Evaluation and Monitoring for the EU Directive on Energy End-Use Efficiency and Energy Services

EMEEES bottom-up case application 2: Improvement of the building envelope of residential buildings (residential sector)

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evaluate energy savings EU

coordinated by
Wuppertal Institute for Climate, Environment and Energy

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The Project in brief

The objective of this project is to assist the European Commission in developing harmonised evaluation methods. It aims to design methods to evaluate the measures implemented to achieve the 9% energy savings target set out in the EU Directive (2006/32/EC) (ESD) on energy end-use efficiency and energy services. The assistance by the project and its partners is delivered through practical advice, technical support and results. It includes the development of concrete methods for the evaluation of single programmes, services and measures (mostly bottom-up), as well as schemes for monitoring the overall impact of all measures implemented in a Member State (combination of bottom-up and top-down).

Consortium

The project is co-ordinated by the Wuppertal Institute. The 21 project partners are:

Project Partner	Country
Wuppertal Institute for Climate, Environment and Energy (WI)	DE
Agence de l'Environnement et de la Maitrise de l'Energie (ADEME)	FR
SenterNovem	NL
Energy research Centre of the Netherlands (ECN)	NL
Enerdata sas	FR
Fraunhofer-Institut für System- und Innovationsforschung (FhG-ISI)	DE
SRC International A/S (SRCI)	DK
Politecnico di Milano, Dipartimento di Energetica, eERG	IT
AGH University of Science and Technology (AGH-UST)	PL
Österreichische Energieagentur – Austrian Energy Agency (A.E.A.)	AT
Ekodoma	LV
Istituto di Studi per l'Integrazione dei Sistemi (ISIS)	IT
Swedish Energy Agency (STEM)	SE
Association pour la Recherche et le Développement des Méthodes et Processus Industriels (ARMINES)	FR
Electricité de France (EdF)	FR
Enova SF	NO
Motiva Oy	FI
Department for Environment, Food and Rural Affairs (DEFRA)	UK
ISR – University of Coimbra (ISR-UC)	PT
DONG Energy (DONG)	DK
Centre for Renewable Energy Sources (CRES)	EL

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1 Summary

1.1 Title of the method

Improvement of the building envelope of existing residential buildings

1.2 Type of EEI activities covered

End-use EEI action	
Sector	residential buildings/households
Energy end-use	heating, (hot water), electricity
Efficient solution	insulation of the building envelope (facade, windows, roof, basement or basement ceiling)
EEI Facilitating measure	
Types of EEI facilitating measures	▪ regulations: e.g. building codes and enforcement, standards ▪ Financial instruments: e.g. subsidies ▪ information: e.g. energy consulting, energy audits, motivation, focused information campaigns

1.3 Detailed definition of EEI activities covered

The EEI activities are listed in section 1.2 above.

1.4 General specifications

1.4.1 Choosing the calculation level

The method for the improvements to the buidling envelope of existing residential buildings described here consists of two approaches, depending on the level (level 2 or level 3) at which the calculations of energy savings are performed:

- Level 1: Given the heterogeneity of the building stock in the EU, it is not possible to define a level 1 approach (or EU default values) for the calculations related to energy-saving actions on the building envelope.

- Level 2: For the calculation of energy savings at Level 2 (national), two options are proposed here. As a first possibility (here labelled as Level 2a) a building stock model is proposed. Within the classification of methods used in the EMEEES-Project, this method corresponds to a No 6 method (modelling of the whole stock based on surveys). As a second possibility (level 2b) 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. The same method can be used at Level 3 as described below.

- Level 3: The level 2b method based on Energy Performance Certificates can also be used for the calculation of energy savings at Level 3 (level of EEI measures or packages), if individual energy savings are evaluated for all individual buildings, but also if the method is used for a regional (sub-national) measure.

Whenever possible, priority should be given to the Level 2b approach. If for some reason calculations at Level 2b or 3 are not feasible, then the building stock model defined for level 2a calculations can be used at the national level.

If estimated in an appropriate way, the building stock model at Level 2a could be also used to calibrate the overall results of the other bottom-up monitoring methods on the building envelope and heating systems. In addition, if applicable, the building stock model could be used to callibrate top-down results on residential fuel consumption.

1.4.2 General description of the Level 2a method (building stock model)

The first approach followed here for the evaluation of improvements to the building envelope at the national level (Level 2a) consists in setting up a model of the building stock. In this model, a building typology is specified according to building age classes, types of buildings (e.g. single-family houses, etc) and the heating system (energy carrier). Within a given category, buildings are assumed to be homogenous. That is, an average building is used to represent the corresponding category.

The building stock model described here has to be seen as only one possible approach. Member states that have their own models will have to check if the features in their models correspond to the needs of ESD. The goal of the description conducted here is to give an overview on necessary elements and calculations. A detailed descripition of the building stock model is presented in Appendix II.

There are reasons why a model for the building stock may be 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 and to sum up any real (measurable) unitary savings. 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 followed here, 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.

The building stock model focuses on the total building stock but it also includes the effects of changed heating systems in residential buildings. There are several interactions (see below) between the building envelope and the heating system and the effects can only be separated in a sufficiently detailed model.

Main features of the building stock model are:

- The main unit can be either sqm (default) of conditioned area, or a flat, or a building (depending on the data availibility, first choice is sqm)
- The starting point is year n (either 1995 or 2008, depending on the consideration of “early energy savings”)
- The time resolution of the model can be one year up to the entire reporting periods (1995-2008, 2008-2016), depending on the data availability.
- The following necessary categories are included in the building stock model:

categories	energy efficiency measure	short description	calculation, comments
demolished buildings		A certain fraction of the building stock is demolished. This leads to a reduction of final energy demand (FED).	demolition rate (or actual numbers), derived from building statistics; calibration with data before year n (5 or 10 years); specific FED of demolished buildings
new buildings		new buildings are not in focus of this method but have to be considered for the calculation of the baseline	rate (or actual numbers) of new buildings derived from building statistics; calibration with data before year n (5 or 10 years); specific FED of new buildings in year n
refurbished buildings	improvement of the building envelope	The improvement of the building envelope reduces the (specific) heat demand. It has to be considered that even though the heating system is unchanged the efficiency (relation of heat demand to FED) will change (see below).	rate (or actual numbers) of refurbished buildings derived from building statistics or other sources; calibration with data before year n (5 or 10 years); specific heat demand and FED after refurbishment from energy certificates (energy certificate database) or other sources
	improvement of the building envelope and change of the heating system	The improvement of the building envelope reduces the (specific) heat demand. The efficiency of the heating system is likely to increase with a new heating system (see below). The effects of both measures have to be	rate (or actual numbers) of refurbished buildings (including a change of the heating system) derived from building statistics or other sources; calibration with data before year n (5 or 10 years); specific heat demand and

		separated.	FED after refurbishment from energy certificates (energy certificate database) or other sources
	change of the heating system	The effect of the change of the heating system is an increased energy efficiency (see below). This has to be considered in the model. However, savings will be allocated to the specific method dealing with heating systems.	rate (or actual numbers) of buildings with changed heating systems derived from building statistics or other sources; calibration with data before year n (5 or 10 years); energy efficiency data from the method dealing with heating system
	improvement of single elements	assumption: the efficiency of heating system is not changed	rate (or actual numbers) of refurbished buildings (with single energy efficiency measures) derived from building statistics or other sources; calibration with data before year n (5 or 10 years); specific heat demand and FED after refurbishment from energy certificates (energy certificate database) or other sources
not refurbished buildings	no measures	fraction of unchanged buildings; necessary for model	no additional data necessary

1.4.3 General description of the Level 2b method

The Level 2b method takes advantage of the work done in the European member states in the course of the implementation of the Energy Performance of Buildings Directive (EPBD) 2002/91/EG and it utilises the resulting Energy Performance Certificates (EPCerts).

Energy Performance of Buildings Directive (EPBD) 2002/91/EG and Energy Performance Certificates (EPCerts)

The Energy Performance of Buildings Directive (EPBD) 2002/91/EG has been implemented in the European member states since 2006. In few countries, such as Austria, implementation has been delayed. However, at least from 2009 on energy performance certificates (EPCerts) will be available in the majority of European member states. In the course of the national implementation of the EPBD, member states are obliged to develop a methodology at national or regional level of calculation of the energy performance of buildings on the basis of the general framework set out in the Annex of the EPBD (article 3). Furthermore, member states are obliged to set minimum energy performance requirements. The EPBD commits the member states to review these minimum requirements at regular intervals which should not be longer than five years, in order to update them according to the technical progress in the building sector (article 4).

EPCerts have to be issued for new buildings and for existing buildings if they are sold or rented or if they undergo a major renovation. It has to be ensured that these buildings comply with the minimum energy performance requirements (article 5 and article 6).

EPCerts provide valuable data for the evaluation of energy efficiency improvements of the building envelope. They contain data on:

- Final energy demand
    - Heating energy demand
    - Efficiency of the heating system
- Conditioned area

- Suggestions for measures to improve the energy efficiency of the building envelope (additional insulation of façade, roof, and basement; exchange of windows; airtight envelope; ventilation system with heat recovery)

EPCerts provide much more information which is not presented here, for example on energy demand for warm water and electricity.

Calculation of EPCerts is harmonized on the European level. It must comply with the methodological framework presented in the EPBD. Therefore it is suggested to use EPC data as input in the evaluation of energy efficiency improvements concerning the building envelope.

Collection of EPCerts and data collection for energy efficiency improvement evaluation

In the ongoing EU project DATAMINE[1] a framework for data collection from EPCerts in the European member states is being developed: The project is about collecting data from energy certification to monitor performance indicators for new and existing buildings. DATAMINE will be completed by end of 2008.

In Austria, for example, the software called „ZEUS“ is used for the electronic data management of EPCerts, and an interface with the DATAMINE project was developed like it was done with corresponding systems in the other participating countries. ZEUS (http://www.energieausweise.net/) is an internet-software, which transforms the EPCerts (after they have been compiled with one of the existing calculation programs) automatically into the internet. ZEUS can be used by consultants, building owners, and public bodies to process energy certificates, to store them and to evaluate them. Public bodies have the opportunity to evaluate data provided in the course of EPCerts calculation such as decrease of heating energy demand during a defined period of time.

[1] http://www.iwu.de/forschung/energie/laufend/datamine/

1.5 Formula for unitary gross annual energy savings

For this method, the unit used in the formula for the unitary gross annual energy savings is square meters of conditioned area.

If the rebound effect is to be taken into account for evaluation of ESD energy savings, the equation (S1) used in section 3, step 1 for the Level 2b and Level 3 calculation will be:

unitary gross annual energy savings =

$$UFES = UFED_{baseline} - UFED_{action} = \left(\frac{SHD_{baseline}}{\eta_{baseline}} - \frac{SHD_{action}}{\eta_{action}}\right) \bullet (1 - RE)$$

(equation S1a)

Where:

UFES = Unitary Final Energy Savings [kWh/m^2/a]

UFED =Unitary Final Energy Demand [kWh/m^2/a]

SHD = Specific Heating Demand [kWh/m^2/a]

η = energy efficiency of the heating system (seasonal)[2]

RE = coefficient for the Direct Rebound Effect

At levels 2a and 2b, the unitary gross annual energy savings can be estimated as the average gain (in kWh/m²/a) per categories (building types and construction periods) based on a sample and a difference between "before" and "after" Energy Performance Certificates.

