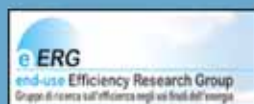


Evaluation and Monitoring for the EU Directive on Energy End-Use Efficiency and Energy Services

EMEEES bottom-up case application 8: Non residential space heating improvement in case of heating distribution by a water loop (tertiary sector)

Andrew Pindar, Nicola Labanca, Daniele Palma

30-04-2009



evaluate
energy savings^{EU}

coordinated by



Wuppertal Institute
for Climate, Environment
and Energy

supported by

Intelligent Energy  Europe

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

Contact

Dr. Stefan Thomas, Dr. Ralf Schüle
 Wuppertal Institute
 for Climate, Environment and Energy
 Döppersberg 19
 42103 Wuppertal, Germany

Tel.: +49 (0)202-2492-110
 Fax.: +49 (0)202-2492-250
 Email: info@evaluate-energy-savings.eu
 URL: www.evaluate-energy-savings.eu
www.wupperinst.org

The sole responsibility for the content of this publication lies with the authors. It does not necessarily reflect the opinion of the European Communities. The European Commission is not responsible for any use that may be made of the information contained therein.

EMEEES bottom-up case application 8: Non residential space heating improvement in case of heating distribution by a water loop (tertiary sector)

Andrew Pindar, Nicola Labanca, Daniele Palma

Contents

1 Summary	5
1.1 Title of the method	7
1.2 Type of EEI activities covered	7
1.3 Detailed definition of EEI activities covered	7
1.4 .General specifications	9
1.4.1 Scope for end use (EEI) Actions.....	9
1.5 Formula for unitary gross annual energy savings	10
1.6 Indicative Level 1 default value for annual unitary energy savings	11
1.6.1 Efficient Heat generators: Installation of condensing boilers	11
1.6.2 Emitters:.....	13
1.6.3 Distribution systems:	14
1.7 Formula for total ESD annual energy savings	15
1.8 Indicative default value for energy savings lifetime	16
1.9 Main data to collect	16
Level 2 and Level 3 evaluation efforts.....	17
2 Introduction	19
2.1 Twenty bottom-up case applications of methods	19
2.2 Three levels of harmonisation	20
2.3 Four steps in the calculation process	21
2.4 Pilot tests	22
3 Step 1: Unitary gross annual energy savings	24
3.1 Step 1.1: General formula and calculation model	24
3.2 Step 1.2: Baseline and reference energy savings	29
3.2.1 Data Sources.....	30
3.2.2 Heat generators	31
3.2.2.1 Replacing conventional boilers with efficient systems: Level 1 Data.....	32
3.2.2.2 Replacing standard boilers with Heat Pumps: Level 2 and 3 Requirements	37
3.2.3 Heat Emitters and controls	39
3.2.3.1 Stock Inefficient Baseline ($\eta_{e,st}$).....	40
3.2.3.2 Market Inefficient Baseline ($\eta_{e,st}$)	41
3.2.3.3 Market Efficient ($\eta_{e,eff}$).....	41
3.2.3.4 Level 1 Data Summary.....	42
3.2.4 Heat Distribution system.....	42
3.2.4.1 Boundaries between distribution and generation sub-system	42
3.2.4.2 Efficiency of heating distribution systems and baselines.....	43
3.2.4.3 Level 1 Data Summary.....	45
3.3 Step 1.3: Normalisation factors	45
3.4 Step 1.4: Calculation method and its three related levels	46
3.4.1 Default values and levels of effort.....	46

3.4.1.1 Default values for energy consumption and related parameters (level 1)	46
3.4.2 Definition of level 2 and level 3 values	46
3.4.3 Direct rebound effect.....	47
4 Step 2: Total gross annual energy savings.....	48
4.1 Step 2.1: Formula for summing up the number of actions	48
4.2 Step 2.2: Requirements and methods for accounting for the number of actions	48
5 Step 3: Total ESD annual energy savings.....	49
5.1 Step 3.1: Formula for ESD energy savings.....	49
5.2 Step 3.2: Avoiding double counting.....	49
5.3 Step 3.3: Technical interactions	50
5.4 Step 3.4: Multiplier energy savings	50
5.5 Step 3.5: Free Rider effect	51
5.5.1 Heat generators: Replacing standard boilers with condensing boilers: Free Riders	52
5.5.2 Emitter systems: Free Riders.....	52
5.5.3 Levels of effort 2 and 3	52
6 Step 4: total ESD energy savings for year “i” (2010 and 2016).....	53
6.1 Step 4.1: Energy saving lifetimes and early energy savings	53
6.2 Timing and Lifetime of End-Use actions	54
6.2.1 Measure Retention	54
6.2.2 Performance Degradation	54
6.2.3 Effective Useful Life (EUL)	55
6.2.4 Skills Required to Conduct Retention, EUL, and Technical Degradation Evaluations	56
6.3 Uncertainties	56
Appendix I: Justifications and sources	58

1 Summary

The present document has been prepared by eERG to provide a method for calculation of the energy savings obtainable by installing efficient models of heating systems, considering the heating system as a whole or also only specific subsystems (generator, emitters,...).

In this summary the main results of the method are reported, summarizing the factors and the default values which can be assumed in order to estimate the energy savings.

In particular, the reference values of efficiency of the heating subsystems will be provided, at a level 1 of detail (EU-wide). While as regards the heating load, the default EU-wide value of 117 kWh/(m² year) is reported, but for a more accurate evaluation we suggest considering the country specific values reported in Table 7.

The value of 117 kWh/(m² year) represents only a weighted average among the EU countries, but obviously it may be very far from the different specific values of many countries. This is why the modification in Table 7 is proposed.

Where possible, reference is made to European or International Standards, or product standards.

Heating systems differ among the member countries due to climate, traditions and national regulations. In cases where the standards contradict with national regulations, the latter should be followed.

Scope

This method constitutes the general approach to estimate the energy savings obtainable by improving the efficiency of heating systems in the tertiary sector.

The calculation method may be used for the following main applications:

- **new installation:** in phase of new construction, installation of an equipment more efficient than the standard one (market baseline);
- **programmed substitution:** replacement of an equipment at the end of its lifetime with a new system more efficient than the standard one (market baseline if the objective is to calculate additional energy savings, or stock baseline for all energy savings);
- **anticipated retrofit:** forced replacement of an equipment before the end of its lifetime with a new system more efficient than the standard one (stock baseline until the end of the lifetime of the replaced equipment);

Therefore, in the document the correspondent baselines (stock and market) to consider in the different cases will be reported.

Moreover, the requirements to fulfil in order to consider an equipment as efficient will be provided.

The method here developed standardises the required inputs and outputs in order to achieve a common European calculation method.

It allows the energy analysis of the different heating subsystems (emission, distribution, generation, each including its controls) by comparing the system losses and by defining system performance factors.

This performance analysis permits the comparison between subsystems and make possible to monitor the impact of each subsystem on the energy performance of a building.

The detailed calculation of the system losses of each part of the heating subsystems is defined in other EU standards (prEN 15316 parts 2 to parts 4). The thermal system losses, the recoverable losses and the auxiliary consumption of the heating subsystems are here summed up. The heating system losses contribute to the overall energy use in buildings (prEN 15315).

Note: Ventilation systems (e.g. air systems with heat recovery) and air heating system are not included in this method.

How to apply the method

In section 1.5 and chapter 3, the general formula to estimate the unitary gross annual energy savings is reported (equation 1).

The data required to apply the formula (1) can be obtained in the next section (1.6 and 3.2), where baselines and reference energy savings are reported.

In chapter 5 the way to estimate the total ESD annual energy savings is explained. In particular, the free-rider effect is to be considered with attention (chapter 6).

In the present summary, some examples of application of the method are synthetically reported, but obviously the possible cases are much more, therefore these ones represent only a guide line on how to carry on the estimation. In other words, we recommend to apply the equation (1) as fundamental tool to estimate the energy savings correspondent to a generic end-use (EEI) action, but the correspondent values of the parameters to use strictly depend on the specific case (e.g. boiler substitution, heat pump installation, control system improvement, etc.).

