MAKING THE RESULTS OF BOTTOM-UP ENERGY SAVINGS COMPARABLE

by

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The Energy Service Directive has pushed forward the issue of energy savings calculations without clarifying the methodological basis. Savings achieved in the Member States are calculated with rather non-transparent and hardly comparable Bottom-up methods. This paper develops the idea of parallel evaluation tracks separating the Member States' issue of Energy Service Directive verification and comparable savings calculations. Comparability is ensured by developing a standardised Bottom-up calculation kernel for different energy efficiency improvement actions which simultaneously depicts the different calculation options in a structured way (e. g. baseline definition, system boundaries, double counting). Due to the heterogeneity of Bottom-up calculations the approach requires a central database where Member States feed in input data on Bottom-up actions according to a predefined structure. The paper demonstrates the proposed approach including a concrete example of application.

Key words: *energy efficiency improvement measure, bottom-up evaluation, comparability, energy savings calculations*

Introduction

In 2008, the European Commission presented the climate and energy package, specifying (1) a reduction in EU greenhouse gas emissions of at least 20% below 1990 levels, (2) a 20% share of EU energy consumption to come from renewable resources, and (3) a 20% reduction in primary energy use to be achieved by improving energy efficiency (known as 20-20-20 targets). Further reasons for the growing importance of the calculations of energy savings are several legislative and political foundations.

The calculation of energy savings is made mandatory by the Energy End-Use Efficiency and Energy Services Directive (ESD) 2006/32/EG in order to verify the achievement of energy saving targets. For an example of how national energy efficiency strategies under the ESD look like, see [1].

Several countries have agreed on voluntary agreements with various branches on energy saving targets; some countries (such as France, Italy, and UK) have gone a different

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way by introducing schemes with non-voluntary supplier obligations and tradable White certificates; furthermore, there is a need for policy evaluation based on reliable and quantifiable data on energy saving impacts of policy programmes and other facilitating measures [2].

In this case, macroeconomic indicators [3] are not sufficient for evaluation purposes. As energy efficiency targets (*e. g.* in the mentioned agreements) are usually not formulated for one party, the requirements on methodology, precision and data used for the calculations require serious efforts of the parties participating in the programme, in order to achieve comparable results. In the case of ESD, the 27 Member States of the EU are required to reduce their end-use energy consumption by 9% in the period 2008 to 2016. The requirements for the member states for reporting the achieved energy savings therefore need to guarantee comparable results of their energy efficiency improvement efforts. Nevertheless, since only the achieved savings, but not the data about their implemented actions (*e. g.* number of thermal insulated buildings including specifications of the thermal resistance of the applied parts) need to be reported, an evaluation of the savings by the responsible authority is not possible. Since no general standard exists for calculating these saving figures (so far), comparability of the values is not likely. This paper strongly argues for the collection of data about the implemented energy efficiency actions rather than their savings. Moreover, it recommends the storage of this data in a data bank with standardized requirements to achieve homogenisation of the reported energy efficiency savings figures. This will also ease their evaluation by authorities and experts.

In the context of this paper the terms energy efficiency programme, energy efficiency measure and energy efficiency action are defined as follows: An energy efficiency programme initiates a number of energy efficiency measures and provides the (legal) framework for their implementation. An energy efficiency measure is a single project that motivates a target group to realise certain energy saving actions, such as the assembling of energy efficient heating devices in households. Furthermore, a bottom-up calculation method in which "*energy savings obtained through the implementation of a specific energy efficiency improvement measure are measured in kilowatt-hours (kWh), in Joules (J) or in kilogram oil equivalent (kgoe) and added to energy savings results from other specific energy efficiency improvement measures*" (ESD, Annex IV).

Calculating energy savings in the context of the ESD

The ESD does not specify a uniform and harmonised method for energy savings calculations. Indeed, Annex IV of the ESD provides a general framework for this issue and a procedure for further development of methodological prescriptions but also states that the European Commission will, in time, prepare a harmonised calculation model. It further states, that "*Member States that so wish may use further bottom-up measurements in addition to the part prescribed by the harmonised bottom-up model ….*" Since then, the European Commission has presented "Recommendations on Measurement and Verification Methods" [4] and the European Committee for Standardization (CEN) prepared a draft standard on how to calculate energy savings achieved by energy efficiency improvement (EEI) measures [5]. Both documents contain major principles and processes for the calculation of energy savings and can thus be seen as important steps towards methodological harmonisation. But on the one hand side, these documents are 'recommendations' and 'drafts' only while on the other hand, the standards are too general in contrast to the specific recommended methods.

Therefore, they are not capable to decidedly converge the possible results of energy savings calculations.

This follows, that in practice, the evaluation and verification of energy savings will be conducted according to national methodologies for the reporting under the ESD as well as for calculation procedures used in voluntary agreements and in supplier obligation schemes. Aside of the motivation to keep administration simple and costs low, national authorities have considerable interest to keep methodological issues under their own control and thus have little interest to go for a further harmonisation beyond the levels achieved so far.

