62	800		62	482		62	700		62	657	
E savings per lamp			49.60			29.88			43.40			40.73
	33.4	800		33.4	482		33.4	700		33.4	657	
E savings per lamp			26.72			16.10			23.38			21.94
	36	800		36	482		36	700		36	657	
E savings per lamp			28.80			17.35			25.20			23.65
	44.5	800		44.5	482		44.5	700		44.5	657	
E savings per lamp			35.60			21.45			31.15			29.24

In table 5 we present the same calculations, but now keeping the same delta P and using the *burning hours* from the other states. It shows that, in the California case, using the French burning hours, the energy savings would be 35.6 kWh. So the energy saving would be 21% higher and, when using the average Dutch value, 27% lower. On the other hand, if The Netherlands would use the France value, this would result in 66 % higher savings and, when using the California value, 36% higher.

One might conclude from this data that the data collection method has a major influence on the energy savings. But this is misleading. The high value of the old light bulb and high number of burning hours in the France case is related to the assumption that the CFLs will be installed in the living room. This room has the highest Wattage and burning hours. In the Dutch documentation it is shown that the burning hours in the Dutch kitchen and living room were about 890 hours in 1995.

Table 5. Energy savings per land, using same **delta Watt**

	Values France			Values Netherlands			Values Spain			Values California		
	delta P	t	kWh	delta P	t	kWh	delta P	t	kWh	delta P	t	kWh
	to CFL			to CFL			to LED			to CFL		
	62	800		33,4	800		36	800		44,5	800	
E savings per lamp			49.60			26,72			28,80			35,60
	62	482		33,4	482		36	482		44,5	482	
E savings per lamp			29,88			16,10			17,35			21,45
	62	700		33,4	700		36	700		44,5	700	
E savings per lamp			43,40			23,38			25,20			31,15
	62	657		33,4	657		36	657		44,5	657	
E savings per lamp			40,73			21,94			23,65			29.24

On the other hand, in official French calculationa for the White certificate scheme, it is assumed that 30% of the installed CFLs replace CFL and does not result in energy savings. While the Netherlands was one of the countries that already started in the early 1990s with programmes to stimulate the use of CFL, in the energy savings calculation the assumption is still that CFLs do not replace existing one. This is not related to data collection, as information is available on the net annual increase of installed CFLs. In the Dutch case, the change is Wattage and burning hours are based on an average of all rooms and all households. While in the 1990s the CFLs were indeed mainly installed in the living area (in the Dutch case in 1995 on averages about 1 in the living areas; 0.5 outdoor and 0.5 in all others together; in 2000 1.2 in the living areas, 0.6 outdoor and 0.9 in all others together), nowadays this is no longer the case. They are mainly installed in cellars, bedrooms etc. Changing the assumption into e.g. only using the average Wattage and burning hours in such a room would result in about no change in the Wattage but a very substantial change into about 200 burning hours.

For the lighting cases, we hold the opinion that the impact of assumptions is higher than those from more sophisticated data collection methods. Of course these later result in much better data on the energy use after installing the CFLs. But they are outranged by a change in the baseline.

In all case applications, it is assumed that a bought CFL is installed immediately. From research it is known that an increasing number of bought CFLS are spare lamps. This does not influence the savings per lamp, but the overall impact of summed annual savings.

During the IEA DSM project, the experts documented the assumptions as used in the case application. But in the discussion in the meeting it became more and more obvious that over years assumptions are seldom changed. Once they are agreed, they are repeated over and over in programmes. Information from case applications in other countries will provide an easy indication of the reliability of assumptions at the present time. But the experience in the project was that often this type of information is not published in articles. For example, the immediate installation of CFLs. This was a proper assumption when the CFLs were rather expensive, but nowadays with give away actions and low prices, more often CFLs will also be held in reserve.

Conclusions

In the IEA DSM project a template was developed to document the key elements for energy savings calculations. With this template the evaluator has a tool to provide information more transparently. He can increase the understanding on how the calculation is conducted and what choices were made. The information for energy savings calculation using this template for five technologies from different countries shows that, although calculated energy savings are different, they can be made comparable to each other. This is a good starting point for harmonisation of savings calculations.

The experiences from the IEA project as well as those from the development of a European standard on energy savings calculations show an important first step is taken by creating a common framework. This should make the documentation and presentation of calculations more easy and transparent. But the number of case applications is very small and more are needed to improve the framework and the understanding. Recently started work by the international standardisation organisation ISO on energy savings calculations is targeted to get a broader agreement on a common framework. In parallel, more case applications should be developed providing data in a comparable way and prove the strong elements in the framework as well as the weak ones which need to be improved.

It appears that for energy savings calculation we are developing a common ‘language’ how to put our work (songs) on paper in such a way that another evaluators can sing this song and reuse it to create his or her own song. Let us hope this will be a way to enable singers in the future to form a harmonious chorus.

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