1.1 Title of the method

Tertiary space heating improvement in case of heating distribution by a water loop

1.2 Type of EEI activities covered

End-use (EEI) action	
Sector	Tertiary
Energy end-use	Heating
Efficient solution	Use of efficient heat generators, emitters, distribution systems and control strategies
(EEI) Facilitating measure	
Types of EEI facilitating measures	<ul style="list-style-type: none"> ✓ Improvement of heating system efficiency by: <ul style="list-style-type: none"> ● Information and legislative-informative measures → Energy labelling schemes (see Directive 92/42/CE Classification) ● Financial instruments → Subsidies (Grants), energy efficiency public procurement, Bulk Purchasing ● Energy services for energy savings → Guarantee of energy savings contracts ● EEI mechanisms → Public service obligation for energy companies on energy savings including “White certificates”

1.3 Detailed definition of EEI activities covered

The most broadly accepted definitions for heating tasks and performance criteria can be found in the study “Eco-design of Boilers and Combi-boilers”, and also other regulations/standards (e.g. UNI, prEN norms) better defined in the following.

A heating system can be assumed as constituted by the following subsystems:

- 1) **Heat generator**: core of the heating system (e.g. boiler, heat pump).
- 2) **Emission and control**: the emitter system is defined as the agglomerate of heat emitting devices that is used for the purpose of obtaining and maintaining a comfortable temperature in a room or building, either by radiation, convection or a combination of both.

The heat emitters play a significant part. In particular, radiant panels are very effective in reducing energy consumption and increasing indoor comfort. However, the more commonly adopted in tertiary sectors are fan-coils, together with radiators.

Control strategies: room temperature controls systems are defined as the aggregate of sensors, actuators and software algorithms on the basis of which a certain room temperature is achieved. They control the on- and off switching of the boiler and often also the boiler feed temperature for the purpose of achieving a predefined temperature

in a heated room.

3) **Distribution**: the “distribution system” is defined as the agglomerate of pipe work, fittings, valves, applied insulation, etc. that is necessary to distribute the thermal energy to the heat emitters. Also distribution system efficiency may be influenced by control strategies, as indicated in prEN 15316-2-3.

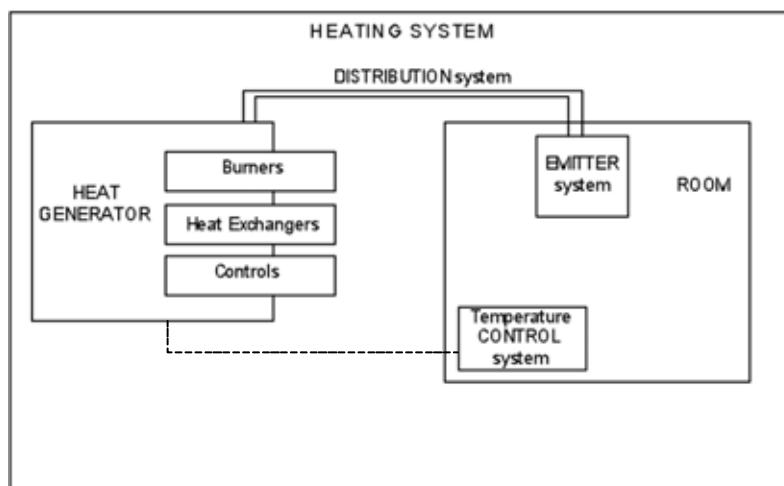


Figure 1 – Heating system scheme

Note: the Energy Performance of Buildings Directive (EPBD) standards integrate the control strategies in the subsystems. Therefore, in the following, emitters and control strategies will be treated as a whole subsystem.

In some cases one part of a heating system can be made energy efficient without requiring changes to other components. For example: replacement of boilers.

In other cases modifications to improve energy efficiency of a component can be much more effective if coupled with modification of other components. The secondary modifications may themselves lead to energy savings or may not.

For example:

it may prove cost effective to install thermostatic valves when replacing a standard boiler with an efficient one if there are radiators as heat emitters. However, it is recommended to check carefully the hydraulic distribution network operating system, because thermostatic valves may introduce sensitive disturbs if not correctly installed (e.g. noises, overheating).

In general an integrated approach to the heating system is suggested in order to actually improve its energy performances.

Finally, another important concept to underscore is that replacing a conventional heat generator, operated at constant temperature, with an efficient (condensing) one working at lower temperatures, modulated with a sliding mode of operation, is likely to improve also

the efficiencies of “emitters“ and “distribution“ subsystems with respect to the standard case. This virtuous cascade effect will be taken into account in the examples of this paper, and generally it has to be considered in the EEI actions regarding heating systems by referring to the standard EN 15316-2-1

1.4 .General specifications

Conditions for energy savings to be eligible (minimum level of energy performance): CE marking.

The new equipment must present the CE marking in order to make eligible the consequent energy savings.

Council Directive 92/42/EEC of 21 May 1992 on efficiency requirements for new hot-water boilers fired with liquid or gaseous fuels

Article 7

*1. Member States shall deem that boilers which comply with the harmonized standards, the reference numbers of which have been published in the Official Journal of the European Communities and for which the Member States have published the reference numbers of the national standards transposing those harmonized standards, to be in conformity with the essential efficiency requirements stipulated in Article 5 (1). Such boilers must bear the **CE mark** referred to in Annex 1, section 1, and be accompanied by the EC declaration of conformity.*

Other Regulations and Standards to be considered are:

- Heat generators
 - EPBD – Energy Performance of Buildings Directive (2002/91/EC)
 - Boiler Efficiency Directive (92/42/EC)
 - GAD – Gas Appliance Directive (90/396/EEG + 93/68/EC)
 - Construction Products Directive (89/106/EEC)
 - PED – Pressure Equipment Directive (97/23/EEC)
 - LVD – Low Voltage Directive (73/23/EEC + 93/68/EC)
 - EMC-D – Electromagnetic Compatibility (92/31/EC + 93/68/EC + 2004/108/EC)
 - MD – Machinery Directive (98/37/EC + 98/79/EC + 89/392/EEC + 91/368EEC + 93/44/EEC + 93/68/EEC)
 - Packaging Directive (2004/12/EEC)

1.4.1 Scope for end use (EEI) Actions

With the term replacement we also mean the installation of more efficient equipment in the

place of the standard one that would have been installed in the absence of the end use Action. In general, as already mentioned, there are mainly three possible kinds of intervention:

- **programmed substitution:** replacement of an equipment at the end of its lifetime with a new system more efficient than the standard one (market baseline if the objective is to calculate additional energy savings, or stock baseline for all energy savings);
- **anticipated retrofit:** forced replacement of an equipment before the end of its lifetime with a new system more efficient than the standard one (stock baseline until the end of the lifetime of the replaced equipment; thereafter, market baseline if the objective is to calculate additional energy savings, or stock baseline for all energy savings);
- **new installation:** in phase of new construction, installation of an equipment more efficient than the standard one (market baseline).

With the term standard system we intend an equipment characterized by average efficiency, referring to the stock or to the market situation (see step 1.2 for further details).

1.5 Formula for unitary gross annual energy savings

For this method, the unit used in the formula for unitary gross annual energy savings is one m² of building floor area.

Annual energy savings (kWh/year/unit) are determined by using the following engineering estimate formula.

$$\Delta E = \left(\frac{1}{\eta_{p,st} \cdot \eta_{e,st} \cdot \eta_{d,st}} - \frac{1}{\eta_{p,eff} \cdot \eta_{e,eff} \cdot \eta_{d,eff}} \right) \cdot E \cdot S \quad [\text{kWh/year}] \quad (1)$$

- ΔE = Total gross final energy savings from the EEI Action
- E: useful heat demand for the specific tertiary building and climatic zone (kWh/m²/year): average for level 1 or 2 calculations, building-specific for level 3 calculations
- S: Heated surface area interested by Action (m²)
- $\eta_{p,eff}$: efficiency of the efficient heat generator
- $\eta_{e,eff}$: efficiency of the efficient emission system
- $\eta_{d,eff}$: efficiency of the efficient distribution system
- $\eta_{p,st}$: efficiency of the standard heat generator
- $\eta_{e,st}$: efficiency of the standard emission system
- $\eta_{d,st}$: efficiency of the standard distribution system
- $\eta_g = \eta_p \cdot \eta_e \cdot \eta_c \cdot \eta_d$: global efficiency of the heating system

1.6 Indicative Level 1 default value for annual unitary energy savings

As already noted, single actions can be implemented alone or in combination as part of a comprehensive end-use Action. Here energy savings that may be associated to:

- improvements of heat generators, emitters and control apparatus, and distribution system, when undertaken as stand alone single actions
- integrated improvement actions for the whole heating system

are estimated.