It seems that a comprehensive harmonisation – in the sense of *unification* – of energy savings calculation is an unrealistic goal for the time being (for an approach to ensure homogenisation by the design of the energy efficiency measures itself, see [6]). However, improved *comparability* of energy savings calculation seems an achievable aim. This requires transparency of the calculation methodologies applied and the assurance that energy savings calculation results are compared only if they use the same calculation kernel. This paper proposes an approach towards increased comparability in energy savings calculation.

Several analogies to the proposed parallel evaluation stream in order to achieve comparability of results exist:

- ISO 14064 was launched in 2006 for the monitoring, reporting and verification of greenhouse gas emissions.
- For the calculation of unemployment rates national methodologies as well as EU-wide methodologies exist.
- The same is true for the calculation of state budgets, where the harmonised calculation approaches have become of major importance with respect to the stability of the Euro monetary union.

Comparability of energy savings calculations

The application of national methodologies is in line with the ESD; however, it leads to incomparable results due to various reasons, such as:

- the complexity of the algorithms of energy savings calculations themselves (*i. e.* varying calculation rules and data needed),
- the difference in interpreting the term "energy savings" simply because of the fact that energy savings cannot be directly observed but always need some interpretation, and
- the differences in input data used, partly due to different levels of data availability.

Monitoring and verification as part of the policy evaluation process

For each policy evaluation, the monitoring and verification (M&V) of the results achieved by the respective policy is crucial. The same is true for any energy efficiency policy.

Figure 1 illustrates the policy process initiated and enforced by the ESD as a sequence of the design of energy efficiency policies, of implementation of these policies and their evaluation.

The evaluation may lead to a further redesign of the policy instruments and enable continuous improvement of the performance of energy efficiency policy. In this sequence, the National Energy Efficiency Action Plans (NEEAP) to be delivered by the Member States to the Commission are a valuable evaluation tool.

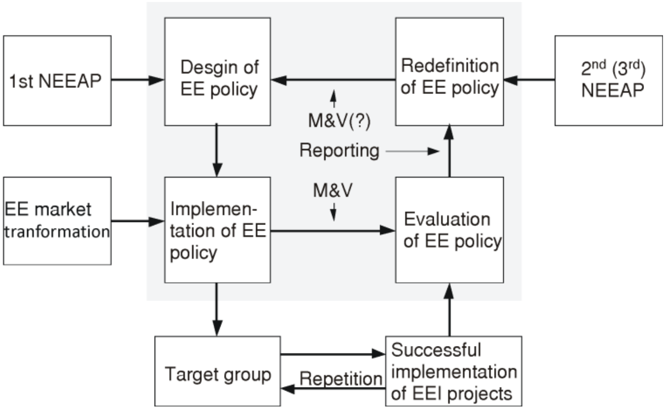

Figure 1. The role of M&V in an effective energy efficiency policy process. Source: [7]

Furthermore, the ESD refers to the achievement of absolute energy saving targets (in TWh), whereas for policy evaluation – as for any kind of evaluation – relative comparability (in per cent) gives more valuable results than a comparison of absolute values. In this context, two aspects of comparability need to be addressed:

- The comparability between actors (*e. g.* Member States) and measures such as different EEI programmes allows distinguishing whether EEI measure A or EEI measure B has a higher impact and thus choosing priorities and addressing problems on this basis.
- The comparability over time, which is perhaps even more important and which can help to analyse the development of one specific EEI measure over several years.

Common principles and terms in bottom-up calculation

In order to understand the origins of incomparability, a first look at the most common principles in M&V of Bottom-up (BU) energy savings calculations needs to be taken. *Gross energy savings* of one unit subject to the measure (*e. g.* one building) are calculated and then these unitary gross savings are added up in order to obtain the total gross savings of all units affected [6, 8-11]. The main principle of a BU calculation can therefore be expressed with the formula:

$$GES_t = BEC_t - AEC_t \tag{1}$$

where AEC_t is the actual energy consumption, BEC_t – the baseline energy consumption, GES_t – the gross energy savings, and t – the period of interest.

Baseline energy consumption is the energy consumption that will occur if no additional EEI actions are taken to reduce energy consumption. Additionality means that only EEI actions which are implemented due to the respective policy instrument are accounted for (*i. e.* EEI actions implemented anyway or due to another policy instrument are disregarded). Actual energy consumption is the measured or estimated energy consumption of the object after the implementation of the EEI action. Subscript t in formula (1) implies that baseline energy consumption and actual energy consumption are not necessarily constant from the year of the implementation of the energy efficiency measure to the last year in which the measure is effective.

Formula (1) describes the unitary gross energy savings. All EEI actions within the scope of one measure have to be summed up and then corrected for certain factors that might lead to biased results, such as the rebound effect, multiplier and spill-over effects, and dead weight, *etc*.