Using the same expression at level 3, the unitary gross annual energy savings can be estimated as the actual difference between the "before" and "after" Energy Performance Certificates for each registered building if energy savings are evaluated for all individual buildings involved in a given action or as an average gain per categories based on a regional sample if the method is applied at a regional (sub-national) level.

[2] η is not the efficiency of the boiler or the heating system as a technical unit. It is the relation of heat demand to final energy demand for heating and, thus, the characteristics of the whole building have to be considered. The final energy demand (FED) also includes losses by the heating and the distribution system, expressed by efficiency parameters (details in method 4, improvement of the heating system)

1.6 Indicative default value for unitary gross annual energy savings (when relevant)

It is not possible to define a default or a harmonised value for energy savings related to the building envelope due to the wide heterogeneity of residential buildings in the EU.

Unitary annual energy savings: **EU default/harmonised values**	
EU default	n.a.
EU harmonised	n.a.

1.7 Formula for total ESD annual energy savings

For the Level 2a building stock model, the total net final energy savings (TNFES) are computed at a given time t. They are the summation of the unitary savings across building age classes (index i), building types (index m) and across the categories of measures described above (index j) corrected for free-rider, direct rebound and multiplier effects. If all correction factors are included, the formula for the total ESD (net) annual energy savings is as follows:

$$TNFES_t = (1 - FR) * (1 - RE) * (1 + M) * \left(\sum_j \sum_m \sum_i \left(\frac{SHD_{i,j,m,baseline}}{\eta_{baseline}} - \frac{SHD_{i,j,m,action}}{\eta_{action}} \right) A_{i,j,m,t} \right)$$

(equation S2c)

Where:

TNFES: Total Net Final Energy Savings

SHD= Specific Heating Demand [kWh/m^2/a]

η = energy efficiency of the heating system (annualized)

A = conditioned area (m^2/a), either gross or net area, per building age class i, building type m and for and a given category of measures j

FR = Fraction of free-riders

RE = Direct Rebound Effect

M = Fraction of multipliers

Since the modelling is on all end-use actions taken in the building stock regardless of any facilitating measures that may have caused the actions, there is no double-counting issue in the level 2a method.

Indexes

i ... building age class (construction period) {1 ... x}

j ... description of the energy efficiency measure/action:

- nb ... new buildings
- de ... demolished buildings
- be ... change of the building envelope
- hs ... change of the heating system
- behs ... change of the building envelope and heating system
- sm ... single measures
- nm ... no measures

m ... building type (single family houses, multi-family houses)

t ... time (year); n = starting point for the calculation (either 1995 or 2008)

If all correction factors are included, the formula for the total ESD (net) annual energy savings for the Level 2b approach will read, as presented in section 5:

Total ESD annual energy savings =

$$TNFES = \left(\frac{SHD_{baseline}}{\eta_{baseline}} - \frac{SHD_{action}}{\eta_{action}} \right) * A * (1 - DC) * (1 - FR) * (1 - RE) * (1 + M)$$

(equation S2a)

Where:

TNFES: Total Net Final Energy Savings

SHD = Specific Heating Demand [kWh/m²/a]

η = energy efficiency of the heating system (seasonal)

A = total conditioned area (m²/a), either gross or net area[3] (obtained by summing up the areas of individual buildings)

DC = Double-counting coefficient

FR = Fraction of free-riders

RE = Direct Rebound Effect

M = Fraction of multipliers

The formula for the total ESD (net) annual energy savings for the Level 3 approach will add the individual energy savings across all buildings involved in the energy-saving action, as presented in section 5:

Total ESD annual energy savings =

$$TNFES = \left[\sum_{k=1}^{N} \left(\frac{SHD_{baseline,k}}{\eta_{baseline,k}} - \frac{SHD_{action,k}}{\eta_{action,k}} \right) * a_k \right] * (1-DC) * (1-FR) * (1-RE) * (1+M$$

(equation S2b)

Where:

TNFES: Total Net Final Energy Savings

SHD = Specific Heating Demand [kWh/m²/a]

η = energy efficiency of the heating system (seasonal)

a_k = conditioned area (m²/a), either gross or net area per building[4]

DC = Double-counting coefficient

[3] In Europe, there are many different ways to define the “conditioned area”. For the architecture of the building stock model it does not make any difference as long as all variables refer to the same definition.

[4] In Europe, there are many different ways to define the “conditioned area”. For the architecture of the building stock model it does not make any difference as long as all variables refer to the same definition.

FR = Fraction of free-riders

RE = Direct Rebound Effect

M = Fraction of multipliers

k= 1..N= summation over N buildings involved in the energy-saving action

1.8 Indicative default value for energy savings lifetime

The following value is suggested as a harmonised value according to CEN/CENELEC CWA27 (2007).

Energy savings lifetime: **EU default/harmonised values**	
EU default	n.a.
EU harmonised	Insulation of the building envelope: 25 years or more Windows: 24 years

1.9 Main data to collect

Data needed in calculation for EU values (level 1)	**Corresponding data sources**
Data 1	n.a.
Data 2	n.a.
etc.	

Data to be collected national values (level 2a)	**Corresponding data sources**
heat demand HD	Energy certificates for refurbished buildings (before and after EEI measures), surveys, studies, expert judgement
conditioned area	building statistics, reports from building administration (granted subsidies, building permitions), surveys, studies
efficiency of the heating system (seasonal) η	energy certificates, energy certificates database, studies, surveys, expert judgement
final energy demand (FED)	Energy certificates for refurbished buildings (before and after EEI measures), surveys, studies
final energy demand/use (top down)	energy statistics, surveys, studies
number of buildings with EEI measures on the building envelope (and heating system)	Building statistics, reporting from building administration (data on granted subsidies, number of building permitions etc.)
Number of free-riders, multipliers, rebound effects	Ex-post surveys for samples of participants, non-participants and/or trade allies

Data to be collected national values (level 2b)	Corresponding data sources
Final energy demand (FED) for space heating before and after end-use actions for a sample of actions	Building energy performance certificates
Number of free-riders, multipliers, rebound effects	Ex-post surveys for samples of participants, non-participants and/or trade allies
Double-counting coefficient / exclusion of double counting	Database tracking participants and end-use actions vs. facilitating measures If no database possible, ex-post surveys for samples of participants

Data to be collected measure-specific (or participants-specific) (level 3)	Corresponding data sources
Final energy demand (FED) for space heating before and after end-use actions for all individual builidngs involved in the energy-saving action	Building energy performance certificates
Number of free-riders, multipliers, rebound effects	Ex-post surveys for samples of participants, non-participants and/or trade allies
Double-counting coefficient / exclusion of double counting	Database tracking participants and end-use actions vs. facilitating measures If no database possible, ex-post surveys for samples of participants

2 Introduction

2.1 Twenty bottom-up case applications of methods

Within EMEEES, task 4.1 provided methodological materials in the internal working paper "Definition of the process to develop harmonised bottom-up evaluation methods", version 20 April 2007; an update has been published as an Appendix to the report on Bottom-up methods at www.evaluate-energy-savings.eu. Based on this draft report, concrete bottom-up case applications were developed by EMEEES partners within task 4.2, and reference values were to be specified within task 4.3.

This report deals with case application 2 "Improvement of the building envelope of residential buildings" developed by the Austrian Energy Agency.

Eleven project partners have developed concrete bottom-up case applications for a specific type of technology or energy efficiency improvement measure or end-use action. All gave comments and input to the methods developed by the other organisations.

The 20 case applications developed are presented in the table below:

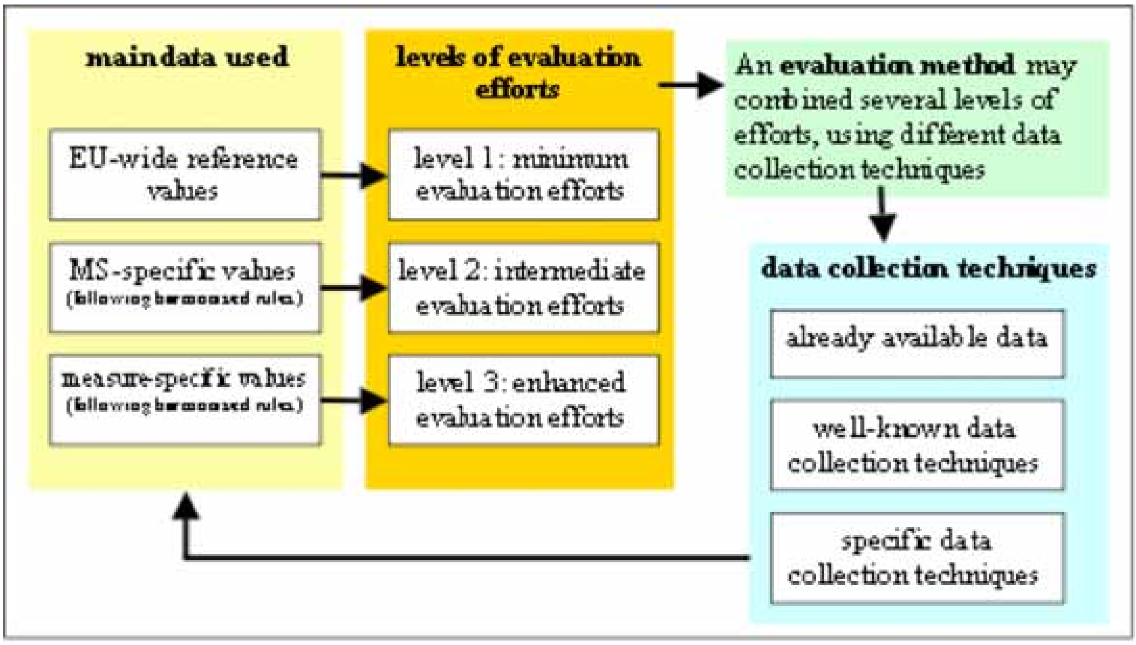
N°	End-use or end-use action, technology, or facilitating measure	Sector	Responsible organisation
1	Building regulations for new residential buildings	Residential	SenterNovem
2	Improvement of the building envelope of residential buildings	Residential	AEA
3	Biomass boilers	Residential	AGH-UST
4	Residential condensing boilers in space heating	Residential	Armines
5	Energy efficient cold appliances and washing machines	Residential	ADEME
6	Domestic Hot Water – Solar water heaters	Residential	AGH-UST
7	Domestic Hot Water - Heat Pumps	Residential	AGH-UST
8	Non residential space heating improvement in case of heating distribution by a water loop	Tertiary	eERG
9	Improvement of lighting systems	Tertiary (industry)	eERG
10	Improvement of central air conditioning	Tertiary	Armines

N°	End-use or end-use action, technology, or facilitating measure	Sector	Responsible organisation
11	Office equipment	Tertiary	Fraunhofer
12	Energy-efficient motors	Industry	ISR-UC
13	Variable speed drives	Industry	ISR-UC
14	Vehicle energy efficiency	Transport	Wuppertal Institute
15	Modal shifts in passenger transport	Transport	Wuppertal Institute
16	Ecodriving	Transport	SenterNovem
17	Energy performance contracting	Tertiary and industry end-uses	STEM
18	Energy audits	Tertiary and industry end-uses	Motiva
19	Voluntary agreements – billing analysis method	Tertiary and industry end-uses	SenterNovem
20	Voluntary agreements with individual companies – engineering method	Tertiary and industry end-uses	STEM

2.2 Three levels of harmonisation

In order to be as practicable as possible and to stimulate continued improvement, the harmonised reporting on bottom-up evaluation is structured on three levels (cf. figure 1).

