Will ESD reporting using bottom-up energy savings calculations be a nightmare or the next step in a better understanding of national energy savings?

Harry Vreuls
SenterNovem
The Netherlands
h.vreuls@senternovem.nl

Dick Both
SenterNovem
The Netherlands
d.both@senternovem.nl

Stefan Thomas
Wuppertal Institute for Climate Environment Energy
Germany
stefan.thomas@wupperinst.org

Jean-Sébastien Broc
École des Mines de Nantes
France
jean-sebastien.broc@emn.fr

Keywords

energy savings calculation, bottom-up evaluation methods, energy efficiency action plans, energy services directive

Abstract

The ESD (Energy Services Directive) requires that EU Member States increase their use of bottom-up energy savings calculations to report on the results of their energy efficiency policies. To make the results more comparable over the Member States harmonised methods should be developed and improved. The first experiences with this harmonisation process from the EMEEES project are presented in this paper. It starts with the introduction of the areas that could be dealt with in the harmonisation: the policies and measures, the individual appliances and installations and the aggregation level of a building, a company or an organisation. Each of them has its own characteristics and complexity to handle with. Some case applications (Voluntary Agreements, Energy Audits, Boilers and Building envelope of existing buildings) for bottom up energy savings calculations are presented to illustrate this. But if harmonisation should be realised for all these levels and economic sectors (industry, agriculture, transport, commercial and non-commercial services and households) it would results in thousands of pages with instructions. This would be a nightmare, but is there another way to reach improved harmonisation? The paper argues on what key elements the harmonisation should concentrate: a general structure for documentation of bottom-up energy savings, the selection of baseline and baseline parameters, and a dynamic approach to ensure improvement over time.

Introduction

The ESD (Energy Services Directive) requires that EU Member States increase their use of bottom-up energy savings calculations to report on the results of their energy efficiency policies. During the first period the harmonised bottom-up model shall cover between 20 and 30% of the annual energy consumption in a Member State, while from 2012 onwards the further developed model shall cover a significantly higher level of the annual final energy consumption. The European Commission with assistance of the Energy Demand Management Committee develops and improves harmonised methods. These harmonised methods should make the results more comparable over the Member States.

The first experiences with this harmonisation process including the problems, open issues and suggested solutions from the EMEEES project for the bottom-up energy savings calculations are presented in this paper. Two further papers for the 2009 eceee Summer Study (3170 Thomas et al.; 3270 Bosseboeuf and Lapillonne) are presenting the project's overall conclusions and top-down calculation methods. This paper starts with a short overview of the EMEEES activities and with an overview of the areas that could be dealt with in the harmonisation: the policies and measures (single policies and packages of policies and measures), the individual appliances (e.g. boilers, air conditioners, electric motors) and installations and the aggregation level of a building, a company or an organisation (e.g. heating system, production process, energy management system). Each of them has its own characteristics and complexity to handle with. Some case applications (Voluntary Agreements, Energy Audits, Boilers and Building envelope of existing buildings) for bottom-up energy savings calculations are presented to illustrate this. But if harmonisation should be realised for all these

Table 1. Four steps of energy savings calculation in combination with the level of evaluation efforts

Level 1 step 1	describe and report the calculation of *mean gross ex ante EUROPEAN DEFAULT VALUE energy savings* per measure, project, or participant
Level 1 step 2	describe and report how mean ex ante savings was extrapolated to the entire program population to arrive at *total gross EUROPEAN DEFAULT VALUE ex ante saving*
Level 1 step 3	describe and report on how a net-to-gross factor was calculated (can include free rider effects, multi-plier effects, rebound, etc.) for estimating *total net ex ante EUROPEAN DEFAULT VALUE saving*
Level 1 step 4	describe and report on how measure lifetimes were calculated and used to arrive at *lifetime total net ex ante EUROPEAN DEFAULT VALUE savings*
Level 2 step 1	describe and report the calculation of *mean gross ex ante NATIONAL DEFAULT VALUE energy savings* per measure, project, or participant
Level 2 step 2	describe and report how mean ex ante savings was extrapolated to the entire program population to arrive at *total gross NATIONAL DEFAULT VALUE ex ante savings*
Level 2 step 3	describe and report on how a net-to-gross factor was calculated (can include free rider effects, multi-plier effects, rebound, etc.) for estimating *total net ex ante NATIONAL DEFAULT VALUE savings*
Level 2 step 4	describe and report on how measure lifetimes were calculated and used to arrive at *lifetime total net ex ante NATIONAL DEFAULT VALUE savings*
Level 3 step 1	describe and report the calculation of *mean gross EX POST (EVALUATION-BASED) energy savings* per measure, project, or participant
Level 3 step 2	describe and report how mean *EX POST* savings was extrapolated to the entire program population to arrive at *total gross EX POST (EVALUATION-BASED) savings*
Level 3 step 3	describe and report on how a net-to-gross factor was calculated (which can include free rider effects, multiplier effects, rebound, etc.) for estimating *total net EX POST (EVALUATION-BASED) savings*
Level 3 step 4	describe and report on how measure lifetimes were calculated and used to arrive at *lifetime total net EX POST (EVALUATION-BASED) savings*

levels and economic sectors (industry, agriculture, transport, commercial and non-commercial services and households) it would result in thousands of pages with instructions. This would be a nightmare, but is there another way to reach improved harmonisation? The paper argues on what key elements the harmonisation should concentrate: a general structure for documentation of bottom-up energy savings, the selection of baseline and baseline parameters, and a dynamic approach to ensure improvement over time.