In the table 1 below and in the tables reported in the paragraphs from 1.6.1 to 1.6.3, the reference values to be used for the level 1 evaluation effort in case of some typical EEI actions are indicated. In paragraphs 3.2, 3.2.3, 3.3 and 3.4 it is explained how these values have been estimated.

Each of the following examples has been calculated both with the stock baselines for all energy savings, and with the market inefficient baselines for additional energy savings.

Level 2 or 3 is required for all buildings over 1000 m² (EPB Directive).

Table 1 - Level 1 default efficiency values for the heating systems

System	Stock Baseline (%)	Market inefficient Baseline (%)	Minimum efficiency for efficient solutions (%)
Heat generation	82,0	89,0	94,0
Emission	78,0	83,0	93,0
Distribution	93,0	-	97,0

1.6.1 Efficient Heat generators: Installation of condensing boilers

This example concerns Level 1 estimated energy savings generated by replacing standard boilers with condensing boilers. The rest of the heating system remains unchanged.

According to the general rules proposed by the EMEEES project, a safety factor of 0.8 is always applied, even in case of reliable EU average values calculated from literature and statistical data, to take possible uncertainties into account. This holds for all level 1 data on unitary gross annual energy savings given hereunder.

Table 2 - Level 1 default values for annual unitary energy savings provided by substituting a standard boiler with an efficient one (condensing boiler)

	Variables in relation to Equation (1)	Level 1 Data	
Baseline			
Average efficiency of the standard boiler – stock baseline :	$\eta_{p,st}$	82,0	%
Average efficiency of the standard boiler – market inefficient baseline :	$\eta_{p,st}$	89,0	%
Average efficiency of the standard emitter and controls system:			
- with stock baseline boiler	$\eta_{p,st}$	78,0	%
- with market inefficient baseline boiler		84,0	%
Average efficiency of the standard distribution system:	$\eta_{p,st}$	93,0	%
Efficient Models			
Average efficiency of the efficient condensing boiler	$\eta_{p,eff}$	94,0	%
Average efficiency of the standard emitter system:	$\eta_{p,st}$	84,0	%
Average efficiency of the standard distribution system:	$\eta_{p,st}$	94,1	%
Thermal demand	E	117*	kWh/m ² /y
Heated surface	S	1	m ²
Annual unitary energy savings ΔE condensing boiler vs. stock baseline condensing boiler vs. market inefficient baseline	equation (1)	39,2* 12,8*	kWh/m²/year
Safety factor	-	0,8	
Energy Savings: condensing boiler vs. stock baseline condensing boiler vs. market inefficient baseline	ΔE (all) ΔE (additional)	31,4* 10,3*	kWh/m²/year

* value **must be corrected with national correction factor** as given in tables 6 or 7. Stock baselines used for calculating all energy savings. Market inefficient baselines for calculating additional energy savings.
Note: the other efficiency values considered are indicated in Table 1.

As it can be noted, the efficiency values of emission and distribution systems improve because of the operating temperature reduction. Actually, the installation of a condensing boiler is likely to cause a slightly greater improvement in the efficiency of emission and distribution systems with respect to a non-condensing boiler, but this difference has been neglected to simplify.

1.6.2 Emitters:

Level 1 estimated energy savings generated by replacing conventional emitters with efficient emitters.

To be realistic, it has been assumed that the generator efficiency is improved in conjunction with emitters replacement. In fact, simple emitters replacement may be quite unlikely because achievable energy savings are not as high as those obtainable with a more integrated approach (i.e. heat generator+emitters improvement). As a side effect, this solution may lead to a distribution system efficiency improvement, because of a general reduction in supply/return temperature. This effect may be evaluated at a level of effort 2 or 3 , but it has been considered in the estimate below as well.

Table 3 - Level 1 default values for annual unitary energy savings related to the use of efficient emitters in the place of the conventional ones

	Variables in relation to Equation (1)	Level 1 Data	
Baseline			
Average efficiency of the standard boiler – stock baseline:	$\eta_{p,st}$	82,0	%
Average efficiency of the standard boiler – market inefficient baseline:	$\eta_{p,st}$	89,0	%
Average efficiency of the standard emitter system:	$\eta_{p,st}$	78,0	%
Average efficiency of the standard distribution system:	$\eta_{p,st}$	93,0	%
Efficient Systems			
Average efficiency of the efficient boiler:	$\eta_{p,eff}$	94,0	%
Average efficiency of the efficient emitter system:	$\eta_{p,st}$	93,0	%
Average efficiency of the standard distribution system:	$\eta_{p,st}$	94,1	%

Thermal demand	E	117*	kWh/m ² /y
Heated surface	S	1	m ²
ΔE vs. stock baseline vs. market inefficient baseline	equation (1)	54,5* 28,1*	kWh/m²/year
Safety factor	-	0,8	
Energy Savings: vs. stock baseline vs. market inefficient baseline	ΔE (all) ΔE (additional)	43,4* 22,5*	kWh/m²/year

* value **must be corrected with national correction factor** as given in tables 6 or 7.
Stock baselines used for calculating all energy savings. Market inefficient baselines for calculating additional energy savings.

Just to have an idea of the reciprocal interaction between generator and emitter efficiency, it might be worth noticing that in case of condensing boilers the heat generator efficiency improves by 2÷2,5% for a 10°C decrease in the return temperature. For example, emitter systems with an operating temperature of 35°C (radiant panels) instead of 85°C (radiators) would improve the generator efficiency by 10-12,5%.

It is hence recommended to carry on a Level 3 evaluation effort to better estimate the savings obtainable with the combined installation of condensing boilers and radiant panels. This more accurate and specific evaluation can be carried out by considering the prEN Standards listed in the Appendix I of this paper.

1.6.3 Distribution systems:

Level 1 estimated energy savings generated by replacing conventional distribution systems with efficient distribution systems. Again, it is assumed that the boiler will also be replaced by a condensing boiler.

Table 4 - Level 1 default values for determining annual energy savings provided by using efficient distribution systems.

	Variables in relation to Equation (1)	Level 1 Data	
Baseline			
Average efficiency of the standard boiler – stock baseline:	$\eta_{p,st}$	82,0	%
Average efficiency of the standard boiler – market	$\eta_{p,st}$	89,0	%

inefficient baseline:			
Average efficiency of the standard emitter system:	$\eta_{p,st}$	78,0	%
Average efficiency of the standard distribution system:	$\eta_{p,st}$	93,0	%
Efficient Systems			
Average efficiency of the efficient boiler:	$\eta_{p,eff}$	94,0	%
Average efficiency of the standard emitter system:	$\eta_{p,st}$	84,0	%
Average efficiency of the efficient distribution system:	$\eta_{p,st}$	97,0	%
Thermal demand	E	117*	kWh/m ² /y
Heated surface	S	1	m ²
ΔE vs. stock baseline vs. market inefficient baseline	equation (1)	43,9* 17,5*	kWh/m²/year
Safety factor	-	0,8	
Energy Savings: vs. stock baseline vs. market inefficient baseline	ΔE (all) ΔE (additional)	35,2* 14,0*	kWh/m²/year

* value **must be corrected with national correction factor** as given in tables 6 or 7. Stock baselines used for calculating all energy savings, market inefficient baselines for calculating additional energy savings.

Energy efficient distribution system installation has been assumed to happen in conjunction with the installation of an efficient heat generator and control system in the example addressed in table above.