In this case, multiplier and spill-over effects refer to EEI actions which (1) are implemented "outside" the energy efficiency policy instrument but (2) are initiated by the energy efficiency policy itself or EEI actions implemented in the course of the policy due to the diffusion of information, improvements in recognition and image of a technology, or the benefits of combined implementation. The dead weight of an energy efficiency policy (*e. g.* subsidies for EEI actions) contains those EEI actions which would have been implemented anyway, *i.e.* without subsidization. Economic actors who benefit from the policy despite of their EEI action being dead weight are called "free-riders".

In most cases it is not possible to individually account for these factors at the unit level with a reasonable amount of effort, but previous studies and experiences from the monitoring of similar measures typically provide some information on the average effect of these factors on the overall outcome of the savings. Accordingly, the sum of all gross unitary energy savings achieved by the energy efficiency measure being evaluated is corrected for these factors to obtain the total net energy savings. Thus, the formula for the total net energy savings is:

$$total_{NES} = total_{GES} - corr_{net} \tag{2}$$

where $corr_{net}$ is the net value of correction factors, *GES* – the gross energy savings, and *NES* – the net energy savings.

Sources of incomparability

From formulas (1) and (2) several reasons of the incomparability of calculation results can be derived. Incomparability may arise, first, from the calculation of the savings on the unit level as depicted in formula (1) or, second, from the application of different correction factors or even from applying a correction procedure different from formula (2). Therefore, the reasons for incomparable results of BU energy savings calculations according to the relevant stage of the calculation process need to be classified and the reasons for incomparability on the unit level as Level 1 origins, and reasons emerging from the aggregation and correction process as Level 2 origins have to be denoted.

For the determination of the baseline and the actual energy consumption in formula (1), a number of procedural steps are used. These steps are outlined in [10] and include decisions on and assumptions about:

- What is the boundary of the system which energy consumption is calculated for?
- What is the baseline technology?
- What is the lifetime of the new technology?
- Does the EEI action incorporate a change in the provided energy service?
- How are different circumstances (*e. g.* climate) between the baseline scenario and the actual scenario accounted for?

Source of incomparability: system boundaries

The first important source for incomparability is the decision where the system boundaries are drawn. The system boundaries in the context of BU energy savings calculations are defined (standardisation draft prEN 16212 [5]) as the "*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*". Replacing an oil boiler with a district heating system offers two options which are reasonable for drawing the system boundaries. Depending on where the system boundaries are drawn *actual energy consumption varies*, and so do the calculated energy savings:

(1) Drawing the system boundaries around the residential building means that every kWh that enters the building through the district heating pipeline is accounted for by the *actual energy consumption*.

(2) Defining the district heating plant as part of the heating system, and thus drawing the system boundary including the heating plant means that every kWh, *e. g.* from coal or biomass, that enters the heat production process is accredited to the *actual energy consumption* of the residential building.

Both possibilities are crucially different. The *actual energy consumption* of option (2) incorporates all conversion losses from primary energy to heat and transmission losses from the heating plant to the residential building, so that the *actual energy consumption* in option (2) is inevitably higher than the one of option (1), which neglects these energy losses.

Source of incomparability: baseline definition

The second important source of incomparability at the level of unitary savings is the definition of the baseline case. Usually, at least three different general baseline options can be distinguished (c.f. prEN 16212 [5]):

- the baseline can be defined using the "before"-situation, *i. e.* the situation before the implementation of the EEI action is interpreted as baseline case,
- the baseline can be defined using a reference situation which is based on the "market average" energy use for a certain technology, and
- finally, the baseline can be defined by a reference situation which reflects the "stock" energy use of a certain technology.

In addition, it needs to be taken into account that baselines can be stable (unchanging) over time or dynamic assuming a certain development of the reference situation without additional EEI actions ("autonomous trend"). Firstly, Member States can choose from these options and, secondly, adapt the individual options to their needs.

Source of incomparability: determination of actual consumption data

A third major origin of incomparability of energy savings calculations at the unitary level are the approaches chosen for the determination of actual consumption data. In this respect, the following approaches are distinguished:

- use of measured data: If *measured* data are used for energy saving calculations additional accompanying data for the necessary adjustment process (*e. g.* information about weather conditions, usage patterns, plant throughput, *etc.*) is needed; measured data can be gained either by billing analysis or by direct measurement with the latter supposedly being the case only for a very limited number of EEI actions or,
- use of calculated data which are gained by enhanced *engineering* estimates, prevailingly using input data related to a concrete EEI action, and
- use of calculated data gained from a *deemed* estimate prevailingly built on default values; the default values used can be defined on the European level as well as on the national or even regional level, depending on the energy use or technology in question.

In the case of the Italian White Certificates Scheme all approaches listed in the text are eligible for the M&V of EEI actions. In Italy, the approaches used for the determination of consumption data are denoted as ”deemed”, ”engineering”, and ”monitoring” approach.