EMEEES bottom-up case applications – the development process

From November 2006 to April 2009, the IEE project "Evaluation and Monitoring for the EU Directive on Energy End-Use Efficiency and Energy Services" (EMEEES) worked on a set of calculation methods and case applications, with 21 partners and co-ordinated by the Wuppertal Institute. For the bottom-up energy savings calculation, the first step was to define the process to develop harmonised bottom-up evaluation methods. A draft report was discussed and used for the case application. A final version (Broc, 2009) includes smaller revisions based on the experiences during the drafting of the case applications. In this process two general approaches were introduced: the three levels of evaluation efforts and four steps of calculations.

The level 1 includes low evaluation efforts and European default values can be used – when available –; Level 2 includes moderate evaluation effort and the use of national (default) values. For the level 3 program specific evaluations and/or impact analysis are used. The four calculation steps can be taken on each level of evaluation effort. Table 1 holds an overview of the combinations.

Each case application holds information on the main data to collect for level 2 and 3 of evaluation efforts and detailed information for each step of the calculation. Table 2 presents the structure in more details

The second step was the selection of case applications. For the selection, it was important that the ESD set a minimum level of coverage of the energy savings by bottom-up calculations in the second National Energy Efficiency Plan (NEEAP-2) at 20-30% of the inland energy consumption and this coverage should increase for later NEEAPs. The ESD also is in favour of cost-effective monitoring and reporting and a low administrative burden. Case applications should result in insight to what extent calculation could be done with default values and how cost could be reduced. As the Member States have freedom to select actions to improve energy efficiency, the reporting on results could be related to specific actions directly oriented to energy end-users (e.g. subsidy of highly efficient glazing), a combination of actions (e.g. awareness raising campaign, rebate for solar hot water systems and low-interest loans), actions to intermediate organisations (training of installers), a policy (labelling scheme, minimum level) or a combination of measures (e.g. voluntary agreement in combination with subsidy scheme and/or tax reductions). The case applications should cover several end-use sectors and should result in information whether the bottom-up methods could be used for individual appliances (e.g. boilers, air conditioners, electric motors), installations (e.g. heating system including boiler, hot water, water loop, etc.) and the aggregation level of a building, a company or an

Table 2. Structure of the EMEEES bottom-up case applications

Summary	Title of the method Type and details of EEI activities and definitions covered General specifications Formula for unitary gross annual energy savings Indicative default value for unitary gross annual energy savings Formula for total ESD annual energy savings Indicative default value for energy savings lifetime Main data to collect (for level 2 and 3 evaluation efforts)
Introduction	Twenty bottom-up evaluation methods Three levels of harmonisation Four steps in the calculation process Pilot projects
Step 1: unitary gross annual energy savings	Step 1.1: general formula / calculation model Step 1.2: baseline Step 1.3: requirements for normalisation factors Step 1.4 Specifying the calculation method and its three related levels Conversion factors Considering the rebound effect Defining values and requirements
Step 2: total gross annual energy savings	Step 2.1: formula for summing up the number of actions Step 2.2: requirements and methods for accounting for the number of actions
Step 3: total ESD annual energy savings	Step 3.1: formula for ESD savings Step 3.2: requirements for double counting Step 3.3: requirements for technical interactions Step 3.4: requirements for multiplier energy savings Step 3.5: Requirements for the free-rider effect
Step 4: total ESD energy savings for year "i"	Requirements for the energy saving lifetime
Special items	Special requirements for early actions Treatment of uncertainties
Appendix 1	Justification and sources
Other appendices	

Table 3. Criteria used to select case applications

Criteria		
Coverage	ESD Annex IV: 20-30% of inland energy consumption (NEEAP 2)	ESD Annex IV: increased % (after NEEAP 2)
Cost effective and low administrative burden	Measuring, monitoring, evaluation efforts	Default values
Level of aggregation	Activities/actions (facilitating measures / end-use actions / energy services	Combination / packages of actions
	Measure types (programmes/mechanisms/ facilitating)	Combination of measure types
Action status	On-going / known actions	Early actions
	Future (unknown) actions	
Action target	End-use sectors	Technologies
Links with other work in EMEES	Pilot projects	Coverage with TD cases

organisation (e.g. production process, energy management system). At least the selection should also take into consideration that there should be some overlap with top down case applications and with the applicability in the testing of the developed method in practice in pilot projects. Table 3 holds an overview of the criteria used to select the 20 case applications.

Three draft case applications were discussed in the project team and presented late 2007 and early 2008 in national workshops EMEEES organised in several EU Member states. These three case applications should give an impression for the level of a specific technology (electric motor, variable speed drive), a system (lighting) and a policy (audit scheme). The feed back during the workshop was used during drafting more case applications. In the second half of the year 2008 all case applications were peer reviewed and most (draft) case applications were available at the EMEEES workshop October 2008. The twenty case applications (see Table 4) were finalised early 2009.