1.7 Formula for total ESD annual energy savings

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

$$\text{total gross annual energy savings} = \text{unitary gross annual energy savings} * \text{area} * (1 - \text{double-counting coefficient}) * (1 - \text{free-rider fraction} + \text{multiplier effect})$$

(equation S2)

1.8 Indicative default value for energy savings lifetime

CWA 27 gives the following harmonised and default values for the lifetimes that we propose to consider for the present case application.

Category	End-use EEI action	EU Savings Lifetime values
Heat generator	Large boilers*	17 years (default value)
Heat generator	Heat pumps (commercial sector)	20 years (harmonised)
Control system	Heating control*	5 years (default value)**
Heating load	Heat recovery systems	17 years (harmonised)

* The CWA27 proposes this value for the residential sector. We propose to consider this default value also for the energy efficient boilers considered in the present case application.

** can be extended by repeated analysis of statistical samples, provided sample control system efficiency results to remain unchanged with time.

As far as emitters are concerned, lifetimes may vary significantly according to the technological solution installed. Indeed lifetimes may be over 20 years for traditional radiators, whereas 10 years should be considered for average lifetimes of fan coils and 15 years for radiant panel average lifetime.

The average lifetime of energy-efficient heat distribution systems sensibly depends on specific technological solutions considered as well. However, 15 years may be assumed as a rough estimate of the existing distribution system average lifetime.

In case energy savings generated by end-use actions addressing a combination of heating system components (e.g. heat generator + control system + emitters) have to be estimated the shortest lifetime among components' average lifetimes shall be considered as the end-use action lifetime at level 1.

1.9 Main data to collect

Level 1 : average tertiary building heated area addressed by the (EEI) facilitating measure being evaluated plus number of end-use (EEI) actions implemented (i.e. number of buildings addressed by the facilitating measure).

Level 2 : average tertiary sector heated area addressed by the facilitating measure possibly corrected for climatic effects, plus national estimates of efficiency factors used in equation 1 and number of end-use actions totally implemented.

For level 2, data to collect should take interactions with thermal insulation actions into

account in case the facilitating measure being evaluated includes these kind of actions.

Level 3 : area heated in each tertiary building addressed by the facilitating measure plus end-use action specific efficiency factors to be used in equation 1. Other end-use actions besides the heating action possibly implemented should be taken into account in order to estimate possible interaction effects (e.g. insulation of the same building which decreases the heating demand; distribution network improvements that increase the total gain).

For all the three levels: data on double-counting between facilitating measures, free-riders, rebound effect and multiplier effects should be collected in order to estimate “all” and additional energy savings

Concerning the counting of the number of end-use actions implemented, financial incentive schemes, eg., under White certificates, plans for renovation of building stock, application of article 6 of EPBD, etc. give all the necessary data. They just need to be monitored.

Level 2 and Level 3 evaluation efforts

In the present methodology energy savings are determined through engineering calculations which take account of

- the type and power of installed heat generator
- the type of installed emitters
- the control apparatus type
- the distribution system type

The Level 1 default values reported in Tables 3 to 5 were determined by considering conservative estimates for all the above typologies both in relation to the stock and the market average values used.

It has proven possible to define per unit Level 1 values for the following end-use actions

- replacement of standard heat generators with efficient generators
- replacement of standard emitters with efficient emitters
- improvement of distribution system

Estimate of energy savings achievable by the following end-use actions requires instead Level 3 data:

- use of air-source heat pumps (prEN 15316-4-2)
- use of CHP systems (prEN 15316-4-4)
- use of district heating (prEN 15316-4-5)
- use of biomass combustion systems (prEN 15316-4-7), cf. EMEES case

application 3

- use of thermal solar systems (prEN 15316-4-3)), cf. EMEEES case application 6.

Level 2 or 3 is required for all buildings over 1000 m² (EPB Directive)

Concerning heat pumps, it is necessary to achieve a level 2 or 3 evaluation effort to obtain more reliable estimations, level 3 especially for air-source heat pumps, whose performances highly depend on local climatic conditions.

The same calculation procedure used for the Level 1 evaluation effort and based on the Equation (1) in Chapter 3.1 may be used in principle to determine Country- (Level 2) or Measure- Specific (Level 3) energy savings.

This requires collecting more detailed data for the three action typologies above mentioned.

Potential data sources for the Level 2 and Level 3 evaluation efforts may be :

- End-use Metering campaigns
- Detailed building audits (which may or may not include energy metering)
- Existing studies and databases: Odyssee Database, Previous European (e.g. SAVE II 1999, Eurostat, VHK Study) and MS Studies (EEC in UK, White Certificates in France and Italy), case studies (e.g. GreenBuilding)
- Manufacturer and product catalogues

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 8 “Non residential space heating improvement in case of heating distribution by a water loop” developed by eERG.

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:

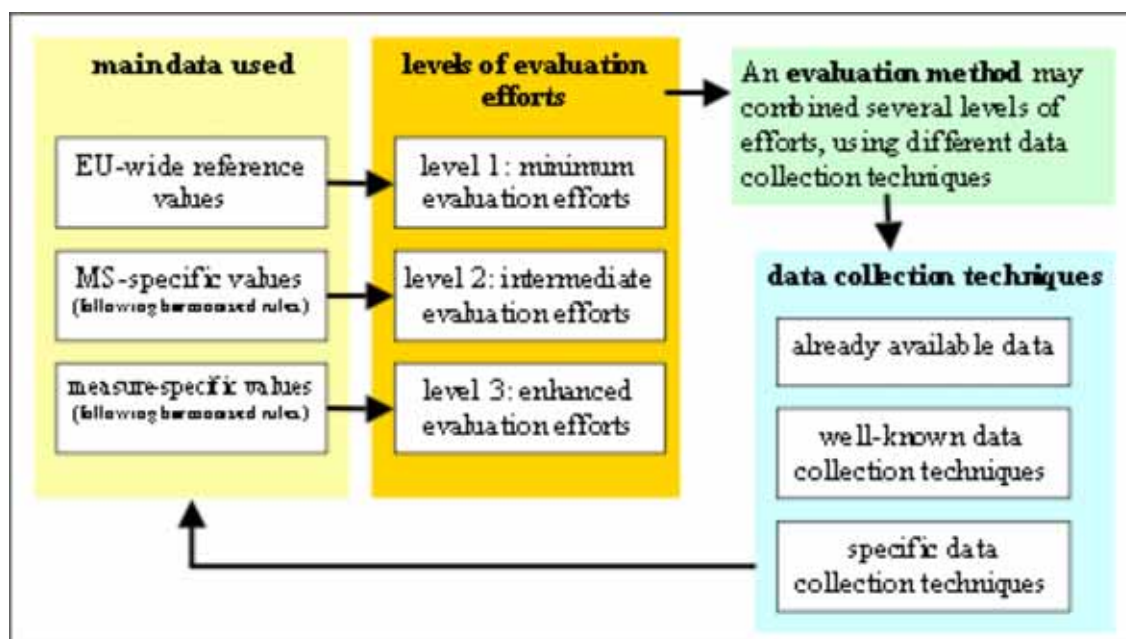
N°	End-use or end-use action, technology, or facilitating measure	Sector	Responsible organisation
1	Building regulations for new residential buildings	Residential	SenterNovem
2	Improvement of the building envelope of residential buildings	Residential	AEA
3	Biomass boilers	Residential	AGH-UST
4	Residential 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
11	Office equipment	Tertiary	Fraunhofer

N°	End-use or end-use action, technology, or facilitating measure	Sector	Responsible organisation
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