The type of approach chosen for the energy savings calculations primarily depends on the availability of data. In general, measured data is assumed to better reflect actual consumption and resulting savings thereof than are default values. This in turn means that default values have to be chosen very accurately in order not to over-estimate energy savings. The principle of conservatively determining default values is reflected in many standards and regulations such as in CEN standards for the calculation of the energy performance of buildings or in CEN WS 27 on saving lifetimes [12]. Therefore it seems advisable to apply conservative values for energy savings calculations in general.

There is no universally valid answer to the question which of the different calculation options derived from the approaches as presented above is the most adequate, but when comparing the savings of similar EEI measures differences in calculations need to be transparent, *i. e.* savings are only comparable given that identical methods of calculation are in use.

The main origins for incomparability at the level of net energy savings (formula 2) are therefore characterised by issues like:

- How is the issue of free riders handled?
- How is it ensured that double counting for different policy instruments (reduced additionality) does not bias the results?
- How can the rebound effect be evaluated and corrected for?

Again, these issues can be addressed independently and differently by the member states. Summing up the numerous ways in which energy savings are calculated, the conclusion is that it is hardly possible to directly compare the results of energy savings calculations – as for example presented in the NEEAP of the EU Member States.

Proposed approach to achieve comparability

The approach presented in this paper does not aim at forcing Member States to use a unified method. It should rather be an automatically processed parallel calculation which allows for comparability.

Parallel evaluation stream to achieve comparability of results

The ESD regime defines fixed savings targets; however, it allows for methodical flexibility in energy savings calculations. Member States' are interested in complying with the ESD targets at minimum costs. Thus, the definition of national M&V approaches underlies strong incentives towards a reduction of efforts necessary to demonstrate compliance. Consequently, a parallel evaluation approach is needed that is not directly linked to the non--transparent national approaches in order to achieve comparability of the results of energy savings calculations. Moreover, it needs to work under a standardised procedure. In the following, the term ESC-COMP ("energy savings calculation for comparability") is used as abbreviation for the proposed approach.

Figure 2 gives an overview of this approach, which is then followed by a more detailed description of its different parts.

Object of assessment

At first it is important to clarify the object of assessment of the ESC-COMP approach. Energy savings are realised (only) by end-user actions that can be of a technical,

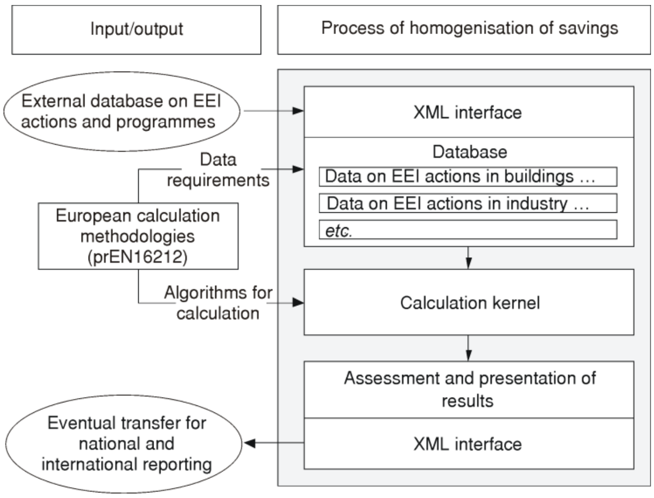

Figure 2. Overview of the ESC-COMP approach

organisational or behavioural nature. Therefore the object of assessment in the proposed approach is the elementary unit of end-user action; *i. e.* a certain system where an improvement of technology, organisational process and/or user behaviour leads to verifiable and measureable energy savings. This starting point is in line with the draft standard prEN 16212 which further describes that the elementary units of action can be defined at very different aggregation levels which are hierarchically related:

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

Measures facilitating EEI actions such as energy efficiency policy programmes and other support measures are not subject to the ESC-COMP assessment proposed although, the approach can process data which was generated in the framework of measures facilitating EEI actions. Figure 3 illustrates the object of assessment of the proposed ESC-COMP approach and compares it with an approach that starts with policy instruments.

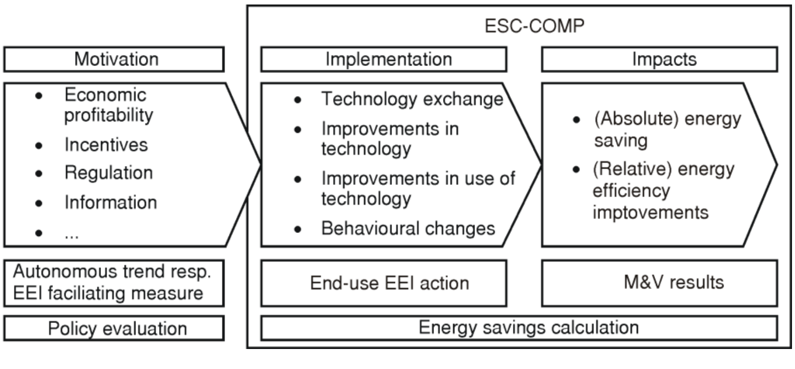

Figure 3. Object of assessment of ESC-COMP

Thus, the results achieved by the proposed ESC-COMP approach can only be used for a policy assessment if additional information on the impact of policy instruments on EEI actions is available, *i. e.* information on the motivation behind the actual implementation of EEI actions.