Figure 1: Three levels of harmonisation



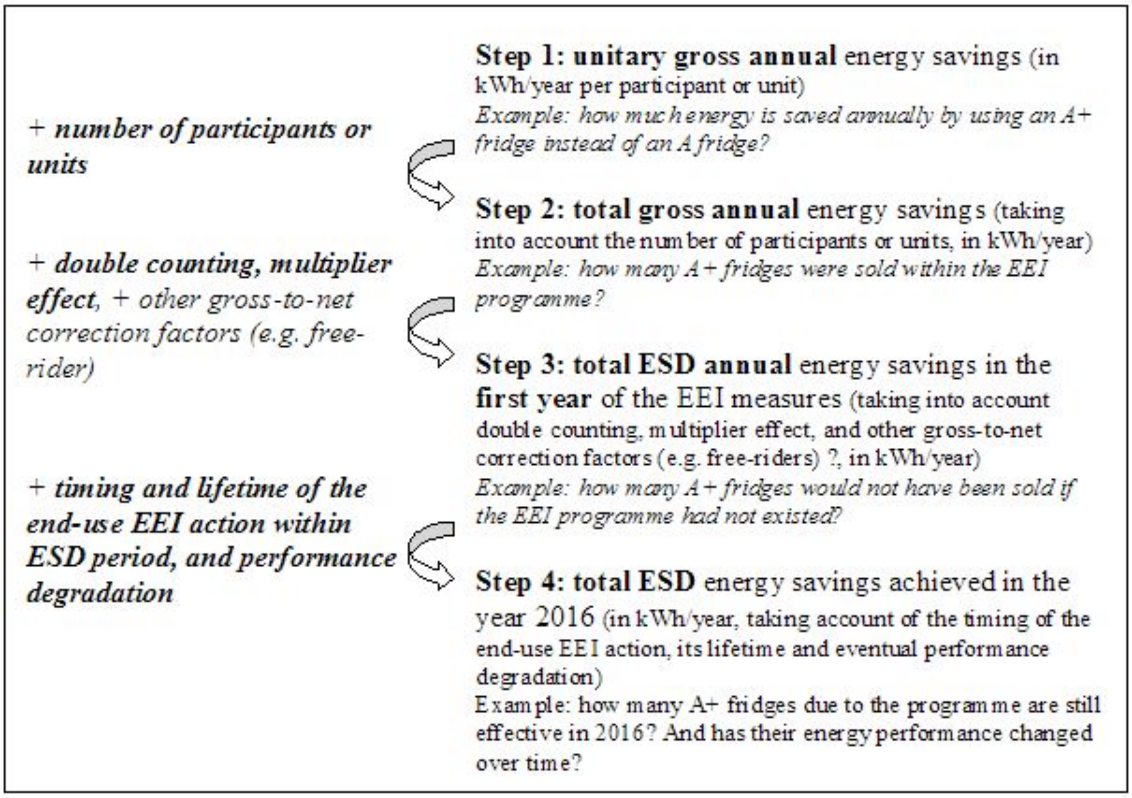
As a consequence, the EMEEES case applications for bottom-up evaluation methods present:

- EU wide reference values, if applicable;
- Guidelines how Member States can use country-specific values following harmonised rules;
- Guidelines how measure- or action-specific (national) values can be developed, following harmonised rules.

2.3 Four steps in the calculation process

The harmonised rules for bottom-up evaluation methods are organised around four steps in the calculation process (cf. figure 2). These steps are presented in detail in the report for WP 4.1.

Figure 2: Four steps in the calculation process



The reports on the concrete bottom-up case applications follow the format of these four steps and they each hold six chapters plus some annexes:

1. summary
2. introduction
3. step 1: unitary gross annual energy saving
4. step 2: total gross annual energy savings
5. step 3: total ESD annual energy savings
6. step 4: total ESD energy savings for year “i”

2.4 Pilot tests

Additional to the development of the 20 bottom-up case applications, some of these cases were tested in practice in Work Package 8.
Pilot tests of the following case applications were performed by EMEEES partners in Italy, France, Denmark, and Sweden:

EMEEES case application	Sector	Italy	France	Denmark	Sweden
Building envelope improvement	Residential		X		
Energy-efficient white goods	Residential	X			
Biomass boilers in the residential sector	Residential		X		
Condensing Boilers	Residential	X	X		
Improvement of lighting system	Tertiary (industry)				X
High efficiency electric motors	Industry	X			
Variable speed drives	Industry	X			
Energy audits	Tertiary and industry end uses			X	
Energy performance contracting	Tertiary and industry				X

The following EEI measures were evaluated ex-post using the above-mentioned EMEEES bottom-up case applications:

Country	Subject	Sector(s) addressed
France	Condensing boilers, building envelope improvements and compact fluorescent lamps under the French White Certificates.	Residential
Italy	Schemes under the Italian White Certificates system	Residential, tertiary, industry
Sweden	Energy Efficiency Investment Programme for Public Buildings (2005-2008)	Public non-residential buildings
Denmark	Energy audits performed in Denmark between 2006 and 2008	Industry, tertiary

As a result of the pilot tests, some of the case applications tested were updated to reflect the findings of the tests.

3 Step 1: Unitary gross annual energy savings

3.1 Step 1.1: General formula and calculation model

For this method on improvements to the building envelope of residential buildings, the unit is square meters of conditioned area.

For the Level 2b and Level 3 approaches the unitary gross annual energy savings are expressed as:

unitary gross annual energy savings =

$$UFES = UFED_{baseline} - UFED_{action} = \left(\frac{SHD_{baseline}}{\eta_{baseline}} - \frac{SHD_{action}}{\eta_{action}}\right) \bullet (1 - RE)$$

(equation 1a)

Where:

UFES = Unitary Final Energy Savings [kWh/m²/a]

UFED =Unitary Final Energy Demand [kWh/m²/a]

SHD = Specific Heating Demand [kWh/m²/a]

η = energy efficiency of the heating system (seasonal)[5]

The basis for the calculation of final energy demand (FED) is the specific heat demand of a building, which is determined mainly by the building envelope (area and U-values for windows, facade, upper roof and cellar top), some parameters for the use (people living in the building, ventilation), energy gains by the sun, a standard inside temperature (20° C) and a figure for the outside temperature (usually: heating degree days).

Specific heat demand usually refers to a reference climate and therefore no additional normalisation is needed. It should be noticed that the calculation of the specific heat demand may differ from country to country. Generally, this calculation should follow the specifications of the European Norm EN832 (2000).

[5] η is not the efficiency of the boiler or the heating system as a technical unit. It is the relation of heat demand to final energy demand for heating and, thus, the characteristics of the whole building have to be considered. The final energy demand (FED) also includes losses by the heating and the distribution system, expressed by efficiency parameters (details in method 4, improvement of the heating system)

At level 2b, the unitary gross annual energy savings can be estimated as the average gain (in kWh/m²/a) per categories (building types and construction periods) based on a sample and a difference between "before" and "after" Energy Performance Certificates.

At level 3, the unitary gross annual energy savings can be estimated as the actual difference between the "before" and "after" Energy Performance Certificates for each registered building if energy savings are evaluated for all individual buildings involved in a given action or as an average gain per categories based on a regional sample if the method is applied at a regional (sub-national) level.

For the Level 2a building stock model, unitary final energy savings (UFES) should be understood as average unitary energy savings in a building age class i and building type m at time t. That is:

$$UFES_{i,m,j,t} = UFED_{baseline,i,m,j,t} - UFED_{action,i,m,j,t} = \left(\frac{SHD_{baseline,i,m,j,t}}{\eta_{baseline}} - \frac{SHD_{action,i,m,j,t}}{\eta_{action}}\right) \bullet (1 - RE)$$

(equation 1b)

Where:

i =building age class (construction period) {1 ... x}

j =description of the energy efficiency measure/action:

nb ...	new buildings
de ...	demolished buildings
be ...	change of the building envelope
hs ...	change of the heating system
behs ...	change of the building envelope and heating system
sm ...	single measures
nm ...	no measures

m =building type

t =time (year)

Again, the unitary average gross annual energy savings at Level 2a can be estimated as the average gain (in kWh/m²/a) per categories (building types and construction periods) based on a sample and a difference between "before" and "after" Energy Performance Certificates.

3.2 Step 1.2: Baseline

For the improvement of the building envelope, the baseline is the individual situation before the refurbishment. However, due to the requirements of the EU Directive on the overall energy performance of buildings (EPBD), national building codes of EU Member States have to require that in case of major renovations of buildings with an area exceeding 1,000 m^2, these buildings have to meet energy performance requirements that are derived from the requirements for new buildings. A number of Member States have set these requirements equal to those for new buildings, and/or valid for buildings smaller than 1,000 m^2 as well.

Therefore, the calculation has to be done in two steps for building envelope refurbishments that are subject to national building codes:

- In the first step, the baseline is the individual situation of the energy performance of the building before the refurbishment. The end-use (energy efficiency improvement) action is that needed to reach the national building code requirements. The energy savings are those attributable to the EPBD implementation.
- In the second step, the baseline is the energy performance level required by the national building code. Any EEI measure achieving lower values (e.g., low energy or passive house levels) of kWh/m^2/year than those required by the national building code will lead to additional energy savings.

These baselines are identical for calculation of either all or additional energy savings. The baseline for both steps will automatically be dynamic: the first one for the individual buildings, the second step one according to the national laws.

level 1	EU default baseline: *not possible*
level 2	guidelines: *(how to define a MS-specific baseline):* EITHER *the situation of the energy performance of the building class before the refurbishment* OR *the national requirements according to EPBD implementation* data required: Information for each building class with comparable end-use actions taken
level 3	guidelines: *(how to define a measure-specific baseline):* Baseline for heating energy demand is EITHER *the individual situation of the energy performance of the building before the refurbishment* OR the minimum requirement according to EPBD data required: Information for each building or for sample of similar buildings with comparable end-use actions taken

3.3 Step 1.3: Requirements for normalisation factors

Specific heat demand usually refers to a reference climate, and therefore no additional normalisation is needed.