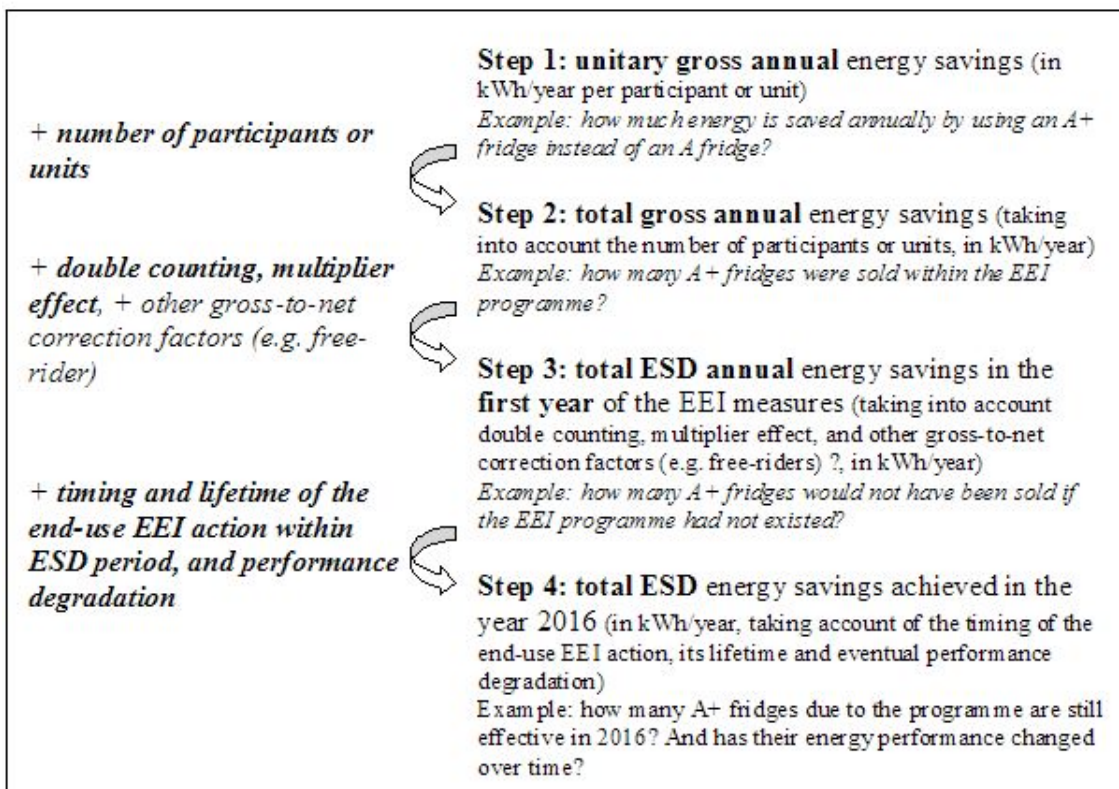
As a consequence, the EMEES case applications for bottom-up evaluation methods present:

- 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

Annual energy savings (kWh/year/unit) are determined by using the following engineering estimate.

$$\Delta E = \left(\frac{1}{\eta_{p,st} \cdot \eta_{e,st} \cdot \eta_{d,st}} - \frac{1}{\eta_{p,eff} \cdot \eta_{e,eff} \cdot \eta_{d,eff}} \right) \cdot E \cdot S \quad [\text{kWh/year}] \quad (1)$$

- ΔE = Total gross final energy savings from the EEI Action
- E: useful heat demand for the specific tertiary building and climatic zone (kWh/m²/year): average for level 1 or 2 calculations, building-specific for level 3 calculations
- S: Heated surface area interested by Action (m²)
- $\eta_{p,eff}$: efficiency of the efficient heat generator
- $\eta_{e,eff}$: efficiency of the efficient emission system
- $\eta_{d,eff}$: efficiency of the efficient distribution system
- $\eta_{p,st}$: efficiency of the standard heat generator
- $\eta_{e,st}$: efficiency of the standard emission system
- $\eta_{d,st}$: efficiency of the standard distribution system
- $\eta_g = \eta_p \cdot \eta_e \cdot \eta_c \cdot \eta_d$: global efficiency of the heating system

The following sections provide numerical estimates for a Level 1 evaluation effort by using data from existing studies or by making reasoned assumptions (where no specific data exists) for the general situation in Europe. Level 2 or 3 is required for all buildings over 1000 m² (EPB Directive) and for special types of heat generators (cf. chapter 1.9).

The equation (1) above may be used to achieve Level 2 and Level 3 evaluation efforts in estimating energy savings at the country or the single action level.

Note: for level 1 data, efficient and inefficient equipment performances are estimated by considering EU market and stock averages.

In case a Member State decides to incentive efficiency measures directed to improve the heating system as a whole, the energy savings achieved may be evaluated by estimating the individual efficiency values reported the equation (1) as indicated in the following paragraphs. However, since the improvement of a single system component (e.g. the heat generator) may lead to increase the efficiency of another system component (e.g. the distribution and/or the emission system), a more realistic approach should consider the reciprocal influence of such components, as made in some of the examples described in this report.

The following pages will illustrate how E and the efficiency parameters reported in the

formula above may be estimated.

Estimate of E: Thermal demand per unit surface (kWh/m²/year)

The databases consulted in order to acquire detailed information about the thermal demand in the tertiary sector are the followings:

- **SAVE II** Labelling & other measures for heating systems in dwellings, 1999. Contract no. 4.1031/Z/99-283. This review of standards describes the partner country's national standards which are applied to improve energy efficiency, governing design, installation & maintenance of heating systems in dwellings.
- **Odyssee** database (<http://www.odyssee-indicators.org>), provides specific data of thermal energy consumption in Europe.
- **Eurostat** "Energy Consumption in the Services Sector" project (data 1995-1999): the purpose of this project was to collect information on energy consumption in the services sector directly through surveys complemented by other studies. Energy statistics have been collected and analysed from the supply side. For this reason, information on energy consumption in the services sector is estimated indirectly, making this approach not precise. Moreover, the disaggregation of the energy consumption in services for the various branches of activity and the knowledge of the consumption in the different uses was rather poor in most Member States. Eurostat data were hence not considered for this study.
- **VHK** Preparatory Study on Eco-Design of Boilers (2007) (<http://www.ecoboiler.org>), provides specific data of thermal energy consumption in Europe, in the context of the Ecodesign of Energy-Using Products Directive 2005/32/EC. As such study reports data for the tertiary sector, this has been the data source used for most of the estimates made in this study.

The Odyssee database provides thermal energy consumption (toe/m²/year) for the commercial sector in six countries. The Commercial Sector (*Services*) is defined to include activities like hotel and restaurant, health, education, administration, trade, offices, though no distinction is made between these separate categories.

The Odyssee database provides also thermal energy demand (toe/dwelling) for the residential sector in fifteen countries.

More data are available for the residential sector than for the Commercial sector.

The 1999 SAVE II Study provides a detailed analysis of the heating systems for the residential sector, included average energy demand and efficiency of the existing stock. The study also includes a stock model which considers the possible development of heating systems for 15 countries in the period 2000-2020.

The question is how well do the figures for the residential sector match with those for the tertiary sector.

Building energy demand mainly depends on climate, building energy codes and usage patterns.

In most EU countries similar building codes are applied to both the tertiary and residential sectors so that buildings built in the same period will have similar thermal performance characteristics (for example insulation levels). In some cases buildings in the tertiary sector may have higher unit specific heating consumption ($\text{kWh}/\text{m}^2/\text{year}$) due to particular geometric features (e.g. height).

However on the other hand the operating hours in the tertiary sector are probably less than the residential sector, because of the limited occupancy time (typical 8 hour shift work, week-end, festivity). We assume that the operating hours in the tertiary sector are in the region of 20% lower than operating hours in the domestic sector.

Therefore, as a very rough approximation, we could say that the two effects (increased specific consumption vs. lower heating hours) cancel each other, and roughly specific heat demand for the two sectors is the same.

Therefore, the two sectors (residential and tertiary), with the exception of specific cases, such as Hospitals, should have similar energy consumption for heating.

However, VHK Study (2006) provided some useful data regarding particularly the tertiary sector. Therefore most of the assumptions made will be based on these data, because of their specific reference to the tertiary sector.

Assessment of the number of tertiary boilers is extremely difficult. For instance, about 8% (0,5 mln.) of “residential” boiler sales may actually be sales to the tertiary sector. The tertiary sector is highly heterogeneous and it is almost impossible to make an assessment at the point-of-sales whether a customer is residential or tertiary. So for sure we can assume that a fraction of the residential sales data may be “contaminated” with tertiary sales, e.g. to small offices, shops, bars, etc.. To make matters worse, many of these smaller enterprises are sharing the heating boiler, not only with each other (e.g. in an office building) but also with residential customers (e.g. shop or bar in the ground floor of an apartment building).