Standardised calculation kernel

As indicated, the core of each energy savings calculation is a comparison of the actual energy consumption or the demand estimated, resp. with a reference case but details in this calculation procedure can be handled very differently. The prescriptions of the draft standard prEN 16212 as well as the European Commission paper with "Recommendations on Measurement and Verification Methods" deliver guidance in fixing the algorithms. For comparability, in principle, it does not matter which calculation approaches are chosen as long as the same approach is applied for similar EEI actions and the calculation kernel is able to reflect different calculation options regarding:

- definition of the baseline,
- choice of the system boundaries and aggregation level,
- adjustment of energy consumption,
- different quality levels of input data, and
- application of correction factors for double counting, multiplier effect, free-rider effect, *etc.*

Obviously, considerable differences occur in the calculation algorithms when differing methods are used for measuring the object's actual consumption (monitoring, engineering and deemed approach). Measured consumption data need adjustments for weather conditions, occupation levels, production throughput, *etc.* – which is reflected in the respective formula. Calculated data use standardised framework conditions so that further adjustments are unnecessary.

Database for input data

The calculation kernel defines the set of required input data. If the calculation kernel offers different calculation options this has to be reflected by different sets of required input data. In any case, the required input data will depend very much on the approach chosen with respect to the different levels of data quality as described above, *i. e.*:

- approach using measured data,
- approach using calculated data gained by enhanced engineering estimates adapted to the conditions of individual EEI actions, and
- approach using calculated data gained from deemed estimates prevailingly built on default values.

For practical operability of the ESC-COMP approach, it is inevitable to create an automatic transfer mechanism between existing databases *e.g.* those databases which have been developed by the Member States to fulfil the M&V requirements related to ESD reporting. This is usually done by defining a standardised file that defines the data requirements of the target database, whereas the available data in the origin database are transferred into the structure given by it (This file can be written in the Extensible Markup Language (XML) which is a language in which rules are defined about how to encode documents so that they are human-readable as well as machine-readable).

Evaluation of results

Since the proposed ESC-COMP approach does not produce a single result, only a wider range of results depending on the calculation option chosen, the results of different calculation options have to be presented in a transparent way. Major features of a comprehensive evaluation support are:

- In a first step, only those results of energy savings calculations are compared which are derived using the same methodology, *i. e.* the same combination of calculation options: The comparisons of results are made between countries as well as over time (*i. e.* for one country resp. region but over several periods of time); the comparisons are made in absolute values as well as in specific benchmarks (*e. g.* average amount of energy savings per square meter of a building improved by a certain EEI measure).
- In a second step, it is also useful to compare results for the same EEI actions derived with different methodologies (if available). In doing so, the sensitivity of energy savings calculation results dependent on the methodological approach chosen, can be controlled for. Furthermore, the degree to which the default values applied are conservative can be checked.

Case study for the example of EEI measure "boiler exchange"

The following chapter demonstrates with the help of a simplified typical example how the approach could work in practice. The example consists of a set of 10 boiler exchange measures in central heating systems of a multi-family residential building. The replacement of old boilers is one of the measures that the ESD (Annex III) lists as *"eligible energy efficiency improvement measures"*. It furthermore is a measure that is of relevance for all European Union member countries (albeit it probably is more important in the North than in the South). The substitution of an out-dated gas boiler by a modern gas condensing boiler including usual accompanying measures in the boiler room is assumed without further measures related to the distribution system or the regulation of the heating system in the single flats. Also the building itself remains unchanged. Integrating these complexities in the further analysis would not change the outcome as any of these accompanying measures would only change the level of the energy savings achieved not the way they are calculated.

The following calculation options for this example are limited to one year. Therefore, in a first step, the example excludes the additional complexity of the life-time of energy savings derived from a certain EEI action [13].

Calculation option 1: Measured data based on billing analysis

Calculation option 1 is based on measured data [14] derived from energy bills. Although it is difficult to collect measured data in many cases, several data sources exist which can be used in this context, such as data from energy book-keeping systems, data related to the evaluation of energy performance contracting projects, *etc.*

This option is characterised by the following features:

- Using the energy bills as fundamental source of consumption data implies that the system boundary used for the energy savings calculation is the building as a whole.
- The baseline is defined by the energy consumption derived from the bill for the baseline period. The actual consumption is read from the bill for the assessment period as well.
- The calculation kernel is based on a simple comparison of the actual consumption to the baseline consumption [11, 12] where the actual consumption is adjusted to the side conditions observable in the baseline period. The formula for the adjustment is as follows:

$$EC_{m,t,n} = EC_{m,t}\left[(1-f_u)+f_u\left(\frac{UI_b}{UI_t}\right)\right]\left[(1-f_w)+f_w\left(\frac{WI_b}{WI_t}\right)\right] \tag{3}$$

where $EC_{m,t}$ is energy consumption metered in the observed period t, $EC_{m,t,n}$ – the energy consumption metered in the observed period t normalised to the external conditions in the baseline period, f_u – the usage factor; share of the energy consumption which is dependent on the building use; with $0 \leq f_u \leq 1$, f_w – the usage factor; share of the energy consumption which is dependent on weather conditions; with $0 \leq f_w \leq 1$, UI_b – the indicator for usage conditions in the baseline period, UI_t – the indicator for usage conditions in the observed period t, WI_b – the indicator for weather conditions in the baseline period, and WI_t – the indicator for weather conditions in the observed period t.

- The input data necessary for calculation option 1 are as follows: energy consumption (information from the energy bill); heat degree days (as a proxy for weather conditions) and information about the degree of tenancy. All information has to be available in a comparable way for the baseline period as well as for the assessment period. In practice, the availability of this information is problematic even for energy consumption since the duration of meter-reading periods varies from one year to the next. For larger deviations an extra adjustment has to be made.

Table 1 summarises input data and results of calculation option 1 for our simplified boiler exchange example.

Table 1. Input data required and results for calculation option 1: measured data based on billing analysis

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
Gross floor area [m^2]	850	1,560	2,011	619	770	1,233	1,756	550	1,178	912
Baseline measured										
Heat consumption measured [MWh a^{-1}]	205.3	281.7	333.6	182.0	197.3	243.4	372.4	149.0	200.4	210.7
Usage indicator [%]	100%	95%	90%	98%	100%	82%	89%	97%	95%	95%
Yearly heating degree days	2,970	3,020	3,400	3,100	3,550	2,970	2,970	3,480	2,970	2,970
After boiler exchange measured										
Heat consumption measured [MWh a^{-1}]	164.2	216.9	270.2	151.0	151.9	206.9	309.1	114.7	176.3	183.3
Usage indicator [%]	100%	97%	92%	95%	100%	86%	85%	90%	100%	95%
Yearly heating degree days	3,119	3,141	3,570	3,131	3,621	3,119	3,119	3,619	3,119	3,119
Heat consumption total adjusted [MWh a^{-1}]	158.0	206.4	254.9	154.1	149.5	190.7	309.9	119.0	162.0	176.3
Energy savings measured & adjusted [MWh a^{-1}]	47.3	75.4	78.8	27.9	47.8	52.7	62.5	30.0	38.4	34.4

Total for all EEI action assessed [MWh a^{-1}]	**495.1**
Specific energy savings [kWh m^{-2}]	**43.3**

B1 to B10 is a sample of boilers replaced during EEI measures which is consistently used for the illustration of the effects of varying calculation options

Calculation option 2: Enhanced estimate for each EEI action

Calculation option 2 uses the enhanced engineering estimate method which is applied separately for each of the individual EEI actions. Instead of using metered data, energy consumption values are calculated. In this case the Austrian standards for the calculation of energy performance of buildings according to the Energy Performance of Buildings Directive have been used. Calculation option 2 features the following characteristics:

- The approach uses the building as system boundary since the energy consumption of the whole building is calculated (not only the losses related to the heating system).
- The baseline energy consumption is calculated by using the technical characteristics of a given building as input data, for a detailed calculation of the energy performance of the building.
- The energy consumption of the assessment period is calculated by reflecting the EEI action in the technical characteristics of the calculated building. This means, that the baseline calculation is adapted by substituting the old boiler by a new condensing boiler.
- Then, the energy savings are simply the result of subtracting the energy consumption of the assessment period from the baseline energy consumption. No further adjustment with respect to weather conditions and/or usage patterns is necessary, provided that the input parameters used for the impact factors on energy consumption are realistic.
- In order to be able to conduct an enhanced engineering estimate, a wider range of input parameters is needed. On the first sight, it seems difficult to implement this in an energy savings calculation for a larger number of EEI actions. However, there are several possibilities for simplification which hardly influence the accurateness of the result: thermal losses of buildings can be estimated quite accurately by using information on the gross floor area, the surface-volume-ratio of the building, the share of the window area in the building envelope and typical data on heat transmission factors (*e. g.* according to the standards in force for the specific building period). The losses of the heating system can be estimated according to reference equipment which is typical for the building period. All these data are usually available from energy certificates. In addition, if energy certificate data are available in databases, as this is the case for some regions in Austria where energy certificate data are centrally administered (www.energieausweise.net which is a portal for the administration of energy certificates in the region of Salzburg), an automatic transfer of the required data to the ESC-COMP tool could be organised.

Table 2 gives a summary of the main results of calculation option 2 for the example.