(new) normalisation factor 1	
level 1	default coefficient: *(when possible):* : none (normalisation not necessary)
level 2	guidelines: *(how to include the normalisation factor in calculation model or how to calculate a level 2 coefficient of normalisation)* data required: : none (normalisation not necessary)
level 3	guidelines: data required: : none (normalisation not necessary)

3.4 Step 1.4 Specifying the calculation method and its three related levels

level 1	Level 1 is not possible
level 2	Building stock model, i.e., modelling of the whole stock based on surveys
level 3	enhanced engineering estimates (if individual energy performance certificates are used) or mix of deemed and ex-post estimates

3.4.1 **Conversion factors** (when relevant)

None

3.4.2 Considering the direct rebound effect

This section only applies for lighting, cars, and for measures related to the internal temperature of dwellings, unless there is clear evidence that it is relevant.

The direct rebound effect is not explicitly mentioned in the ESD. It is created by final energy consumers who increase the intensity of the use of energy-efficient equipment after an EEI measure, e.g., when the internal temperature of a building is increased after insulation. This reduces the energy savings achieved in comparison to the baseline of autonomous consumption changes. Consequently, including energy savings “eaten up” by the direct rebound effect in the total ESD annual energy savings would mean to include too high energy savings compared to the autonomous energy consumption changes. It has not yet been decided by the European Commission and the ESD committee, whether this effect shall be included in the total ESD annual energy savings or eliminated from them. In the latter case, the following requirements apply.

Direct rebound effects refer to fact that a consumer may choose to use more of the resource instead of realising the energy cost savings (Gottron, 2001). There is empirical evidence about direct rebound effect for measures related to the building envelope. Esentially, this refers to the fact that after improvements in the building envelope people may tend to increase the inner temperature of the dwellings. This leads to a higher final-energy consumption for heating purposes. Using the case study of space heating in Austria, Haas and Biermayr (2000) estimated a rebound effect between 20% and 30%. Greening *et al.*, (2001), as cited by Gottron (2001), report a size of rebound of 10% to 30% for space heating applications based on a survey of previous studies.

Sorrel (2007) conducted a comprehensive analysis of the available evidence of rebound effects and their policy implications. According to his study, rebound effects appear difficult to quantify, but they are sufficiently important to merit explicit treatment when estimating energy savings. The magnitude of the direct rebound effect may be expected to be directly proportional to the share of the energy costs in the total costs of the energy service. As the consumption of the energy service increases, however, saturation effects reduce the size of the direct rebound effect. In connection to the building envelope this manifests as the fact that people will not increase the inner temperature of their dwellings beyond their level of confort. The evaluation of Sorrel (2007) shows that in developed countries, the long-run direct rebound effect is likely to be less than 30% for household space heating.

Biermayr *et al.*, (2004) conducted a study of rebound effects associated to refurbishment of residential buildings in Austria. Their findings are that the rebound effect depends on the initial condition of the building. For buildings that were already in a good condition and a lower-than-average energy consumption, a rebound effect of up to 5% was found. For buildings with an average energy consumption, a rebound effect of up to 20% was reported. For buildings in a bad condition and a correspondingly higher energy consumption, the rebound effects amounted up to 50%.

On the basis of the estimates provided in the literature, here it is proposed that a factor of 20% be applied as the default level 1 estimate to account for rebound effects. Member states can apply level 2 or level 3 estimates if they are able to provide the corresponding supporting evidence.

3.4.3 From EMEEES tasks 4.2 to 4.3: defining values and requirements

3.4.3.1 Default values for energy consumption and/or related parameters

EU level default values are not possible for this case.

3.4.3.2 Requirements to define level 2 and level 3 values

For the level 2b approach, the Energy Performance Certificates (EPCerts) provide data for the evaluation of energy efficiency improvements of the building envelope. They contain data on:

- Final energy demand
  - Heating energy demand
  - Efficiency of the heating system
- Conditioned area

- Suggestions for measures to improve the energy efficiency of the building envelope (additional insulation of façade, roof, and basement; exchange of windows; airtight envelope; ventilation system with heat recovery)

EPCerts provide much more information which is not presented here, for example on energy demand for warm water and electricity.

Due to the validity level of 1000 m^2 the EPBD does not require EPCerts for single-family houses and semidetached houses. Nevertheless, relevant information will be available also for part of these buildings because there is the tendency that building permits and social housing grants are linked with EPCerts according to EPBD.

Calculation of EPCerts is harmonized on the European level. It must comply with the methodological framework presented in the EPBD. Therefore it is suggested to use EPCert data as input in the evaluation of energy efficiency improvements concerning the building envelope.

4 Step 2: Total gross annual energy savings

4.1 Step 2.1: Formula for summing up the number of actions

The unit for this method is square meters of conditioned area.

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 above (index j).

$$TGFES_t = \sum_j \sum_m \sum_i \left(\frac{SHD_{i,j,m,baseline}}{\eta_{baseline}} - \frac{SHD_{i,j,m,action}}{\eta_{action}} \right) A_{i,j,m,t}$$

(equation 2b)

Where:

TGFES: Total Gross Final Energy Savings

SHD= Specific Heating Demand [kWh/m^2/a]

η = energy efficiency of the heating system (annualized)

A= total conditioned area (m^2/a), either gross or net area[6], for a building age class i, building type m and a given category of measures j

Indexes

i ... building age class (construction period) {1 ... x}

j ... description of the energy efficiency measure/action:

- nb ... new buildings
- de ... demolished buildings
- be ... change of the building envelope
- hs ... change of the heating system

[6] In Europe, there are many different ways to define the “conditioned area”. For the architecture of the building stock model it does not make any difference as long as all variables refer to the same definition.

behs ... change of the building envelope and heating system

sm ... single measures

nm ... no measures

m ... building type (single family houses, multi-family houses)

t ... time (year); n = starting point for the calculation (either 1995 or 2008)

For the Level 2b approach the total gross final energy savings (TGFES) are estimated as:

$$TGFES = \left(\frac{SHD_{baseline}}{\eta_{baseline}} - \frac{SHD_{action}}{\eta_{action}} \right) * (1 - RE) * A$$

(equation 2a)

Where:

TGFES: Total Gross Final Energy Savings

SHD = Specific Heating Demand [kWh/m^2/a]

η = energy efficiency of the heating system (annualized)

A = total conditioned area (m^2/a), either gross or net area (obtained by summing up the areas of individual buildings)

In Europe, there are many different ways to define the “conditioned area”. A precise definition of conditioned area has to be specified by the national authorities.

For some classes of similar buildings (e.g., single family houses) with standardised end-use actions taken on them, it may be possible to estimate deemed energy savings in kWh/m^2/a. The validity of such estimates has to be proven by large enough samples (e.g., 50 to 100 buildings of a type). In such cases, equation 2a will be modified to:

$$TGFES = UFES_{av} * A * (1 - RE)$$

(equation 2a, mod)

Where:

$UFES_{av}$ = average Unitary annual Final Energy Savings [kWh/m^2/a]

A = area of the buildings of the type concerned

For the Level 3 approach the total gross final energy savings (TGFES) are estimated adding the individual energy savings across all buildings included in the energy-saving action:

$$TGFES = \sum_{k=1}^{N} \left[\left(\frac{SHD_{baseline,k}}{\eta_{baseline,k}} - \frac{SHD_{action,k}}{\eta_{action,k}} \right) * (1 - RE) * a_k \right]$$

(equation 2a)

Where:

TGFES: Total Gross Final Energy Savings

SHD = Specific Heating Demand [kWh/m^2/a]

η = energy efficiency of the heating system (annualized)

a_k = conditioned area (m^2/a), either gross or net area per building i

k= 1..N= summation over N buildings involved in the energy-saving action

4.2 Step 2.2: Requirements and methods for accounting for the number of actions

The Level 2b (and level 3) method relies on the use of Energy Performance Certificate (EPCerts) data as input in the evaluation of energy efficiency improvements concerning the building envelope. Calculation of EPCerts is harmonized on the European level. It must comply with the methodological framework presented in the EPBD.

Collection of EPCerts and data collection for energy efficiency improvement evaluation

In the ongoing EU project DATAMINE[7] a framework for data collection from EPCerts in the European member states is being developed: The project is about collecting data from energy certification to monitor performance indicators for new and existing buildings. DATAMINE will be completed by end of 2008.

[7] http://www.iwu.de/forschung/energie/laufend/datamine/

In Austria, for example, the software called „ZEUS“ is used for the electronic data management of EPCerts, and an interface with the DATAMINE project was developed like it was done with corresponding systems in the other participating countries. ZEUS (http://www.energieausweise.net/) is an internet-software, which transforms the EPCerts (after they have been compiled with one of the existing calculation programs) automatically into the internet. ZEUS can be used by consultants, building owners, and public bodies to process energy certificates, to store them and to evaluate them. Public bodies have the opportunity to evaluate data provided in the course of EPCert calculation such as decrease of heating energy demand during a defined period of time.

5 Step 3: Total ESD annual energy savings

In this section, the correction factors required by the ESD and potential further correction factors are dealt with. Applying these factors will allow to calculate the total ESD annual energy savings from the gross annual energy savings calculated in step 2.

5.1 Step 3.1: Formula for total ESD annual energy savings

For the Level 2a building stock model, the total net final energy savings (TNFES) are computed at a given time t are the summation of the unitary savings across building age classes (index i), building types (index m) and across the categories of measures described above (index j) corrected for free-rider effects (only when calculating additional enery savings), direct rebound and multiplier effects. That is:

$$TNFES_t = (1 - FR) * (1 - RE) * (1 + M) * \left(\sum_j \sum_m \sum_i \left(\frac{SHD_{i,j,m,baseline}}{\eta_{baseline}} - \frac{SHD_{i,j,m,action}}{\eta_{action}} \right) A_{i,j,m,t} \right)$$

Where:

TNFES: Total Net Final Energy Savings

SHD= Specific Heating Demand [kWh/m^2/a]

η = energy efficiency of the heating system (annualized)

A= conditioned area (m^2/a), either gross or net area, per building age class i, building type m and for and a given category of measures j

FR= Fraction of free-riders

RE= Direct Rebound Effect

M= Fraction of multipliers

Since the modelling is on all end-use actions taken in the building stock regardless of any facilitating measures that may have caused the actions, there is no double-counting issue in the level 2a method.