According to VHK Study, we can make a rough estimate that, excluding the boilers shared with the residential sector, the number of installed tertiary boilers in the EU-25 will amount to around 8 million units (included 1 mln. boilers in the industrial sector) with an average capacity of around 100 kW. The accuracy of these figures is believed to be no higher than $\pm 20\%$.

In conclusion, the situation for residential buildings is still relatively transparent compared to commercial and institutional buildings and buildings that have a mixed use, e.g. residential buildings with bars, restaurants and shops at the ground floor. On these items information is quite scarce.

Another problem is the definition of the sectors. There have been several attempts to capture the floor area in m^2 of the “services sector” or “the other sector” which all have failed for the same reason. Examples are the Odyssee indicators project and the Ecoheatcool project, which are each estimated to make errors of up to a factor of 2.

We have decided to refer to the very first attempt by VHK to calculate an average heat load from the available EU-wide data, with particular reference to the tertiary sector.

EU Tertiary sector Heat Load Assessment (VHK 2006)

VHK/Eurostat 2003	TERTIARY Sector
Country	Heating load
	kWh/m ² /y
EU-25	117

However, we assume this reference value also for buildings not larger than 1,000 m². For greater buildings it is necessary to obtain more detailed data (level 3), especially considering that the tertiary sector include a wide variety of building types and sizes (height > 4 m for example).

More weight has been given to the results of the VHK Study, because:

- it is well documented and provides data specific for tertiary sector;
- data provided seem to be more consistent.

It is basically because of these reasons that the value (kWh/m²/year) reported in the table above has been assumed as the reference value for the energy consumption in the tertiary sector.

However, this value needs to be **modified for each Member State**. This could be done **either by heating degree days or by the values for the annual useful heating energy demand per m² from the Ecoboiler study** (p.62 of ecoboiler task 3 final report; useful heating energy demand is termed “heat load” in that source). It needs to be discussed what is the better choice. Heating degree days reflect the climate and would thus reward countries who have already a better insulated building stock. The annual useful heating energy demand per m² will better reflect the actual situation of the building stock. Tables 6 and 7 are providing more information on the adaptation factors per MS that either choice would entail.

Table 6 factors to adapt the EU level default value for unitary gross annual energy savings to each EU Member State based on heating degree days

Member State	Heating degree days (Kelvin*day/year)	Adaptation Factor
MT	581	0.18
CY	704	0.22
PT	1364	0.43
EL	1596	0.50
ES	1926	0.60
IT	2031	0.63
FR	2469	0.77

IE	2682	0.84
NL	2716	0.85
BE	2734	0.85
HU	2951	0.92
SK	2953	0.92
UK	3100	0.97
LU	3107	0.97
SI	3119	0.97
DE	3162	0.99
DK	3254	1.01
CZ	3518	1.10
PL	3533	1.10
AT	3606	1.12
LT	4031	1.26
LV	4199	1.31
EE	4313	1.34
SE	5183	1.62
FI	5415	1.69
EU-25	3207	1

Basis: data for 2004 and 2005

Table 7 - National reference value for the parameter E (VHK 2006)

	Country	Tertiary Heat demand (E) [kWh/m ² year]
MT	Malta	42
CY	Cyprus	51
EL	Greece	55
SI	Slovenia	62
LU	Luxembourg	75
ES	Spain	91
DE	Germany	98
UK	United Kingdom	100
NL	Netherlands	102
PT	Portugal	109
IT	Italy	117
DK	Denmark	127
FR	France	128
PL	Poland	134
SK	Slovakia	139
BE	Belgium	142
AT	Austria	144
HU	Hungary	154
CZ	Czech Republic	155
IE	Ireland	168
LV	Latvia	207
EE	Estonia	235
LT	Lithuania	239
FI	Finland	240
SE	Sweden	289
EU-25	EU-25	117

3.2 Step 1.2: Baseline and reference energy savings

We will use Equation (1) together with existing studies and reasonable hypotheses to establish two baselines:

- stock baseline, to be used for calculating ‘all’ energy savings

- inefficient market baseline, to be used for calculating energy savings ‘additional’ to autonomous market progress

The present section determines Level 1 estimates for each of the two baselines for heat generators, emitters plus improved control strategies, and distribution systems, and for energy-efficient components or subsystems of these types.

In general, the three levels of harmonization could be achieved by following the correspondent indications reported in the next paragraphs. Here data needed and possible sources are suggested. Each MS could indeed decide to use own and possibly more detailed data for the heating systems in tertiary sector, with the purpose of claiming more energy savings.

The ESD definition of energy savings states the baseline is the situation before implementing an EEI measure. This "before" situation may be interpreted with the EMEEES terms either:

- as "before" annual energy consumption, i.e. energy consumption of the equipment or site in the year before the implementation of the EEI measure,
- or as "before" decision, i.e. whether implementing an end-use action would have occurred or not if the EEI measure had not existed.

The question is, therefore, which situation is prevailing in a specific (EEI) facilitating measure. A general guiding principle defined in the EMEEES project is that the answer depends on what would have happened in the absence of the EEI facilitating measure. In the specific case of the heating systems, we have assessed the stock situation and the market share of the equipments in EU and:

- use the **stock baseline** in the case of **anticipated replacement** (for calculating ‘additional’ energy savings in this case) or for calculating **‘all’** energy savings
- use the **inefficient market baseline** in the case of **programmed replacement** for calculating energy savings **‘additional’** to autonomous market progress

3.2.1 Data Sources

The following sections make much use of data reported in the following study:

- **VHK:** Preparatory Study on Eco-Design of Boilers (2007) (<http://www.ecoboiler.org>), providing specific data of thermal energy consumption in Europe, in the context of the Ecodesign of Energy-Using Products Directive 2005/32/EC.

It gives an overview of different product categorisation options as background information. The largest part of the report is dedicated to an overview of existing legislation and voluntary measures regarding boilers at the level of the EU, the Member States and Third Countries outside the EU.

3.2.2 Heat generators

The main heat generators categories that are used in the tertiary sector are:

- Wall hung boilers
- Floor standing boilers
- Oil-fired boilers

According to the VHK data the stock for the heat generators in tertiary sector can be estimated in 8 million of units. Table 5 reports the main characteristics of the heating systems installed in EU tertiary sector (2004), based on VHK data.

Table 5 - EU Tertiary sector characteristics of the Stock Heating systems (VHK 2006) – year 2004

Category	Stock Share* (%)	Avg. Power (kW)	Efficiency referred to NCV (%)	Efficient Stock Share** (%)	Inefficient Stock Share (%)	Efficiency referred to NCV (%)
Wall hung boilers	20,9	32	83,8	14	18,9	83,8
Floor standing boilers	29,9	106	83,8	6,3	29,4	83,8
Oil-fired boilers	49,2	274	79,9	-	51,7	79,9
EU-Weighted average	100	173	81,9		100	81,8

* Both efficient and inefficient systems are considered.

** This share represents the condensing boilers already installed in percentage with respect to the whole quota of the correspondent category (e.g. 14% of the wall hung boilers are condensing boilers).

In conclusion, the stock baseline is characterised by a weighted average efficiency value of **81,8 %** (referred to NCV), in 2004.

The Boiler Efficiency Directive 92/42/EC distinguishes three classes of boilers (condensing, low temperature, standard) with a minimum efficiency at a specified boiler water temperature and within each class there is a star rating for every 3% points that the efficiency is above this minimum. The star rating system was repealed by the Ecodesign Directive so it no longer formally exists.

Note that the efficiency values in 92/42/EC are given on the **Net Calorific Value (NCV)** and not on the Gross Calorific Value (GCV) as is typically required in building energy performance regulations.

The main potential end-use actions to heat generators here considered are:

- replacement of standard boilers with efficient boilers (condensing boilers)
- replacement of standard boilers with heat pumps

Data regarding the heat generators currently installed and sold throughout Europe were collected in the VHK Project.

According to this research, the European inefficient stock of the heat generators in 2004 had an average efficiency of 81,8 %, as showed in Table 6.

In the following the values to be considered for the years 2008 and 2009 will be provided.