Table 4. The 20 EMEEES bottom-up case applications

	Case application	Sector	Technology	Facilitating measures
1	Building regulations for new residential buildings	Residential	new building	regulations (building codes; standards)
2	Improvement of the building envelope of residential buildings	Residential	building envelope	regulations, financial instruments, information, energy audits and certificates
3	Biomass boilers	Residential	boilers	financial instruments, information, energy performance contracting
4	Residential condensing boilers in space heating	Residential	condensing boiler	white certificates, information, financial instruments
5	Energy efficient cold appliances and washing machines	Residential	washing machines and cold appliances	regulation, information, financial instruments, voluntary agreements
6	Domestic Hot Water – Solar Water Heaters	Residential	solar water heaters	financial instruments, information, energy performance contracting, regulation
7	Domestic Hot Water – Heat Pumps	Residential	heat pumps	financial instruments, information, energy performance contracting, regulation
8	Non residential space heating improvement in case of heating distribution by a water loop	Tertiary sector	heat generators, emitters, distribution and control systems	white certificates, information, financial instruments, energy performance contracting
9	Improvement of lighting systems	Tertiary sector	lighting	financial instruments, information, energy performance contracting, regulation, white certificates
10	Improvement of central air conditioning	Residential	air conditioning system	financial instruments, white certificates, building codes (article 6 EPBD)
11	Office equipment	Tertiary sector	office equipment	regulation, information, financial instruments, voluntary agreements
12	Energy-efficient motors	Industry	induction motors	Energy performance contracting, financial tools, white certificates, regulation, information
13	Variable speed drives	Industry	motors and drives	Energy performance contracting, financial tools, white certificates, regulation, information
14	Vehicle Energy Efficiency	Transport	engine, tyres	financial incentives, labelling, information, EU regulation, RDD
15	Modal shifts in Passenger Transport	Transport	transport mode	traffic management, investments in public transport systems
16	Ecodriving	Transport	behaviour	information, co-operative instruments
17	Energy Performance Contracting	tertiary, industry residential	heating, cooling, ventilation and lighting	energy performance contracting
18	Energy Audits	Industry tertiary sector	all technologies, operation and maintenance	specific programmes, regulation, energy audits as an energy service
19	Voluntary Agreements - billing analysis method	Industry	production processes, utilities, logistics and building and the supply chain	voluntary agreement
20	Voluntary agreement with individual industrial companies - engineering method	Industry	operation and maintenance, industrial processes	voluntary agreement

Overview of bottom-up case applications

The EMEEES project team prepared twenty bottom-up ESD energy savings calculation case applications. These apply the six basic bottom-up calculation methods presented in more detail in Thomas et al. (2007) and Vreuls et al. (2009):

1. Direct measurement of energy savings from the consumption before and after implementation of an end-use action
2. Billing analysis, analysing energy bills of measure participants before and after implementation of an end-use action, and possible in comparison to the bills of a control group
3. Enhanced engineering estimates, e.g., from energy audits or building simulations
4. Mixed ex-ante (deemed) and ex-post estimates, using some participant data and surveys
5. Deemed (ex-ante) savings (with some participant monitoring data)
6. Modelling of the whole stock, based on surveys to monitor the end-use actions taken as a result of measures.

Eight case applications are dealing with the residential sector: five with specific appliances and two on the level of the building and one for a technical system. Three case applications are dealing with the tertiary sector (commercial and not commercial services), two with specific appliances and one with a technical system. Two case applications in the industrial sector are on the level of an appliance, while one is on the policy level. One case in the transport sector is dealing with behaviour change, while the two others are on a system level. Also three case application are dealing with a combination of sectors and then on a policy level. Table 4 gives an overview of these twenty case applications, holding together over 700 pages.

Each of the case applications presents the specific characteristics and complexity to handle with for the selected combination. We selected to include some highlights from five case applications (Voluntary Agreements, Energy Audits, Boilers and Building envelope of existing buildings) to illustrate this.

Examples of bottom-up case applications

VOLUNTARY AGREEMENTS

There is already a long history in EU Member States to make agreements with energy end-users to improve energy efficiencies. The character of such agreements can be very different (e.g. OECD, 2003, Clercq, M. de, 2001; Vreuls 2005) and this instrument continues to be interesting for countries to introduce. Two variations of Voluntary agreements were elaborated as bottom-up case application: one with emphasis on billing analysis and agreement at the level of associations or branches, as in use in The Netherlands (case application 19) and one using engineering methods for energy savings calculation and agreements at the company level, as in use in Sweden (case application 20).

Table 5 shows for the two case applications on Voluntary Agreements the main elements for the energy savings calculations, using the four steps approach. This is presented for the level 2: the moderate level of evaluation effort, using Member State specific data and in most cases already available data and using well-know data collection techniques. The case applications also hold information for a more detailed level 3 and a low level one. The two cases have several common elements, but also some obvious differences in approach. The billing analysis method needs data for annual energy consumption and delivered energy on a company level. The engineering method needs estimated ex-ante savings from actions and realised savings for actions. Both methods take into account several normalisation factors that are relevant on the company and/or the action level. Also for both methods the problem of double counting is not easy to solve: possible solutions are to account the savings on the level of a package of measures or to divide in a simple (but often very subjective) way. For the energy savings lifetime, both make a difference in short and long lasting changes: the maximum period in the engineering method is 12 years while the billing analysis assumes that 15% of the annual savings has a lifetime of 25 years.

ENERGY AUDITS

There is energy auditing in one form or another in most countries in Europe. It varies in e.g. the scope of audits (site, plant, building), pure energy audit programmes or a core element in broader schemes, self-auditing or by inspectors. All (or most) are in line with the ESD definition: 'energy audit' is "a systematic procedure to obtain adequate knowledge of the existing energy consumption profile of a building or group of buildings, of an industrial operation and/or installation or of a private or public service, identify and quantify cost-effective energy savings opportunities, and report the findings."