Indexes

i ... building age class (construction period) {1 ... x}

j ... description of the energy efficiency measure/action:

nb ...	new buildings
de ...	demolished buildings
be ...	change of the building envelope
hs ...	change of the heating system
behs ...	change of the building envelope and heating system
sm ...	single measures
nm ...	no measures
m ...	building type (single family houses, multi-family houses)
t ...	time (year); n = starting point for the calculation (either 1995 or 2008)

For the Level 2b approach, if all correction factors are included, the total net final energy savings (TNFES) are estimated as:

$$TNFES = \left(\frac{SHD_{baseline}}{\eta_{baseline}} - \frac{SHD_{action}}{\eta_{action}} \right) * A * (1 - DC) * (1 - FR) * (1 - RE) * (1 + M)$$

Where:

TNFES: Total Net Final Energy Savings

SHD = Specific Heating Demand [kWh/m^2/a]

η = energy efficiency of the heating system (annualized)

A = total conditioned area (m^2/a)

DC = Double-counting coefficient

FR = Fraction of free-riders

RE = Direct Rebound Effect

M = Fraction of multipliers

At Level 3, a similar expression for the total net final energy savings (TNFES) is used but adding the individual energy savings across all buildings included in the energy-saving action.

$$TNFES = \sum_{k=1}^{N}\left(\frac{SHD_{baseline,k}}{\eta_{baseline,k}} - \frac{SHD_{action,k}}{\eta_{action,k}}\right) * a_k * (1-DC) * (1-FR) * (1-RE) * (1+M)$$

Where:

TNFES: Total Net Final Energy Savings

SHD = Specific Heating Demand [kWh/m^2/a]

η = energy efficiency of the heating system (annualized)

a_k = conditioned area (m^2/a) per building k

DC = Double-counting coefficient

FR = Fraction of free-riders

RE = Direct Rebound Effect

M = Fraction of multipliers

k=1…N= summation over N buildings involved in the energy-saving action

5.2 Step 3.2: Requirements for avoiding double counting

In the level 2b and level 3 methods, there is the possibility of a double-counting problem, e.g., between an energy audit programme for residential buildings or the energy performance certificates on one hand, and a financial incentive programme on the other. Therefore, care must be taken not to double-count energy savings from several facilitating measures. This can best be done if the combined effect of the whole package of measures targeting improvements in the building envelope is measured. A good instrument to avoid double-counting is a database tracking participants and the end-use actions they take vs. the different measures that are facilitating the actions. If no database is possible, ex-post surveys for samples of participants can be an instrument to find out, which end-use actions were taken, and which have benefited from one or more facilitating measures.

In the level 2a method, there is no double-counting issue, since the modelling is on all end-use actions taken in the building stock regardless of any facilitating measures that may have caused the actions. Surveys that are carried out to monitor, which end-use actions have overall been taken, can also keep track of which end-use actions have benefited from one or more facilitating measures.

5.3 Step 3.3: Requirements for taking account of technical interactions

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 can be distinguished as follows:

a. The heating system is replaced and the building envelope remains the same: EMEEES method 3 on the improvement of heating system and its sub-methods should be used to evaluate this case
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

In what follows we discuss the implications of these cases by considering the situation before and the situation after the energy-saving action. As a simplification, the effects of the deterioration of the existing heating system on its efficiency are ignored in this analysis.

a. The heating system is replaced and the building envelope remains the same

In this case, there is no technical interaction between the two end-use actions and hence no double counting of energy savings between them. The efficiency of the heating system is improved but the specific heat demand of the building remains the same. Figure 1 illustrates this effect schematically. Therefore, all the savings can be attributed to the replacement of the heating system.

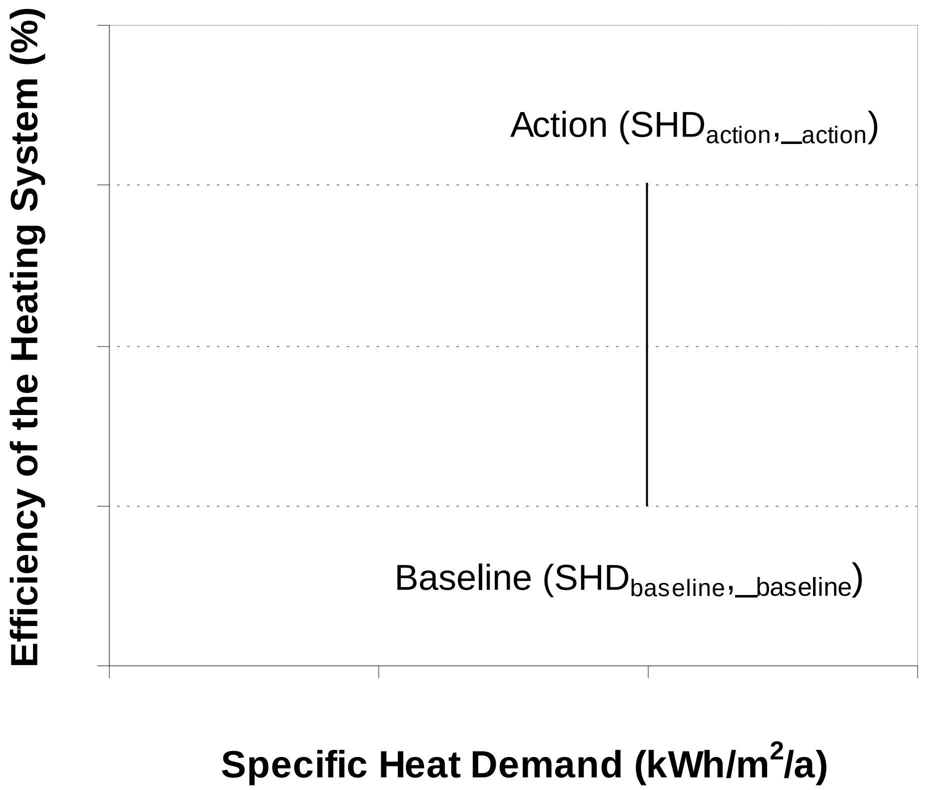


Figure 1: Efficiency of the heating system vs. specific heat demand when the heating system is replaced and the building envelope remains the same (case a)

As explained above, without consideration of a rebound effect the unitary energy savings can be expressed as:

$$UFES = UFED_{baseline} - UFED_{action} = \frac{SHD_{baseline}}{\eta_{baseline}} - \frac{SHD_{action}}{\eta_{action}}$$

In this case the building envelope remains unchanged. Therefore, the Specific Heat Demand of the building is the same before and after the action. Thus, the average unitary energy savings can be defined as:

$$UFES = UFED_{baseline} - UFED_{action} = SHD_{baseline}\left(\frac{1}{\eta_{baseline}} - \frac{1}{\eta_{action}}\right)$$

This is exactly the equation used in the methods on the improvement of heating systems.

b. The building envelope is improved and the heating system remains the same

In this case the improvement of the building envelope leads to a reduction of the specific heat demand of the building. The heating system is now over-dimensioned and operates under different, non-optimal conditions. As a result its efficiency decreases (see Figure 2). Therefore part of the savings that are achieved through the improvement of the building envelope are lost.

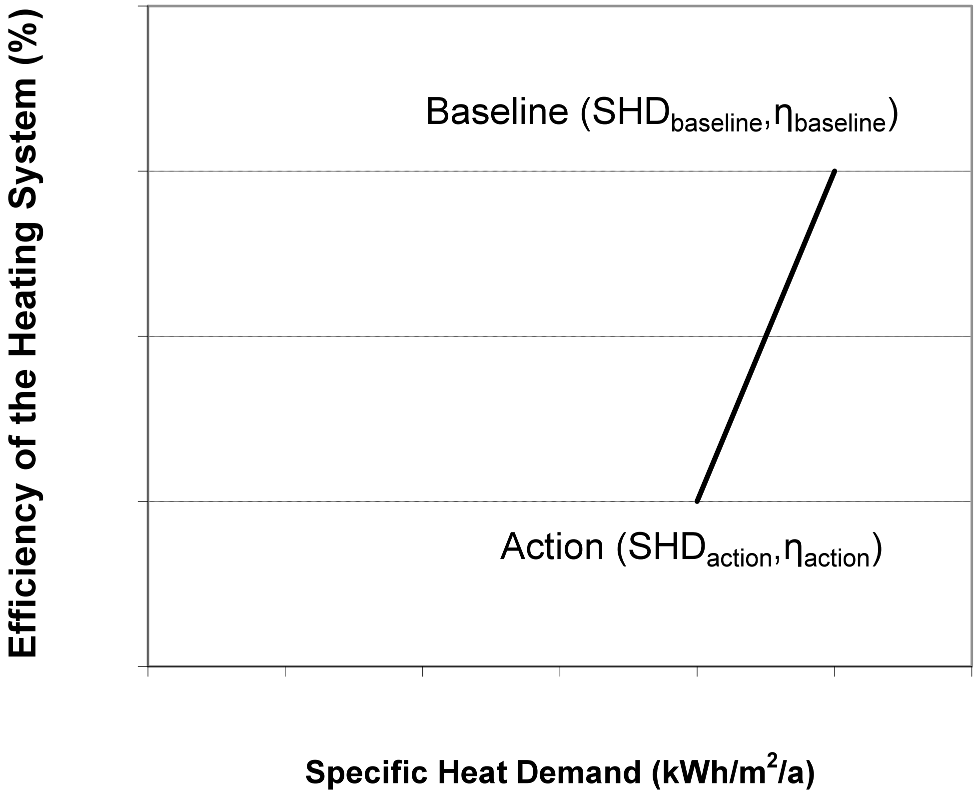


Figure 2: Efficiency of the heating system vs. specific heat demand when the building envelope is improved and the heating system remains the same (case b)

In this case the building envelope is improved but the efficiency of the heating system is reduced due to the mismatch between its dimensioning and the new Specific Heat Demand. The unitary energy savings can be defined as:

$$UFES = UFED_{baseline} - UFED_{action} = \frac{SHD_{baseline}}{\eta_{baseline}} - \frac{SHD_{action}}{\eta_{action}}$$

There is no double counting between the end-use actions in this case. The entire energy savings can be attributed to the building envelope but they must be corrected downwards in order to account for the efficiency loss of the heating system.

An exact estimation of the efficiency loss would require a specification of the efficiency of the heating system as a function of the specific heating demand of the building. This function, however, can be case and technology dependent. As a proxy for the default Level 1 estimate, one can assume that the loss is a constant.

Typical estimates of the efficiency loss reported in Austria by the "Bundesländer" within the framework of building-incentive programs lie around 20%.

c. The building envelope is improved and the heating system is replaced

In this case the specific heat demand of the building is reduced and the efficiency of the heating system is increased (see Figure 3 for a schematic illustration). There are savings due to both the improvement of the building envelope and the replacement of the heating system by a system with a higher efficiency.