Calculation option 3: Deemed estimate using standardised default values

Calculation option 3 can be interpreted as a maximum simplification of calculation option 2. The following characteristics are crucial:

- The calculation kernel is comparable to the one used for option 2 but input data are largely simplified. There is only one figure used for the energy demand to be served by the heating system and one figure expressing the efficiency of the heating system itself.
- Furthermore, the default values do not differentiate between the single buildings and EEI actions. This means, once the default values are fixed, the only information needed for the energy savings estimate is the number of m^2 which are heated by the new condensing boiler.

Table 2. Input data required and results for calculation option 2: enhanced estimate for individual EEI actions

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
Gross floor area [m²]	850	1,560	2,011	619	770	1,233	1,756	550	1,178	912
Baseline calculated										
Net heat demand calculated [MWhm^{-2} a^{-1}]	115.0	86.2	95.4	140.0	122.0	94.9	101.3	129.0	103.0	110.0
Hot water demand default [kWhm^{-2} a^{-1}]	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
Losses of heating system calculated [kWhm^{-2} a^{-1}]	103.0	102.2	93.0	96.6	105.0	99.8	95.7	103.0	99.6	100.2
Heat demand calculated [kWhm^{-2} a^{-1}]	233.0	203.4	203.4	251.6	242.0	209.7	212.0	247.0	217.6	225.2
Heat consumption total [MWh a^{-1}]	198.1	317.3	409.0	155.7	186.3	258.6	372.3	135.9	256.3	205.4
After boiler exchange calculated										
Net heat demand calculated [kWhm^{-2} a^{-1}]	115.0	86.2	95.4	140.0	122.0	94.9	101,3	129.0	103.0	110.0
Hot water demand default [kWhm^{-2} a^{-1}]	15.0	15.0	15.0	15.0	15.0	15.0	15,0	15.0	15.0	15.0
Losses of heating system calculated [kWhm^{-2} a^{-1}]	65.9	55.0	57.3	63.9	50.1	52.3	49,7	60.0	55.6	44.0
Heat demand calculated [kWhm^{-2} a^{-1}]	195.9	156.2	167.7	218.9	187.1	162.2	166,0	204.0	173.6	169.0
Heat consumption total [MWh a^{-1}]	166.5	243.7	337.2	135.5	144.1	200.0	291,5	112.2	204.5	154.1
Energy savings measured [MWh a^{-1}]	31.5	73.6	71.8	20.2	42.3	58.6	80,8	23.7	51.8	51.3

B1 to B10 is a sample of boilers replaced during EEI measures which is consistently used for the illustration of the effects of varying calculation options.

Total for all EEI action assessed [MWh a^{-1}]	**505.6**
Specific energy savings [kWh m^{-2}]	44.2

- In principle, the default values could be fixed at different levels. Regional default values as well as national or European default values can be applied. For the case of energy savings related to buildings, regional default values should be a minimum requirement due to the considerable climatic differences across countries alone. Additional default values could be adapted to the specific EEI actions *e. g.* by introducing a differentiation according to the type of building, the construction year of the building, the construction year of the baseline heating system, *etc*. Further differentiation of default values leading to a more accurate mapping of the real starting conditions of the EEI action gradually transforms calculation option 3 into calculation option 2. In practice, there are many possible intermediate steps between these two options.
- "On paper" calculation option 3 uses the whole building as system boundary, too. In reality, however, if the use of unifying default values prevails over the reflection of specific conditions for each EE action, technical interaction are not taken into account accordingly.

Table 3 summarises input data and the main results of calculation option 3 for the boiler exchange example.

Since this calculation option seems to be frequently used in the M&V practice, some further remarks are needed:

- The results of this calculation option are highly sensitive to the default values used. Only slight changes in the default values for heat demand or, even more sensitive, the value for the performance of the heating system (which is even more sensitive) either on the baseline side or after the implementation of the EEI action lead to remarkable changes in the result.

– It is questionable if default values applied in national energy savings calculation approaches applying deemed estimates are really realistic. Member states can decrease their costs of compliance by attributing exaggerated savings.

Table 3. Input data required and results for calculation option 3: deemed estimate using default values

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
Gross floor area [m^2]	850	1,560	2,011	619	770	1,233	1,756	550	1,178	912
Baseline default										
Net heat demand calculated [MWhm^{-2} a^{-1}]	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Hot water demand default [kWhm^{-2} a^{-1}]	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
Performance ratio of heating system	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90
Heat demand default [kWhm^{-2} a^{-1}]	218.5	218.5	218.5	218.5	218.5	218.5	218.5	218.5	218.5	218.5
Heat consumption total [MWh a^{-1}]	185.7	340.9	439.4	135.3	168.2	269.4	383.7	120.2	257.4	199.3
After boiler exchange default										
Net heat demand calculated [kWhm^{-2} a^{-1}]	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Hot water demand default [kWhm^{-2} a^{-1}]	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
Performance ratio of heating system	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55
Heat consumption default [kWhm^{-2} a^{-1}]	178.3	178.3	178.3	178.3	178.3	178.3	178.3	178.3	178.3	178.3
Heat consumption total [MWh a^{-1}]	151.5	278.1	358.5	110.3	137.3	219.8	313.0	98.0	210.0	162.6
Energy savings measured [MWh a^{-1}]	34.2	62.8	80.9	24.9	31.0	49.6	70.7	22.1	47.4	36.7