While the case application holds calculations on level 1 (using EU default value for electricity, heat and fuel savings as a percentage of the annual energy consumption), making evaluations at this level 1 is not recommended. For the level 2 (as summarised in Table 6) in several steps more than one option are suggested. E.g. for the unitary gross annual energy savings there is a formula assuming that no database of energy savings potentials identified in audits exists yet. The preferred formula is that using the share of savings potential implemented related to the identified potential savings in the energy audit. The case application also shows that there is a strong relationship between the type of an audit, the level of information gathered, and the monitoring costs. Compromises – also on the level 2 and 3 of evaluation efforts – have to be made between the monitoring data desired and what is practically possible to gather. Like the case applications on Voluntary Agreements, also for Audits there is almost no information on multiplier energy savings and free-rider effect (step 3.4 and 3.5). Related to double counting (step 3.2), an information system for monitoring the different (EEI) facilitating measures is suggested that should work together in such a way that double counting can either be avoided or reliably quantified. Alternatively, it might be possible to evaluate energy savings from a package of (EEI) facilitating measures targeting a sector and/or end-use through an integrated monitoring and evaluation process.

There is a wide range of saving lifetimes of the improvement actions, and the number of (potential) improvement actions is very large. Furthermore, some facilities may undergo a follow-up audit with a new set of recommendations before 2016. How to deal with this complex situation given that many countries

Table 5. The Calculation steps (level 2) for case applications Voluntary Agreements

	Voluntary Agreements billing analysis	Voluntary Agreements engineering method
Step 1: unitary gross annual energy savings; Unit = a participant		
Step 1. general formula	[annual energy consumption – delivered energy in $year]_{t-1}$ – [annual energy consumption – delivered energy in $year]_{t}$	Unitary gross annual energy savings = $RS_{h,f} + RS_{e} + (DV2_{h,f} * AC_{h,f}) + (DV2_{e} * AC_{e})$ $RS_{h,f}$ = reported heat and fuel savings from actions identified in an energy audit and actually realised RS_{e} = reported electricity savings from actions identified in an energy audit and actually realised $DV2_{h,f}$ = national default value for savings from changes in routines and O&M $DV2_{e}$ = national default value for savings from changes in routines and O&M
Step 1.2: baseline	Situation before (if the aim is to calculate all energy savings); A modelling of the development of the annual energy consumption over time without the Voluntary Agreement (if the aim is to calculate additional energy savings)	Situation before (used for practical reasons also if the aim is to calculate additional energy savings, since it would demand too much from engineers to define a counterfactual new baseline equipment for each end-use action)
Step 1.3: normalisation factors	3 normalisation factors: - production level - structural change in production - weather	The relevance of normalization factors depends on the type of companies targeted; Companies should, within the framework of the energy management system, consider the impact of external condition and verify normalization factors for compensation
Step 1.4 the calculation method and its three related levels	Billing analysis	**Mixed deemed and ex-post** approach: Participants report the expected energy savings from the actions implemented after an energy audit (**enhanced engineering estimate**) National default value is used for savings from changes in routines and O&M (**deemed savings**) Average annual consumption is monitored and reported by the participant Participants monitor and report their achieved savings (**ex-post**) as far as possible Administrator controls quality and correctness of reports (e.g. through analysing figures, interviewing participants and conduct supervision at the facility)
Step 2: total gross annual energy savings		
Step 2.1: formula summing up actions	SUM over participants [gross annual energy savings of participant $i]_{t}$	SUM of all unitary gross annual energy savings. The unit is one industrial participant
Step 2.2: accounting number of actions	the number of actions equals the number of industrial participants	the number of actions equals the number of industrial participants
Step 3: total ESD annual energy savings		
Step 3.1: formula for total ESD annual energy savings	If all correction factors are included: Total ESD annual energy savings = total gross annual energy savings * (1 - free-rider coefficient + multiplier coefficient) * double-counting factor	If all correction factors are included: Total ESD annual energy savings = total gross annual energy savings * (1 - free-rider coefficient + multiplier coefficient) * double-counting factor
Step 3.2: double counting	3 options: a. All savings that are also influenced by other policies are subtracted from VA; b. All savings that are also influenced by other policies are subtracted from those policies; c. All savings that are also influenced by other policies are divided between the VA and the other policies	Either by evaluating only the combined effects of the whole package of policies and energy services addressed to the companies concerned or by allocation so that each quantified energy saving relates to its specific facilitating measure. The difficulty of attributing savings to specific programs supports the idea that it may be better to focus on assessing the combined effects of the package of EEI measures
Step 3.3: technical interactions	Not relevant	technical interactions are already handled when ex-ante savings estimates are made
Step 3.4: multiplier energy savings	No information available	To assign a credible value for the multiplier effect in relation to an already hard to establish baseline would require rather extensive surveys and research
Step 3.5: free-rider effect	Will automatically be taken into account if a modelling of the development of the annual energy consumption over time without the Voluntary Agreement is used as the baseline	The free-rider effect will only need to be considered if the aim is to calculate additional energy savings. In light of the difficulties of determining the free-rider effect it should only be investigated for companies with major energy uses
Step 4: total ESD energy savings for year "i"	Summation over years	Summation over years
Requirements for the energy saving lifetime	Defaults for the energy savings lifetimes 10% of annual savings: 2 years; 75% of the annual saving: 8 years; 15% of the annual savings: 25 years	default for technical actions: 12 years default for organisational (EMS) actions: 2-4 years