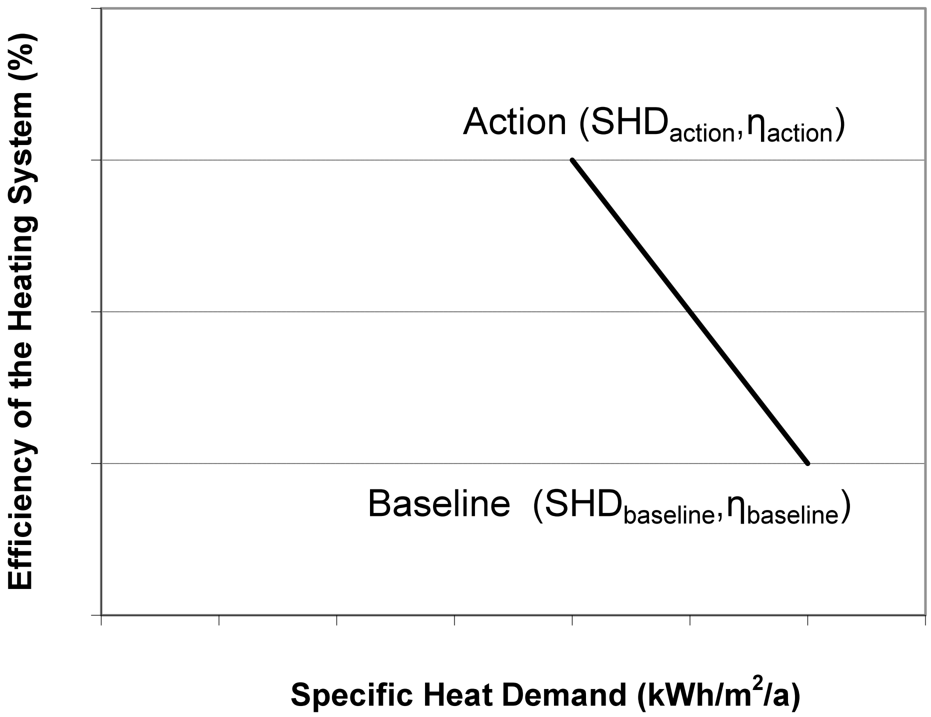


Figure 3: Efficiency of the heating system vs. specific heat demand when the building envelope is improved and the heating system is replaced (case c)

In order to avoid double counting of energy savings, the combined effect of the package of end-use action on the building envelope and the heating system should be evaluated, as it is the case when calculating the final energy demand for a building energy performance certificate. If for some reason the two technical actions shall be evaluated separately, an allocation between them will have to be defined. That is, which fraction of the energy savings can be attributed to the replacement of the heating system and which fraction of the energy savings can be attributed to the improvement of the building envelope. This requires the specification of a function relating the efficiency of the heating system to the specific heat demand of the building.

The following procedure to decompose and allocate the total energy savings is proposed here:

As discussed under item b), in the situation in which only the building envelope is improved, there is a loss of efficiency for the existing heating system. This loss is due to the fact that the existing heating system does not match the specific heat demand anymore. Thus, the heating system functions far from its optimal operation point.

That is, when the refurbishment of the building and the replacement of the heating system are carried out simultaneously, this efficiency loss (and, therefore, loss of energy savings) will be not take place. This situation is illustrated in Figure 4.

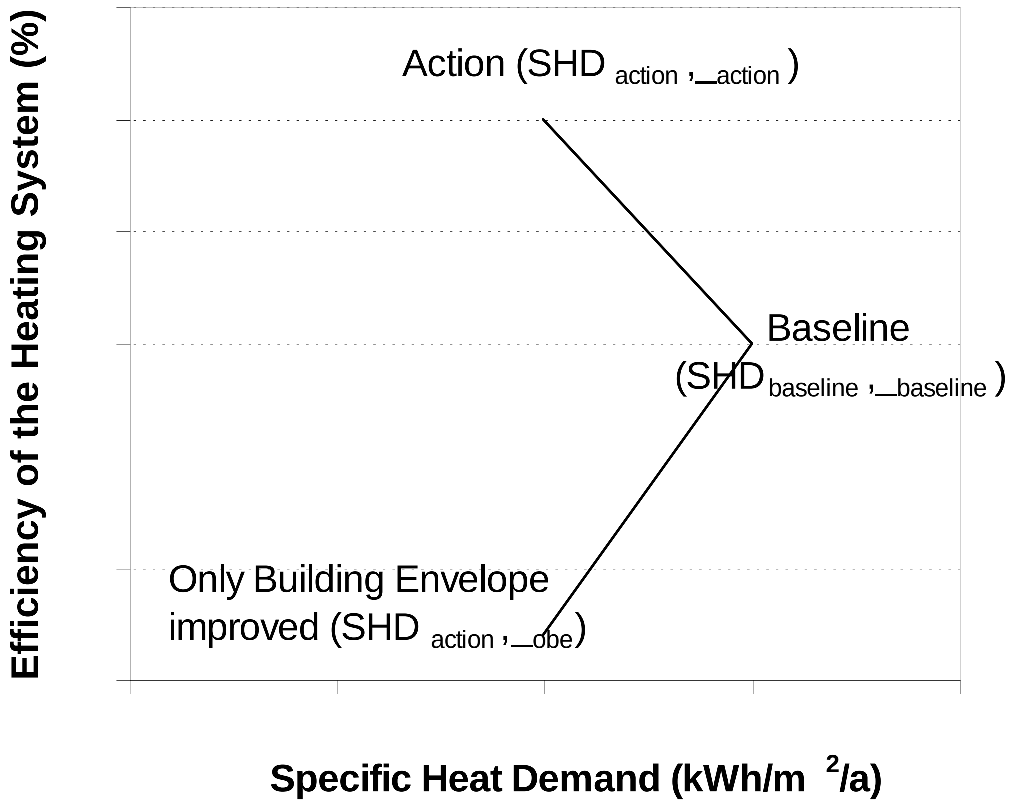


Figure 4: Efficiency of the heating system vs. specific heat demand when the building envelope is improved and the heating system is replaced (case c) compared to the situation in which only the building envelope is improved (case b)

In Figure 4:

- $\eta_{baseline}$, $SHD_{baseline}$ represent the situation before the energy-saving action
- η_{action}, SHD_{action} represent the situation after the energy-saving action
- η_{obe}, SHD_{action} represent the situation after the energy-saving action if only the building envelope (obe) would have been improved

We propose to use the point η_{obe}, SHD_{action} as the reference for the estimation of the efficiency improvement of the heating system. That is, the allocation of the total energy savings between the building envelope and the heating system would be as follows:

The energy savings attributed to the improvement of the building envelope would be computed in a similar way to the savings in case b), namely:

$$UFES = \frac{SHD_{baseline}}{\eta_{baseline}} - \frac{SHD_{action}}{\eta_{obe}}$$

The energy savings attributed to the replacement of the heating system would be defined as follows:

$$UFES_{heating \quad system} = SHD_{action} * \left(\frac{1}{\eta_{obe}} - \frac{1}{\eta_{action}} \right)$$

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.

d. Single technical actions (e.g. window replacement, wall insulation) are conducted in the building envelope

In this case the impacts of the changes to the building envelope on the efficiency of the heating system can be neglected.

5.4 Step 3.4: Requirements for multiplier energy savings

In principle, there can be multiplier effects, if market breakthrough of best available technology in building envelope improvement is accelerated by facilitating measures. In practice, these may be difficult to evaluate.

If at any time in the 2008 to 2016 period, the energy savings due to the current requirements of the national building code for existing buildings are evaluated, they should already contain multiplier effects. This is based on the consideration that a market breakthrough of better thermal insulation levels in existing buildings will allow to set the requirements of the national building code for existing buildings at lower levels of final energy demand in kWh/m^2/year than they would have been without the market breakthrough. These multiplier effects will, however, not have to be measured separately since they will automatically be included in the savings measured for the building code, if compliance to the code is ensured.

5.5 Step 3.5: Requirements for the free-rider effect

The free-rider effect is not explicitly mentioned in the ESD. Free riders are final energy users who are counted when monitoring the effects of facilitating measures but would have taken the end-use actions promoted also without the facilitating measure. Consequently, including energy savings achieved by free riders in the total ESD annual energy savings would mean to include a part of the autonomous energy efficiency improvements. It has not yet been decided by the European Commission and the ESD committee, whether this effect shall be included in the total ESD annual energy savings or eliminated from them. In the latter case, the following requirements apply.

Free-rider effects refer to the fact that some households would have undertaken the energy-saving action even in the absence of any incentives provided by the related energy efficiency improvement (EEI) measure.

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 (up to 89%, Malm, 1996). These values, however, are highly dependent on the method used to conduct the surveys that lead to the estimation and may be susceptible to bias. Moreover, they appear to be country and even program-dependent.

Lees (2006) conducted an ex-post analysis of the Energy Efficiency Commitment in the U.K for the period 2002-2005 (the so-called EEC1). In this analysis, estimates from the U.K. Department for Environment, Food, and Rural Affairs (Defra) about the so-called deadweight (equivalent to the free-rider effect) for energy efficiency actions during this period are presented (see Table 1). The free-rider effect ranged from 11% to 63% for these energy-saving actions.

Table 1: Estimates of the free-rider effect (deadweight) for energy-saving measures related to the building envelope in the EEC 2002-2005 of the UK

	Number of measures	**Deadweight estimate (Defra) (Number of measures)**	**Deadweight (%)**
Cavity wall insulation	791524	235000	29.7
Loft insulation (top-up)	528496	58500	11.1
Loft insulation (virgin)	226245	58500	25.9
Do-It-Yourself loft insulation	355097	225000	63.4
Draught stripping	22743	0	0

Here, it is recommended that a value of 20% be applied as the Level 1 default for improvements of the building envelope from facilitating measures yielding less than 40 million kWh of total gross annual energy savings. Member states are encouraged to provide their own estimates. It should again be noticed that free-rider effects are not mentioned in the Directive 2006/32/EC.

Member states could conduct estimates of free-rider efects for selected programs after a given number of years. If the European Commission and the ESD Committee decide to evaluate free-rider effects, it is recommended to require such analysis in any case for facilitating measures yielding more than 40 million kWh of total gross annual energy savings. For measures yielding more than that threshold of energy savings, the analysis of free-rider effects is likely to cost less than one percent of the energy cost savings achieved[8].

[8] Even at only 3 Cent per kWh of energy import costs saved, 40 million kWh/year will save 1.2 million Euros per year. During 25 years and at 4 % of real interest rate, the net present value of energy cost savings will be around 20 million Euros. A thorough evaluation of free-rider effects through surveys will probably cost less than 200,000 Euros, i.e., less than 1 percent of the energy cost savings.

6 Step 4: total ESD energy savings for 2010 and 2016

The ESD text is interpreted so that only for those EEI measures that have not reached the end of their energy saving lifetime in the years of the intermediate (2010) and final (2016) targets, energy savings will be counted towards a Member State's intermediate or final energy savings target under the ESD.

6.1 Requirements for the energy saving lifetime

According to CWA27 (2007), the lifetime of actions related to the building envelope has been estimated at 25 years or more. The CWA27 recommends adopting this value as a harmonised energy saving lifetime.

For windows, CWA27 recommends a harmonised energy saving lifetime of 24 years.

As a simplification, the effects of the deterioration over time of the existing heating system on its efficiency are ignored in this analysis. Moisture can lead to a deterioration of thermal insulation, and windows can also deteriorate, e.g., by draught or leakage of the insulating gas. No representative data are known to us about the magnitude of such effects, so we have to neglect them for the moment. It is advisable that a study be done at EU level to assess these effects.