3.2.2.1 Replacing conventional boilers with efficient systems: Level 1 Data

The following sections determine the default Level 1 values for $\eta_{p,st}$ and $\eta_{p,eff}$.

3.2.2.1.1 Stock Baseline ($\eta_{p,st}$)

Table 6 reports the stock average value of heat generator efficiency in EU according to the VHK Study.

Table 6 – Statistics regarding heating systems and corresponding efficiency values in EU 2004 (Source: VHK, 2007)

	Seasonal efficiency
Country	Stock (2004)
EU 25	81,8%

This represent the level 1 baseline efficiency value to be considered for the stock in 2004.

Baseline efficiency for 2008 and 2009 may be estimated by considering the share foreseen for the condensing boilers in 2020 and a turn-over rate of 6,7% (corresponding to an average lifetime of 15 years). Based on such assumptions condensing boiler market share results are reported in Table 10 below whereas inefficient stock share and efficiency are represented as in Table 11.

Table 7 – Estimated data from VHK data (tertiary heating systems)

	2008 Condensing Market Share (%)	2009 Condensing Market Share (%)
Wall hung boilers	26,6	27,3
Floor standing boilers	13,4	17,4
Oil-fired boilers	Neglected	neglected
EU-Weighted average	20,0	22,3

Note: condensing market share refers to the total EU market of boilers (i.e. it includes the residential sector). In lack of more accurate data the same trend has been assumed for the tertiary sector.

Table 8 – Estimated data from VHK data (non-residential heating systems)

	2008 Inefficient Stock Share (%)	Efficiency referred to NCV (%)	2009 Inefficient Stock Share (%)	Efficiency referred to NCV (%)
Wall hung boilers	19,7	83,8	19,3	83,8
Floor standing boilers	32,7	83,8	34,2	83,8
Oil-fired boilers	47,6	79,9	46,5	79,9
EU-Weighted average		82,0		82,0

The Level 1 **Stock Baseline** ($\eta_{p,st}$) is taken as the weighted average of the distribution reported in Table 8 , namely 82,0 % (2008-9)

The stock baseline is a weighted average over the EU countries and is calculated on the basis of the projection to 2008-09 of the value reported in Table 6.

Summarizing, the stock and market efficiency values for the period 2008-2009 have been calculated considering the gradual increase of the average efficiency due to the input of the new heating systems in the market, i.e. by weighting for each year the efficiency values of the stock heaters and of the new ones, supposing an exchange rate of 6,7%, corresponding to an average lifetime of 15 years for stock inefficient heaters. The variation of heat generators sales in tertiary sector is supposed to follow the trend of the residential sector.

Proposed baseline levels for stock (only in case of early replacement or when calculating ‘all’ energy savings, needs level 2 or 3 proof):

Level 2	Replaced heat generator based on participants’ control sample (national data).
Level 3	Replaced heat generator based on participants’ data (measure-specific).

3.2.2.1.2 Market Inefficient Baseline ($\eta_{p,st}$)

We consider current sales of energy-efficient heat generators in the context of Free Riders (See par. 5.3) and determine the Market Baseline by taking only inefficient heat generators into account.

A gradual increase in efficiency of the non-condensing boilers, due to new minimum

standards regulations together with technology improvement may be foreseen for 2008 and 2009.

Therefore the **Level 1 Market Inefficient Baseline** ($\eta_{p,st}$) is estimated of **89,0 %** (2008-9)

Three baseline levels proposed for market (normal (re)investment situation to calculate 'additional' energy savings: heat generator would have been replaced or installed in new building anyway):

Level 1	Default standard heat generator: market inefficient baseline value as above calculated
Level 2	Standard heat generator based on national sales data: every MS should prove that its market situation differs from the average showed above
Level 3	A single participant may require a different baseline level by proving that in his specific case the market condition differs meaningfully from that here considered

3.2.2.1.3 Market Efficient Models ($\eta_{p,eff}$)

This section needs further development and we could ultimately arrive at an average market efficiency for new heating systems. For the time being we limit ourselves to listing the seasonal efficiencies of some of the possible efficient systems which may be installed in the tertiary sector.

Indeed it does not seem neither feasible nor reliable to attempt estimating a unique value for efficient heat generators that should be used for any efficient heating technology considered by a given (EEI) facilitating measure or end-use action.

As regards the efficient systems to be considered, we suggest the heating generator systems listed below together with the correspondent efficiency values. It should be pointed out that the efficiency of a generator is influenced by the efficiency of other systems, first of all the emitters. For example, condensing boilers can be very effective if coupled with radiant panels, while traditional radiators limit the overall efficiency because of the high temperature required to operate. In the following table these and other considerations are mentioned.

Table 9 reports the typical efficiency of heat generators.

Table 9 – Characteristics of the efficient heat generators: Boilers

	Heating system	Generation seasonal Efficiency*
		E_1
	Efficient boiler	94%

* In terms of final energy, referred to NCV (Net Caloric Value)

Note: the value of 94%, minimum seasonal efficiency value to consider to evaluate the energy savings obtainable using efficient boilers, has been derived from the technical sheet provided by the AEEG (Electrical Energy and Gas Authority) under the Italian Tradable White Certificate system for the installation of 4-star (****) boilers in the residential sector. In such sheet the efficiency of **** boilers has been estimated of 94%. This value is also the minimum efficiency value achievable by a condensing boiler (at full load), according to table B.1 in prEN 15316-4-1.

We assume that only 4 star-boilers as defined by Dir. 92/42/EC can be considered efficient.

Clarification about the value to be assumed for the conversion factor for electricity

In case of Electric Heat Pumps installation, some assumptions about the “before” situation are needed to estimate the actual energy savings achieved. In fact, in case of anticipated or even programmed substitution, it is important to take into account the consequences of a possible fuel switching, as that involving the replacement of a gas-heater with an electric-grid driven equipment.

If the “before” situation includes that a reversible (electric driven) unit is used for heating in winter, or a direct electrical resistance heating, there will be certainly additional energy savings for the heating from the energy-efficient system.

If the “before” situation does not include that a reversible (electric driven) unit is used for heating in winter, but the new, energy-efficient system will be used for heating, the result will depend, among others, on the choices made by the MS about the conversion factor for electricity.

If the MS decides to use an electricity coefficient different from 1.0 (e.g. like the one in Annex 2 note 3 of the ESD), there may be a gain or a loss depending on the climate, the reference heating system, and the value chosen for the conversion factor for electricity

Note: we are implicitly assuming that electricity is not produced locally with a renewable source (e.g. PV system). In such a case, the actual primary energy consumption would be virtually equal to zero. It will be a MS decision how to consider these particular (but interesting) cases.

3.2.2.1.4 Level 1 Data Summary

Stock Baseline ($\eta_{p,st}$) = 82,0 %

Market Inefficient Baseline ($\eta_{p,st}$)= 89,0 %

Market Efficient Values for gas and oil boilers (2008-2016) ($\eta_{p,eff}$) = 94,0 %

3.2.2.1.5 Examples

We apply Equation (1) and the Stock and Market Baseline values reported in the previous section to determine energy savings resulting from programmes promoting penetration of efficient heat generators.

Programmes directed strictly to improving existing systems (anticipated replacement), or calculation of ‘all’ energy savings.

Standard System – Stock Baseline.

Efficient System – Market Efficient Value.

Table 10 - Average energy savings from the replacement of standard boilers with efficient (condensing) boilers

	Variables in relation to Equation (1)	Level 1 Data	
Stock Baseline			
Average efficiency of the standard boiler:	$\eta_{p,st}$	82,0	%
Average efficiency of the standard emitter system:	$\eta_{p,st}$	78,0	%
Average efficiency of the standard distribution system:	$\eta_{p,st}$	93,0	%
Efficient System			
Average efficiency of the efficient boiler: condensing boiler	$\eta_{p,eff}$	94,0	%
Average efficiency of the standard emitter system:	$\eta_{p,st}$	84,0	%
Average efficiency of the standard distribution system:	$\eta_{p,st}$	94,1	%
Thermal demand	E	117*	kWh/m ² /y
Heated surface	S	1	m ²
Annual unitary energy savings ΔE condensing boiler	equation (1)	39,2*	kWh/m²/year
Safety factor	-	0,8	
Energy Savings: condensing boiler	ΔE	31,4*	kWh/m²/year

* value **must be corrected with national correction factor** as given in tables 6 or 7.