Table 6. The Calculation steps (level 2) for case application Audits

Step 1: unitary gross annual energy savings; Unit = a participant	
Step 1. general formula	Two alternative approaches are suggested A. Annual energy savings of one participant [GWh/y] = = DVh, f (heat+fuels)*TSP(heat+fuels) + DVe (electricity)*TSP(electricity) DV_e = EU default value for the share of the electricity savings potential implemented, % $DV_{h,f}$ = EU default value for the share of the heat and fuel savings potential implemented, % TSP = total annual energy savings potential of the participant identified in the energy audit (GWh/y) B. Annual energy savings of one participant [GWh/y] = AS(heat+fuels) + AS(electricity) AS = annual energy savings of the participant realised as a consequence of the energy audit and collected through a survey of at least 50% of the participants (GWh/y) (this option is recommended only if no database of the total annual energy savings potential of the participants identified in the energy audit can be created, e.g. for past but recent energy audit schemes)
Step 1.2: baseline	In practice, auditors usually calculate the "before the improvement action" and "after the action" energy consumptions for each audited technical system.
Step 1.3: normalisation factors	Normalisation factors are not used when total savings by energy audit programmes are calculated, as the individual audits are producing enhanced engineering estimates. However, some of them can be taken into account in calculations made within an individual energy audit.
Step 1.4 the calculation method and its three related levels	For level 2 and 3 different options of mixed deemed value and ex-post calculations for monitoring energy audits
Step 2: total gross annual energy savings	
Step 2.1: formula summing up actions	The total gross annual energy savings are the sum of the annual energy savings of all participants (energy audits) in a given year
Step 2.2: accounting number of actions	Depends on the level of calculation. The unit is one participant. From each participant, the total annual energy savings potential of the participant must be collected and stored in a database (Option A presented above), or the savings achieved as a consequence of the energy audit must be collected (Option B presented above).
Step 3: total ESD annual energy savings	
Step 3.1: formula for total ESD annual energy savings	If all correction factors are included: *Total ESD annual energy savings = total gross annual energy savings - double counting estimate - technical interactions + multiplier energy savings - free-rider savings*
Step 3.2: double counting	In the case of energy audits, double counting cannot be estimated as a coefficient factor. Instead, it should be estimated in absolute terms. The best is to create a database of participants and end-use action identified in the energy audits, and track if they were implemented in the frame of an incentive programme and/or a voluntary agreement. If that is not possible, a survey of a sample of participants should be used to estimate the double counting.
Step 3.3: technical interactions	Technical interactions - in itself a positive phenomenon - may take place when a (EEI) facilitating measure encourages several (EEI) end-use actions (improvement actions) having an impact on the same technical system. This should be handled in the audits themselves for each end-use action proposed, so it should normally be corrected for automatically in level 2 and 3 calculations.
Step 3.4: multiplier energy savings	It is not known, how common a multiplier effect is or how significant it is in the proportion to energy audit volumes. However, it is not likely to be very significant.
Step 3.5: free-rider effect	The actual evaluation of the free-rider effect can be costly and difficult particularly for energy audit schemes with the many different end-use actions involved. There is, hence, little practical experience with this for energy audits. The case application estimates that 10 to 15% of the energy savings might be realised without the energy audit, based on estimates of Finnish energy auditors.
Step 4: total ESD energy savings for year "i"	Only the annual energy savings achieved and still existing in 2016 are accounted for.
Requirements for the energy saving lifetime	Default value proposed: 6-year sliding average for the services sector or proven national average values per type of participant 8-year sliding average for industry or proven national average values per type of participant Alternatively, national default values can be used based on a sample survey of end-use actions implemented

Table 7. The Calculation steps (level 2) for case application residential condensing boilers

Step 1: unitary gross annual energy savings; Unit = 1 m^2	
Step 1. general formula	Unitary gross annual energy savings = (1/efficiency of replaced plant – 1/efficiency of condensing plant) * E The replaced plant efficiency is different between regular and early replacement E= the heating need, proposed level 1 default value: on EU average 86 $kWh/m^2/y$, but corrected for heating degree days or average national values
Step 1.2: baseline	Before/after" baseline ("Non efficient" **stock** values), to be used for early replacements and when the aim is to calculate **all** energy savings, including autonomous progress. "With and without" baseline ("Non efficient" **market** values), to be used when the aim is to calculate energy savings **additional** to autonomous progress
Step 1.3: normalisation factors	guidelines: if there is a specific climatic condition (altitude, etc.) it is possible to document the specific location of condensing boilers installed Correction for heating degree days between different years, which are the main normalisation factor to take into account
Step 1.4 the calculation method and its three related levels	This is a deemed savings approach. Values for the annual useful heating energy demand per m^2 at level 1 need to be modified for each Member State. This could be done either by heating degree days or by the national average values for the annual useful heating energy demand per m^2. National values are also to be used at level 2 for other parameters on heat distribution, emitters, and controls, if relevant.
Step 2: total gross annual energy savings	
Step 2.1: formula summing up actions	total gross annual energy savings = average unitary gross annual energy savings * floor area of all buildings affected
Step 2.2: accounting number of actions	All actions provide the necessary data. They just need to be monitored.
Step 3: total ESD annual energy savings	
Step 3.1: formula for total ESD annual savings	If all correction factors are included: total ESD annual energy savings = total gross annual energy savings * (1 – double-counting coefficient) * (1 – free-rider fraction + multiplier effect)
Step 3.2: double counting	No double counting has been analysed up to now it is better to evaluate them as a package
Step 3.3: technical interactions	The interactions with insulation actions in case of combined actions
Step 3.4: multiplier energy savings	Has still to be investigated
Step 3.5: free-rider effect	An average of 20% of purchasers that would have selected a condensing boiler without any measure may correspond to some countries. However, it will be much higher in other countries
Step 4: total ESD energy savings for year "i"	Boilers that are up to 17 years by year "i"
Requirements for the energy saving lifetime	harmonised lifetime of 17 years