B1 to B10 is a sample of boilers replaced during EEI measures which is consistently used for the illustration of the effects of varying calculation options

Total for all EEI action assessed [MWh a^{-1}]	**460.4**
Specific energy savings [kWh m^{-2}]	40.3

Calculation option 4: Deemed estimate with a market average baseline

Calculation option 4 is based on calculation option 3 and demonstrates the effect of a different choice in the baseline which is now defined as the consumption of the market average instead of the consumption of the discarded boiler. In practice, market average baselines are often applied as they better describe the energy savings generated by a certain EEI action in which the object substituted would have been replaced anyway. The main questions in defining a market average baseline are as follows:

– What is the market average? In the example presented defining the market average would require a survey on the actual boiler market; however, this kind of market data is very often lacking.

– When should the market average baseline be applied? One can assume that the market average is particularly appropriate when the EEI actions are (in relation to other types of objects) more common to be realised at the end of the lifetime due to economic considerations.

Once again, answers on the questions which are generally agreed-upon are not available. The ESC-COMP approach, however, transparently describes the variation resulting from the numerous Member States' approaches. Table 4 summarises the main input data and results for a deemed estimate with a baseline defined by the market average for our simplified boiler exchange example, where the default value of the performance ratio of the heating system has been improved for the baseline situation (assumption that the old boiler would else be exchanged by a market average boiler instead of a highly efficient one). The example also demonstrates the sensitivity of the results of deemed estimates to adaptations of the default values.

Table 4. Input data required and results for calculation option 4: Deemed estimate with a market average baseline

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
Gross floor area [m²]	850	1,560	2,011	619	770	1,233	1,756	550	1,178	912
Baseline default market average										
Net heat demand calculated [MWhm^{-2} a^{-1}]	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Hot water demand default [kWhm^{-2} a^{-1}]	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
Performance ratio of heating system	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.7
Heat demand calculated [kWhm^{-2} a^{-1}]	195.5	195.5	195.5	195.5	195.5	195.5	195.5	195.5	195.5	195.5
Heat consumption total [MWh a^{-1}]	166.2	305.0	393.2	121.0	150.5	241.1	343.3	107.5	230.3	178.3
After boiler exchange default										
Net heat demand calculated [kWhm^{-2} a^{-1}]	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Hot water demand default [kWhm^{-2} a^{-1}]	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
Performance ratio of heating system	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55
Heat consumption default [kWh^{-2} a^{-1}]	178.3	178.3	178.3	178.3	178.3	178.3	178.3	178.3	178.3	178.3
Heat consumption total [MWh a^{-1}]	151.5	278.1	358.5	110.3	137.3	219.8	313.0	98.0	210.0	162.6
Energy savings measured [MWh a^{-1}]	14.7	26.9	34.7	10.7	13.3	21.3	30.3	9.5	20.3	15.7

B1 to B10 is a sample of boilers replaced during EEI measures which is consistently used for the illustration of the effects of varying calculation options.

Total for all EEI action assessed [MWh a^{-1}]	**197.3**
Specific energy savings [kWh m^{-2}]	17.3

Conclusions

Based on a theoretical approach and supported by a simplified example, this paper describes the numerous methods suitable for the M&V of EEI actions which go in line with the ESD. As the Member States underlie incentives not to harmonise their methods, it can be concluded that a parallel evaluation stream has to be introduced in order to facilitate comparability of energy savings calculations. As a result, the ESC-COMP ("energy savings calculation for comparability") approach is proposed which aims at a transparent description of different calculation options regarding the definition of the baseline, the choice of the system boundaries and the aggregation level, the application of adjustment and correction factors, and the different approaches to collect the data (*i. e.* monitoring, engineering, deemed approach). The practical application of the ESC-COMP approach requires a professional IT tool best combined with a web database in order to ease data handling and a calculation engine that allows for the calculation of different methodological scenarios. ESC-COMP would provide traceable information on the quantitative impact of various BU measures.

In the first version of the EU commission, the energy efficiency directive [15] proposed tradability of savings between individual national supplier obligation schemes. ESC-COMP is an appropriate approach in order to interconnect the various schemes and to provide comparable data for monitoring the schemes. However, the schemes' final calculation methods have to be defined before further research on an optimised IT tool may start. Further research may be conducted in a new and adopted setup of the concerted action ESD project which is financed by the Intelligent Energy Europe programme (www.esd-ca.eu).

Acronyms

BU – Bottom-up
CEN – European Committee for Standardization
EEI – energy efficiency improvement
ESC-COMP– energy savings calculation for comparability
ESD – Energy Service Directive
M&V – monitoring and verification
NEEAP – National Energy Efficiency Action Plan

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