6.2 Special requirements for early actions

The definition of early actions may include two possibilities (to be clarified by the European Commission and the ESD Committee):

- *early (EEI) facilitating measures*, and only those energy savings that result from end-use actions that are implemented during 2008-2016, as a result of these facilitating measures that still have a lasting effect during 2008-2016, are eligible

OR

- *early energy savings* from end-use actions initiated between 1995 and 2008, with the end-use actions having a lasting effect in 2010 (for the intermediate target) or 2016 (for the overall target).

Note:

If early energy savings are accepted, a contribution to the target in 2016 can only be counted if the energy saving lifetime is greater than 8 years plus the time between installation and 2008. The same holds, respectively, for the intermediate target in 2010.

The long energy saving lifetimes proposed for improvements in the building envelope imply that early actions taken in 1995 or later will still count for the ESD energy savings target in the year 2016.

6.3 How to treat uncertainties

An analysis of potential uncertainties was not possible for this case application. Ways to treat potential uncertainties can be found, e.g., in the case application on biomass boilers.

Appendix I: Justifications and sources

Following the same frame as the description of the method, and providing justifications and sources for each choice and default value, using existing data and examples of evaluation methods targeting the same subject wherever possible.

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Appendix II: Description of the building stock model

In what follows a detailed description of the building stock model is presented. The building stock model described here has to be seen as only one possible approach. Member states that have their own models will have to check if the features in their models correspond to the needs of ESD. The goal of the description conducted here is to give an overview on necessary elements and calculations.

General Description of the Method: Level 2a National Method

The focus of the method described below ist the energy efficiency improvement of the residential building stock. This method deals with the refurbishment of existing buildings. It does not deal with the energy efficiency improvement of new buildings although it has to consider the corresponding effects. The approach therefore starts from a top-down perspective. This is necessary for the clarification about how the baseline according to ESD could look like and what corrections will have to be considered.

The first question tackled here is: What are “savings eligible for ESD” that stem from the improvement of the building envelope?

Figure 1 shows the general outline of the approach:

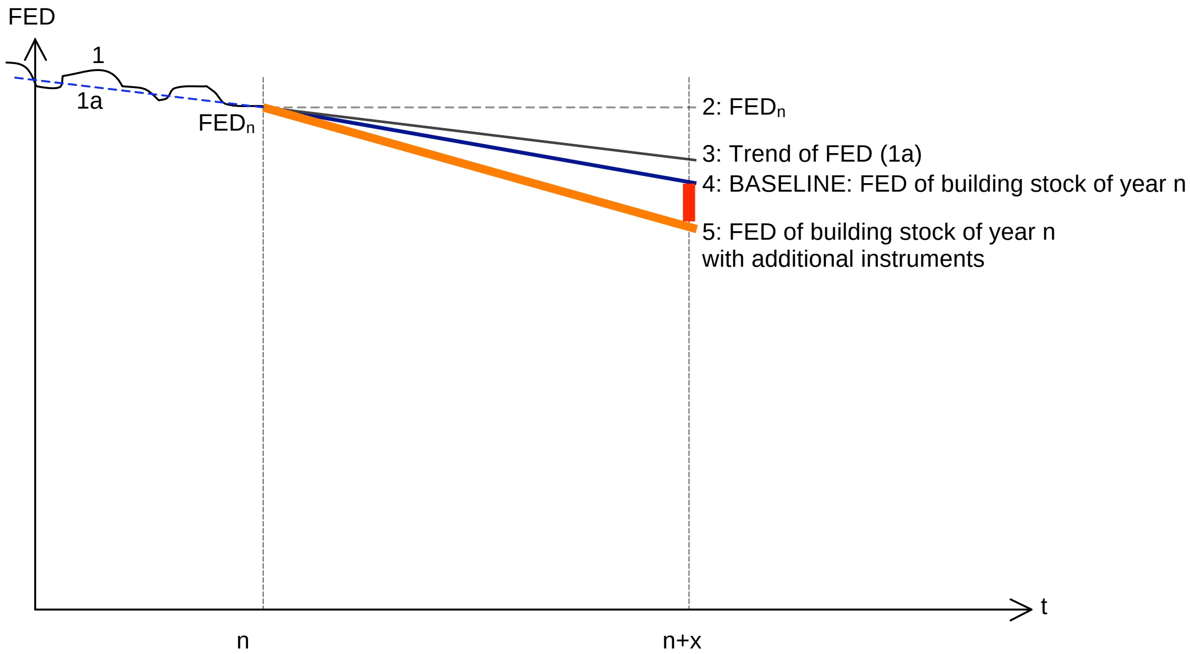

Fig. 1: General outline for the calculation of “ESD energy savings”

- FED_n is the final energy demand (FED) of the total residential building stock in year n. FED does only include energy used for space heating (and losses associated with that). However, due to strong interaction to hot water supply it could make sense to include energy for the production of hot water.

- Curve 1 is FED of the residential building stock before year n (data could come from official statistics or from surveys). This is the observable or measureable FED and it includes new building (built until year n) and it considers the effect of demolishing of buildings (resulting in a reduction of FED). This curve does not include any climate correction.

- Curve 1a is the normalized (climate corrected) FED of the residential building stock until year n.

- Curve 2 is FED_n (= const.), i.e. no new buildings, no refurbishment, no demolition, no other changes after year n are included in this figure.

- Curve 3 is the (linear, non-linear in justified cases) continuation of the normalized FED of the building stock before year n (curve 1a). It is suggested to use five or ten years before year n for the calculation of the trend (depending on the data availibility and on the shape of the trend). This trend does also include new buildings constructed after year n (with a rate and energy efficiency level of year n) and it considers the effects of demolition. This curve can be interpreted as FED of the building stock after year n if everything is unchanged.

- Curve 4 is the baseline for energy improvement of the building envelope. It **excludes** FED of new buildings constructed after year n (with a rate and energy efficiency level of year n) and is therefore the FED of the building stock of year n. The basic idea behind this curve is: What would happen with the building stock of year n if everything is unchanged after year n, i.e. no new or changed political instruments, no change in the general framework conditions. This trend is recommended to be used as the baseline for the calculation of the savings according to the ESD.

- Curve 5 is FED of the building stock of year n with new political instruments and changed framework conditions. Hence, the **difference between 5 and 4** (baseline) **are the energy savings** (according to ESD) of the building stock of year n. This figure does not include FED of new buildings constructed after year n but it does include energy savings due to an efficiency improvement of the heating system.[9]

[9] It could be useful to include savings from efficiency improvements of the heating system in the model. However, it is possible to separate the effects of both measures.

Consideration of "early actions"

Two cases have to be distinguished (Figure 2):

- **Case 1: "Early savings" are eligible for 2016**

In this case, the procedure as described above has been applied for 1995 and for 2008 in a similar way. The focus in this case is on the building stock of 1995 and therefore, the actual trend of FED for the period 1995-2008 has to be continued and can then be used as the baseline for the period 2008-2016. Given that the saving lifetime estimated by CWA 27 (2007) for actions targeted at the building envelope is 25 years or more, savings from the period 1995-2008 will still be effective in 2016. For savings after 2008, new political instruments will have to be implemented.

In other words, Member States with effective energy efficiency policies from 1995 on, will be rewarded with energy savings still in force in 2016. But on the other hand, there is a clear incentive to implement additional policies after 2008, otherwise only the "early savings" and no additional energy savings will be counted in 2016.

- **Case 2: "Early savings" are not eligible for 2016**

If only savings occuring in 2008 or later are eligible, the calculation uses the same methodology as in 1995, with the important difference that instead of FED of the 1995 building stock the 2008 building stock is the unit of analysis, i.e. all buildings constructed in the period 1995-2008 are considered.

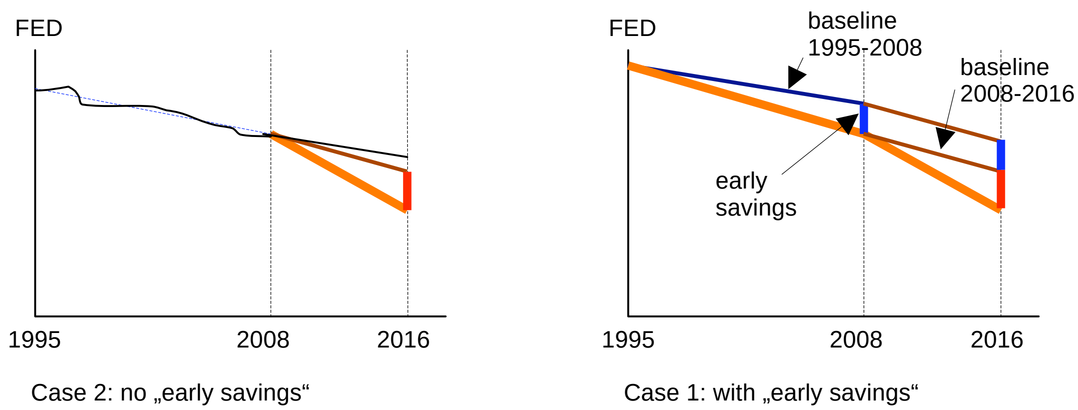

Figure 2: Considering "early savings"

Calculation of the baseline

The baseline is defined here as the trend of FED of the residential building stock of year n that could be observed or measured if framework conditions would have been unchanged and no additional political instruments were set into force after year n (Curve 4 above). FED of buildings constructed after year n has to be excluded in the baseline. A simple continuation of the FED trend before year n (curve 3) does not fulfil this requirement for baselines as new buildings are included there.

With a building stock model, the necessary FED trend can be calculated. The model has to calibrated for FED_n and the FED trend before year n. The baseline can be validated by simply continuing the (5 or) 10 years trend of FED before year n and subtracting the effect of buildings constructed after year n.

Description of the building stock model

The approach followed here for the evaluation of improvements to the building envelope consists in setting up a model of the building stock. In this model, a building typology is specified according to building age classes, types of buildings (e.g. single-family houses, etc) and the heating system (energy carrier). Within a given category, buildings are assumed to be homogenous. That is, an average building can be used to represent the corresponding category.

The model described here has to be seen as one possible approach. Member states that have their own models will have to check if the features in their models correspond to the needs of ESD. The goal of this detailed description is to give an overview on necessary elements and calculations.

There are good reasons why a model for the building stock is needed in addition to a “pure” bottom-up approach. The most important one is that is difficult to extract the baseline directly from empirical data and to sum up any real (measurable) unitary savings. It is suggested to use the model 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.

The model focuses on the total building stock but it also includes the effects of changed heating systems in residential buildings. There are several interactions (see below) between the building envelope and the heating system and the effects can only be separated in a sufficiently detailed model.