do not even monitor the total estimated savings for each energy audit, not to mention the improvement actions proposed in energy audits? The practical approach taken by several countries has been to apply the same average lifetime for all improvement actions. For the audits it is suggested to use for the service sector and industry 6-year and 8-year sliding averages, respectively. The reason for the difference is that there are more short-term operational actions in the service sector, whereas in industry there are more technical actions that can have quite long lifetimes. These defaults are shorter than those for the case application Voluntary Agreement with engineering estimates, while it is quite in line with the 75% group in the Voluntary Agreement using billing analysis.

CONDENSING BOILERS

Boiler replacement by more and highly energy-efficient (condensing boilers) is already since the oil shocks in the 1970s often a topic in action to improve energy efficiency. A broad range of policies and measures is applied for this: subsidies, agreements, loans, tax reduction etc. The case application for residential condensing boilers suggests for the level 2 calculations to use the energy demand per m^2 (see table 7), and this results in data collection for the area treated in each building and the climatic condition for each building. Also an alternative is suggested in case this is difficult given national conditions: first collect data for the total area treated and add them together, then multiply the result by average unitary gross annual energy savings. At level 3 in principle, unitary gross annual energy savings are computed for each building and are multiplied by area treated in each building, then aggregated nationally (by doing

Table 8. the Calculation steps (level 2) for case application Building envelope existing buildings

Step 1: unitary gross annual energy savings; Unit = 1 m^2	
Step 1. general formula	UFES=UFED(baseline)- UFED(action) UFES = Unitary Final Energy Savings [kWh/m2/y] UFED =Unitary Final Energy Demand [kWh/m2/y] While UFED = SHD/η SHD = Specific Heating Demand [kWh/m2/y] η = energy efficiency of the heating system (seasonal) For the Level 2a building stock model, unitary final energy savings (UFES) should be understood as modelledaverage unitary energy savings in a building age class I and building type m at time t For the level 2b the unitary gross annual energy savings can be estimated as the average gain (in kWh/m²/y) per categories (building types and construction periods) based on a sample and a difference between "before" and "after" Energy Performance Certificates.
Step 1.2: baseline	The (individual) situation before the refurbishment
Step 1.3: normalisation factors	Specific heat demand usually refers to a reference climate, and therefore no additional normalisation is needed
Step 1.4 the calculation method and its three related levels	Building stock model, is used for level 2a and enhanced engineering estimates (if individual energy performance certificates are used) or mix of deemed and ex-post estimates for level 2b and 3
Step 2: total gross annual energy savings	
Step 2.1: formula summing up actions	For the Level 2a building stock model, the total gross final energy savings (TGFES) at a given time t are the summation across building age classes (index i), building types (index m) of the unitary savings and across the categories of measures described in the case application (index j). For the Level 2b approach, the total gross final energy savings (TGFES) are estimated by taken into account the total conditioned area (m^2/a), either gross or net area (obtained by summing up the areas and unitary gross annual energy savings of individual buildings)
Step 2.2: accounting number of actions	The method relies on the use of Energy Performance Certificate (EPCerts) data as input in the evaluation of energy efficiency improvements concerning the building envelope
Step 3: total ESD annual energy savings	
Step 3.1: formula total ESD annual energy savings	If all correction factors are included: The total gross annual energy savings calculated in step 2, corrected for free-rider effects (only when calculating additional energy savings), direct rebound and multiplier effects.
Step 3.2: double counting	This can best be done if the combined effect of the whole package of measures targeting improvements in the building envelope is measured
Step 3.3: technical interactions	There exist technical interactions between end-use actions related to the building envelope and those addressing heating systems; four main cases are distinguished (s. above text)
Step 3.4: multiplier energy savings	In practice, these may be difficult to evaluate
Step 3.5: free-rider effect	The estimates of free-rider effects available in the literature for the residential sector are very wide, typically ranging from 0% to 50%. In some cases, even larger values have been estimated. They appear to be country and even program-dependent.
Step 4: total ESD energy savings for year "i"	Summing over years
Requirements for the energy saving lifetime	The building envelope 25 years or more Windows 24 years

so, the interactions with other measures, like the insulation of the same building which decreases the demand, and the other improvements taking place at the same time can be taken into account). For the baseline on level 1, the case application suggests an efficiency of 82% for a boiler in the 'non efficient stock' and 89% for the 'non efficient market'. The case application also holds suggestions on how to deal with energy efficiency measures directed to improving the heating system as a whole, as well as standard and efficient efficiency values for the single steps (heat generator, emission, control, distribution). So for the boilers (an apparatus) there is a simple calculation, while also for the system and the individual components within the heating system an approach and formulas are presented.

BUILDING ENVELOPE OF EXISTING BUILDINGS

Like the boiler also the improvement of the building envelope is an 'old' topic in the actions for energy savings. But the calculation of the energy savings still seems not an easy one. For the calculation of energy savings at level 2, two options are proposed (see table 8). As a first possibility a building stock model is proposed. As a second (preferred) possibility, a bottom-up method counting participants is proposed, which uses deemed savings or engineering estimates obtained from building energy performance certificates (EPCerts). When applied at the national level, this method uses average unitary values for the energy savings estimated for a sample of buildings. As the method relies on the use of EPCerts data as input in the evaluation of energy efficiency improvements concerning the building envelope, and the calculation of EPCerts is already harmonised on the European level (it must comply with the methodological framework presented in the EPBD), this approach is already harmonisaed.

Why is a model for the building stock needed in addition to a "pure" bottom-up approach? The most important reason is that it may be difficult to extract the baseline directly from empirical data (e.g. a database of EPCert results and buildings floor area) and to sum up real (measurable) unitary savings. By contrast, the stock model is based on a survey of only a sample of buildings per building category, which allows, however, to monitor all end-use actions carried out for the envelope of these buildings and in which way they were influenced by energy efficiency improvement measures. The building stock model could also be used to calibrate the overall results of the bottom-up monitoring methods on the building shell and heating system, and also the top-down results on residential fuel consumption. In the approach presented in the case application, correction factors, based on surveys, are included in the modelling in order to calculate only additional energy savings. It is, however, possible to also model all energy savings using a 'frozen efficiency' approach.

There exist technical interactions between end-use actions related to the building envelope and those addressing heating systems. These interactions refer mainly to the fact that improvements in the building envelope produce changes in the efficiency of the heating system (heat generator). Four main cases are taken into account in the case application: a. the heating system is replaced and the building envelope remains the same – this case is identical to the case application on residential heating systems; b. the building envelope is improved and the heating system remains the same; c. the building envelope is improved and the heating system is replaced; d. single technical actions (e.g. window replacement, wall insulation) are conducted in the building envelope. The proposed allocation procedure would reward actions that lead to improvements in the building envelope and in the heating system simultaneously. In this way, an incentive for the member states to conduct these combined energy-saving actions could be offered.

Lessons learned for the development of case applications

During the EMEEES project, the baselines were often discussed, especially as there is a difference between the **baseline options** for all energy savings and those for additional savings. The case application for building envelope is a good example for this differentiation. It also holds a separate baseline for each of the four situations for technical interaction. In general, there are three main options for a baseline defined as a before situation:

1. replacement of existing equipment (e.g. appliances and lighting);
2. retrofit of existing equipment, or building (e.g. building envelope insulation);
3. new building, or equipment (e.g. brown goods).

The **three level approach** works well and gives a clear guidance for priority setting in the energy saving calculations. It often showed to be difficult to produce EU wide default values to be used at the level 1. Nevertheless the majority of the case applications provide (some) default values. More and better default values should become available as Member States will start reporting on the ESD, and from ongoing research projects and evaluations. Also the dynamic approach (for the main areas at least at a level 2 and for the key areas increasing level 3) is already visible in several case applications where a level 2a and 2b is presented. The level approach will also ease the comparison of reported energy savings from Member States.

It is not an easy work to develop case applications, and as experts in the specific field are involved there is a tendency to increase the level of detail. Especially for the discussions within the EMEEES project team and the peer review, the number of pages of a case application increased every time. On average the case applications hold 40-60 pages. During the country workshops and the final conference of the project, is was obvious that there are two main groups: the experts who still want more elements be included, and the policy makers who want more general rules.

Not all elements of the four-step calculation process (as presented in Table 2) are relevant for each case. Some elements are more important for policies and measures (double counting) and others more for an appliance. For free-rider, multiplier, and rebound effects as well as for technical interaction there is still knowledge missing and the suggested defaults are provisional ones.

More analysis and field-testing of methods to calculate ESD energy savings will also be needed to learn more about the magnitude of uncertainty and methods for quantifying it. Total gross annual energy savings from all participants of an energy efficiency improvement measure can be calculated bottom-up with reasonable accuracy. The accuracy will increase while going from level 1 to level 3 calculations, however, at an increasing cost as well. The baselines are also usually quite easily and accurately defined. However, bottom-up methods usually need a significant effort using surveys of participants, non-participants and other market actors to estimate free-rider and multiplier effects. EMEEES therefore thinks that this effort could be spared for groups of measures that save less than, say, 50 million kWh per year and provide less than 5% of a Member State's ESD target. Double-counting can be avoided by evaluating the energy savings from the whole package of measures targeting a group of final consumers, an end use, or an end-use action, but this may require extensive databases of single end-use actions vs. measures.

The case applications give a good impression for the main elements in energy savings calculations, no matter whether it is a policy measure, a system or an appliance. But it was not possible to develop one or a few case applications that have general application. So if for all relevant situations case applications would be needed, this would result in thousand of pages and that is not a task that should be done for the ESD, as the work should concentrate on energy savings and not on monitoring and reporting on savings.

Key elements for harmonised reporting on bottom-up energy savings calculations

The lessons learned from the bottom-up energy savings case applications already indicate on what key elements the harmonisation should concentrate: a general structure for documentation of bottom-up energy savings, the selection of baseline and baseline parameters, and a dynamic approach to ensure improvement over time.