Main features of the model are:

- The main unit can be either sqm (default) of conditioned area, flats or buildings (depending on the data availibility, first choice is sqm)
- The starting point is year n (either 1995 or 2008, depending on the consideration of “early savings” as described above)
- The time resolution of the model can be one year up to the entire reporting periods (1995-2008, 2008-2016), depending on the data availability.
- The following necessary categories are included in the model:

categories	**energy efficiency measure**	**short description**	**calculation, comments**
demolished buildings		A certain fraction of the building stock is demolished. This leads to a reduction of FED.	demolition rate (or actual numbers), derived from building statistics; calibration with data before year n (5 or 10 years); specific FED of demolished buildings
new buildings		new buildings are not in focus of this method but have to be considered for the calculation of the baseline	rate (or actual numbers) of new buildings derived from building statistics; calibration with data before year n (5 or 10 years); specific FED of new buildings in year n
refurbished buildings	improvement of the building envelope	The improvement of the building envelope reduces the (specific) heat demand. It has to be considered that even though the heating system is unchanged the efficiency (relation of heat demand to FED) will change (see below).	rate (or actual numbers) of refurbished buildings derived from building statistics or other sources; calibration with data before year n (5 or 10 years); specific heat demand and FED after refurbishment from energy certificates (energy certificate database) or other sources
	improvement of the building envelope and change of the heating system	The improvement of the building envelope reduces the (specific) heat demand. The efficiency of the heating system is likely to increase with a new heating system (see below). The effect of both measures have to be separated.	rate (or actual numbers) of refurbished buildings (including a change of the heating system) derived from building statistics or other sources; calibration with data before year n (5 or 10 years); specific heat demand and FED after refurbishment from energy certificates (energy certificate database) or other sources
	change of the heating system	The effect of the change of the heating system is an increased energy efficiency (see below). This has to be considered in the model. However, savings will be allocated to the specific method dealing with heating systems.	rate (or actual numbers) of buildings with changed heating systems derived from building statistics or other sources; calibration with data before year n (5 or 10 years); energy efficiency data from the method dealing with heating system

	improvement of single elements	assumption: the efficiency of heating system is not changed	rate (or actual numbers) of refurbished buildings (with single energy efficiency measures) derived from building statistics or other sources; calibration with data before year n (5 or 10 years); specific heat demand and FED after refurbishment from energy certificates (energy certificate database) or other sources
not refurbished buildings	no measures	fraction of unchangend buildings; necessary for model	no additional data necessary

Data structure

According to data availability in building or housing statistics, the building stock has to be disaggregated into classes. These classes should be homogenous to a certain extent in terms of:

- specific heat demand (SHD)
- energy carrier for heating (at least differentiated into: electricity, district heating, natural gas, oil, biomass)

Data for specific heat demand are not available in building or housing statistics in most cases. Hence, the classes can be built upon the following criteria:

- construction period
- number of flats
- (type of building, corresponds to number of flats in most cases)

Basic definitions and calculations

Variables

FED ... final energy demand for space heating [kWh, GWh]

UFED ... unitary FED

FES ... final energy savings

UFES ...	unitary FES
TGFES ...	total gross FES
TNFES ...	total net FES (FES according to ESD)
RE ...	correction factor for rebound effect
FR ...	correction factor for free-rider effect
A ...	conditioned area [sqm]; either gross or net area[10]
HD ...	heat demand [kWh per a] (= energy need for heating)
SHD ...	specific heat demand [kWh per sqm * a]
cf ...	correction factor
η ...	energy efficiency of the heating system (annualized)[11]
r ...	rate [%]

Indexes

i ...	building age class (construction period) {1 ... x}
j ...	description of the energy efficiency measure/action:
nb ...	new buildings
de ...	demolished buildings
be ...	change of the building envelope
hs ...	change of the heating system
behs ...	change of the building envelope and heating system

[10] In Europe, there are many different ways to define the "conditioned area". For the architecture of the building stock model it does not make any difference as long as all variables refer to the same definition.

[11] η is not the efficiency of the boiler or the heating system as a technical unit. It is the relation of heat demand to final energy demand for heating and, thus, the characteristics of the whole building have to be considered.

sm ...	single measures
nm ...	no measures
k ...	heating system/energy carrier
m ...	building type (single family houses, multi-family houses)
t ...	time (year); n = starting point for the calculation (either 1995 or 2008)
before/after ...	before EEI measure/action, after EEI measure/action

Building Class i (year n)

- conditioned area (A_i)
- specific heat demand (SHD_i)
- energy efficiency of heating system (η_k)

New Buildings (year n+1) (nb)

- conditioned area (A_n)
- specific heat demand (SHD_n)
- energy efficiency of heating system (η_k)

Building Class i (year n+1)
> demolished buildings (de)

- conditioned area ($A_{i,de}$)
- specific heat demand (SHD_i)
- energy efficiency of heating system (η_{ik}

Building Class i (year n+1)
> changed building envelope (be)

- conditioned area ($A_{i,be}$)
- specific heat demand (SHD_{ibe})
- energy efficiency of heating system ($\eta_{k,,after}$)

Building Class i (year n+1)
> changed building envelope and heating system (behs)

- conditioned area (A_{ibehs})
- specific heat demand (SHD_{ibehs})
- energy efficiency of heating system ($\eta_{k,,after}$)

Building Class i (year n+1)
> changed heating system (hs)

- conditioned area ($A_{i,hs} = A_i$)
- specific heat demand ($SHD_{i,hs} = sHD_i$)
- energy efficiency of heating system ($\eta_{ik,after}$)

Building Class i (year n+1)
> single measures (sm)

- conditioned area (A_{ism})
- specific heat demand (SHD_{ism})
- energy efficiency of heating system ($\eta_{ik,before} = \eta_{k,after}$)

Building Class i (year n+1)
> no measures (nm)

- conditioned area (A_{inm})
- specific heat demand ($SHD_{inm} = sHD_i$)
- energy efficiency of heating system ($\eta_{ik,before} = \eta_{k,after}$)

Rates or Numbers

- rate/numbers of demolition
- rate/number of new buildings
- rate/number of refurbishment (building envelope)
- rate/number of refurbishment (building envelope and heating system)
- rate/number of refurbishment (heating system)
- rate/number of refurbishment (single measure)

Calculation of FED of building age class i in year n

The Final Energy Demand of a given building class i, building type m at a given time n (for a given type of action j) can be defined as:

$$FED_{i,m,j,n} = \frac{A_{i,m,j,n} * SHD_{i,m,j,n}}{\eta_k} \quad (1)$$

$$\eta_k = \frac{HD_{i,m,j,n}}{FED_{i,m,j,n}} = \frac{SHD_{i,m,j,n}}{UFED_{i,m,j,n}} \quad (2)$$

Calculation of FED in year n

$$FED_n = \sum_j \sum_i \sum_m FED_{i,j,m,n} \quad (3)$$

In a first step, FED_n is calculated only by a bottom-up approach (building stock model). However, there will be a difference to top-down data that is the main indication for the calibration of the model. For sure, there are several ways to calibrate the model but for simplicity reasons we assume the top-down figure to be more valid than the model data and it is suggested here to use a simple correction factor for FED_n:

Calibration of the model

FED_n (top-down) = FED_n (building stock model) * cf (4)

cf = FED_n (top down) / FED_n (building stock model) (5)

If there is empirical evidence or other good reason (data availability, research studies, surveys, expert judgement), it is also possible to adjust $SHD_{i,m,j,t}$ or η_k or even to go on without any correction (e.g. in the case of known errors in energy statistics). This has to be justified in detail!

Calculation of rates

The building stock model highly depends on a correct calculation of rates. It is therefore important to use a correct calculation:

rate in year n: $r_{i,j,m,n} = A_{i,j,m,n} / A_n$ (6)

If data are not collected annually (e.g. every 5 or 10 years = Δt), the rate for class i is calculatd as following:

$r_{i,j,m,n} = ((1+\sum A_{i,j,m,t} / A_n)^{1/\Delta t} - 1)$ (recommended) (7)

(For the frequently used formula $r_{i,j,m,n} = ((\sum A_{i,j,m,t} / A_n) / \Delta t)$ is the error not negligible:

for r = 0,01 (1%) the error is 5%, for r = 0,03 (3%) the error is 12%.)

If data for conditioned area are not available, it is also possible and quite common to calculate rates on the basis of the number of flats or the number of buildings. If so, this has to be considered in the further calculations.

As mentioned before, building classes are defined as homogeneous in terms of energy performance. Hence, in the model suggested here, the fraction of class i without any measures has to be unchanged in terms of SHD and η for the whole period. I.e. the implementation of EEI measures/actions generates new building classes.

Baseline for year t

Two approaches can be applied for the calculation of the baseline:

(1) continuation (linear regression) of the FED trend of year n (on the basis of previous 5 or 10 years) minus FED of new buildings (FED_{nb}) with

$FED_{nb,t} = A_n * ((1 + r_{nb,n})^{\Delta t} - 1) * SHD_{nb,n}$ (8)

$\Delta t = t - n$ (9)

(2) a “bottom up” calculation:

$$FED_{i,m,baseline,t} = FED_{i,m,nm,baseline,t} + FED_{i,m,sm,baseline,t} + FED_{i,m,hs,baseline,t} + FED_{i,m,behs,baseline,t} + FED_{i,m,be,baseline,t} - FED_{i,m,de,baseline,t} \quad (10)$$

$$FED_{baseline,n} = \sum_j \sum_i \sum_m FED_{i,j,m,n,baseline} \quad (11)$$

FED of the building stock of year t with additional instruments (action)

$$FED_{i,m,action,t} = FED_{i,m,nm,action,t} + FED_{i,m,sm,action,t} + FED_{i,m,hs,action,t} + FED_{i,m,behs,action,t} + FED_{i,m,be,action,t} - FED_{i,m,de,action,t}$$

(12)

$$FED_{action,n} = \sum_j \sum_i \sum_m FED_{i,j,m,n,action} \quad (13)$$

Calculation of energy savings (ES, including savings from the change of the heating system) of year t

$$TGFES_t = FED_{baseline,t} - FED_{action,t} \quad (14)$$

Separation of effects of replacement of the heating system

This point will be descussed below in detail.

Data needs and sources

The method defined here relies on several data sources:

Variable	Symbol	Data sources	Reporting period
conditioned area	A	building statistics, reports from building administration (granted subsidies, building permitions), surveys, studies	annually, 5a, 10a, on demand
heat demand, specific heat demand (building, building age class)	HD, SHD[12]	sample of energy certificates, energy certificates database, studies, surveys, expert judgment	continuously, samples: on demand
final energy demand, specific energy demand (building, building age class)	FED, UFED	sample of energy certificates, energy certificates database, studies, surveys, expert judgement	continuously, samples: on demand
efficiency of the heating system (annualized)	η	energy certificates, energy certificates database, studies, surveys, expert judgement	continuously, samples: on demand
final energy demand/use (top down)	FED	energy statistics, surveys, studies	Annually
number of buildings with implemented EEI measure/action	J	building statistics, reports from building administration (granted subsidies, building permits), surveys, studies	Annually, 5a, 10a, on demand

[12] An overview on the relationship of various standards and the energy performance of buildings directive (EPBD) has been published recently (CEN 2007).