A common **general structure for documentation** of bottom-up energy savings ensures that with the reported energy savings, there is also documentation on how the calculation was conducted. This documentation must be the same between reports for the main elements in order to make results comparable. We argue that the four steps of the calculation process - as used in the case applications - should be the general structure for the documentation. The developed reporting checklist (Annex 6 of Vreuls et al., 2009) could also be used as an input for such a general structure. It addresses issues that do not necessarily need to be harmonised at an EU level, but that are relevant when evaluating energy savings. This checklist is a tool for quality assurance (on data, sources, etc.) that would enable the Commission to well compare data provided by the Member States on their achieved energy savings. By pinpointing the main evaluation issues, the aim is also to induce better evaluation designs.

In principle, for the bottom-up energy savings calculation a Member State can use the **country-specific baseline** out of the three options (replacement, adding, new). The documentation could then concentrate on the description of the parameters for calculation of the baseline. If a more specific baseline is selected, then this should be documented in more detail. The baseline for additional energy savings should have a consistent link with that for all energy savings and this link should be reported.

The three level approach for efforts ensures **a dynamic approach to improve energy savings calculations over time.** While Member States will in most cases start reporting on level 2 for main areas of energy savings, this will generate information to improve the more general formulas on this level. On the other hand this will give input for default values on level 1 and for key areas within level 3. For minor areas there will become more reliable formulas and default values available that Member State can use with low efforts and report more complete on their actions. So this approach will improve the quality of bottom-up energy saving calculation in a cost-effective way.

At the end of 2008 the Energy Demand Management Committee started a discussion on common principles on methods to measure energy savings for reporting purposes, while guidelines are foreseen to be available by December 2009. For the bottom-up energy savings calculation, the three level approach and the three categories of baselines are included in these common principles. The reporting checklist as developed during the EMEEES project and the EMEEES case applications could be a good starting point for developing additional guidance.

Conclusion

The EMEEES bottom-up case applications are examples for what elements in energy savings calculations for the ESD reporting are playing a role. For a selection of policies, technologies and types of end-users, they present possible solutions for choices to be made during the process of conducting the energy savings calculations and hold default values that could be used to make a simple calculation. But the experiences also show that it would be a nightmare if on EU level for the vast majority of policies, measures and actions such case applications should be developed, approved and be used by Member States. This would need a project team working for several years, a lot of experts devoting their time on discussion and a long decision making process in the EDM committee and thousand of pages with instructions to be maintained and updated.

In this paper we concluded that from the case application we learned that there are key elements that should be harmonised. Several key elements are under discussion in the EDM Committee as elements in the common principles. Additional to these key elements, guidelines could be developed, using the case applications, dealing with measurements and energy savings calculation and with reporting. The general process developed by EMEEES to develop harmonised bottom-up evaluation methods (Broc et al., 2009) may be helpful to this end. To help the improvements in calculations and reporting over time, guidance and tools could be developed dealing with e.g. EU default values for bottom-up calculations (both for unitary gross annual energy savings and life time) and benchmarks, preferred EU formulas and quality assurance and qualitiy control (QA/QC) guidance for data. The case applications could be used as examples ('good practice').

References

Adnot, J. et al, 2009, EMEEES case application 4: Residential condensing boilers in space heating (residential sector)

Amman, Ch. et al, 2009, EMEEES case application 2: Improvement of the building envelope of residential buildings (residential sector)

Broc, J-S. and others, 2009, Definition of the process to develop harmonised bottom-up evaluation methods, ARMINES, Nantes

Clercq, M. de and others, 2002, A comparative study of environmental negotiated agreements, Ghent University

OECD, 2003, Voluntary Approaches for environmental policies, effectiveness, efficiency and use in policy mixes

Gula, A. et all, 2009, EMEEES case application 3: Biomass boilers (residential sector)

Gynther, L and Suomi, U., 2009, EMEEES case application 18: Energy Audits (tertiary and industry sectors)

Loozen, A. et al, 2009, EMEEES case application 19: Voluntary Agreements – billing analysis method (industry and tertiary sectors)

Nilsson, L.J. et al, 2009, EMEEES case application 20: Voluntary agreement with individual industrial companies – engineering method (industry and tertiary sectors)

Thomas, S., Nilsson, L., Eichhammer, W., Vreuls, H., , 2007, Broc, J.-S., Bosseboeuf, D., Lapillonne, B., Leutgöb, K., 2007. How much energy saving is 1% per year? In: eceee

2007 Summer Study, 4-9 June 2007, Proceedings, Saving energy: Just do it!, Vol. 2, pp.571-582

Thomas, S. and others, How much energy saving is 1 % per year? We still don't know, but we know better how to find out, paper ECEEE summer study 2009

Vreuls, H., Thomas, S., Broc, J.-S., 2009. General bottom-up data collection, monitoring, and calculation methods, Summary report. SenterNovem, Sittard, Wuppertal Institute, Wuppertal, ARMINES, Nantes

Vreuls, H., Zwart, de M., 2009, Summary of the 20 Bottom-up ESD energy savings calculation case applications, prepared in the EMEEES project, SenterNovem, Sittard

Vreuls, H. et al, 2005, Evaluating Energy Efficiency Policy Mesures DSM Programmes, Volume 1, IEA DSM Agreement, SenterNovem, Sittard

EMEEES, Harmonised methods for evaluating energy end-use efficiency and energy services, conference documentation, 15 October 2008, Brussels

All EMEEES reports are available as soon as they are publishable at www.evaluate-energy-savings.eu.

Acknowledgements

The authors wish to thank the European Commission for the financial support to the EMEEES project, within experiences for bottom-up energy savings are shared and case applications developed.