Programmes directed strictly to improving market sales, when calculating ‘additional’ energy savings.

Standard System – Market Inefficient Baseline.

Efficient System – Market Efficient Value

Table 11 - Average energy savings from promoting the sale of efficient (condensing) boilers

	Variables in relation to Equation (1)	Level 1 Data	
Market Inefficient Baseline			
Average efficiency of the standard boiler:	$\eta_{p,st}$	89,0	%
Efficient System			
Average efficiency of the efficient boiler: condensing boiler	$\eta_{p,eff}$	94,0	%
Thermal demand	E	117*	kWh/m ² /y
Heated surface	S	1	m ²
Annual unitary energy savings ΔE condensing boiler	equation (1)	12,8*	kWh/m²/year
Safety factor	-	0,8	
Energy Savings: condensing boiler	ΔE	10,3*	kWh/m²/year

* value **must be corrected with national correction factor** as given in tables 6 or 7.

3.2.2.2 Replacing standard boilers with Heat Pumps: Level 2 and 3 Requirements

Country or EEI measure specific data for all variables in Equation (1) are needed in this case. Such data could be gathered through e.g. energy audits and energy metering campaigns.

This is especially true for air-source Heat Pumps, whose efficiency is strictly related to the outdoor climate. Therefore, the energy saving evaluation requires level 2 or 3 data.

In the following an example of level 2 evaluation for Heat Pump installation is reported in case of air-source Heat Pumps operating in a typical Mediterranean climate.

3.2.2.2.1 Programmes directed strictly to improving existing systems, or calculation of ‘all’ energy savings.

Standard System – Stock Inefficient Baseline.

Efficient System – Market Efficient Value.

This example has not been calculated.

3.2.2.2.2 Programmes directed strictly to improving market sales, when calculating ‘additional’ energy savings.

Standard System – Market Inefficient Baseline.

Efficient System – Market Efficient Value

Table 12 - Average energy savings from promoting the sale of Heat Pumps (e.g. Air-source Electric Heat Pump, with system designed for a flow temperature of 40°C) in a typical Mediterranean climate

	Variables in relation to Equation (1)	Level 1 Data	
Market Inefficient Baseline			
Average efficiency of the standard heater:	$\eta_{p,st}$	89,0	%
Average efficiency of the standard emitter system:	$\eta_{p,st}$	78,0	%
Average efficiency of the standard distribution system:	$\eta_{p,st}$	93,0	%
Market Efficient System			
Average efficiency of the Heat Pump:	$\eta_{p,eff}$	120,0**	%
Average efficiency of the standard emitter system:	$\eta_{p,st}$	84,0	%
Average efficiency of the standard distribution system:	$\eta_{p,st}$	94,1	%
Thermal demand	E	117*	kWh/m ² /y
Heated surface	S	1	m ²
ΔE	equation (1)	47,0*	kWh/m²/year
Safety factor	-	0,8	
Energy Savings:	ΔE	37,6*	kWh/m²/year

* value **must be corrected with national correction factor** as given in tables 6 or 7.

** Heat pump efficiency has been estimated by assuming a conversion factor from final electricity to the primary energy used of 2.5.

3.2.3 Heat Emitters and controls

The emitter system is defined as the agglomerate of heat emitting devices that is used for the purpose of obtaining and maintaining a comfortable temperature in a room or building, either by radiation, convection or a combination of both.

Types of hydronic heat emitters most commonly used are:

- Radiators
- Convectors
- Surface heating (floor-, ceiling and wall heating)

The way heat is transmitted into a room can influence the heat emission efficiency. There are three parameters that are generally linked to the efficiency of the emitter system:

- non-uniform temperature distribution
- space temperature control
- specific losses of the external components

The total efficiency level η_e is fundamentally determined by:

$$\eta_e = \frac{1}{4 - (\eta_{str} - \eta_{ctr} - \eta_{emb})}$$

where

η_{str} is the part efficiency level for a vertical air temperature profile;

η_{ctr} is the part efficiency level for room temperature control;

η_{emb} is the part efficiency level for specific losses of the external components (embedded systems).

We consider the most common emitter types found in the tertiary sector "and related variation in heat transmission", together with their seasonal efficiency as defined by the EN 15316-2-1 Standard and we make an hypothesis of their distribution in the tertiary sector. The percentage distribution refers to heated floor space.

The results are reported in the following. A possible distribution of the emitter systems has been assumed in order to weight the efficiency values of the various systems, leading to a final weighted average efficiency value both for stock and market (inefficient). The resulting value is proposed as representative of the 2008-2009 period.

If incentives are directed to improving the emitters of the heating systems, the energy savings can be estimated by calculating the reduction of annual consumption consequent to the increase of efficiency, by means of equation (1).

Actually, it can be noted that typical emitter values can vary in a wide range, as reported in the following table:

Emitters	η_e
Radiators:	0,74 ÷ 0,91
Fan-coils:	0,89 ÷ 0,93
Panel heaters:	0,68 ÷ 0,94

Therefore, here we indicate as minimum efficiency value an efficiency at least equal to 78%, considering the radiators, because they typically are operated with high temperature heating systems, while the other emitters (especially panel heaters, but also fan-coils) can operate at lower temperatures. Higher efficiency values can be obtained, for example, by integrating an emitter system retrofit with an improvement in the heat generation (e.g. by installing a condensing boiler/heat pump), and also with an improvement in control strategy, because of the consequent improvement in heat emission efficiency. In these cases, it may be appropriate to use the efficiency values indicated in the prEN 15316-2-1, providing efficiency values combining the effect related both to emission and control systems. This can be considered an innovative and more appropriate approach. The parameters and data required to carry out the procedure reported under prEN 15316-2-1 represent a level 3 of effort. In this paragraph we will only provide level 1 data to estimate the savings obtainable by improving emitter performances.

3.2.3.1 Stock Inefficient Baseline ($\eta_{e, st}$)

To determine the average efficiency of the installed stock it is necessary to establish the distribution of emitter types installed. Table 16 reports efficiencies of main emitter types installed.

Table 13 – Typical efficiency values of the emitter systems (prEN 15316-2-1)*

Emitter system	η_e (%) (prEN 15316-2-1)
Radiators	74 ÷ 91
Fan-coils	89 ÷ 93
Panel heaters	68 ÷ 94
Others (room spaces with heights from 4 m to 10 m)	70 ÷ 99
Others (room spaces with heights > 10 m)	62 ÷ 93

* efficiency values combine the effect related both to emission and control systems

Taking the distribution reported in the table above as a starting point we then make a best guess to arrive at a more detailed breakdown of stock inefficient baseline (Table 14).

Table 14 – Distribution of emitters efficiency classes based on prEN 15316-2-1, data integrated with eERG hypothesis of inefficient baseline.

Emitter system	η_e (%) (prEN 15316-2-1)	Relative Distribution for emitters type (ERG expert opinion)
Radiators (<i>worst case</i>)	74	70%
Radiators (<i>intermediate case</i>)	86	20%
Radiators (<i>best case</i>)	91	10%
Fan-coils	89 ÷ 93	0%
Panel heaters	68 ÷ 94	0%
Others (room spaces with heights from 4 m to 10 m)	70 ÷ 99	0%
Others (room spaces with heights > 10 m)	62 ÷ 93	0%
Weighted average -->	78%	100%

* efficiency values combine the effect related both to emission and control systems

3.2.3.2 Market Inefficient Baseline ($\eta_{e, st}$)

In lack of more accurate data, we assume that market inefficient baseline can be considered as the minimum efficiency value for fan-coils, typical emitter systems in tertiary sector. Therefore, the value to consider is 89%. Besides, the current limits of seasonal efficiency value of the heating system could very hardly meet with radiators (and then high operating temperature). Then we can assume that radiators are not being proposed any more in tertiary sector.

The Market Inefficient Baseline considers only sales of standard emitters.

Note: with the term “standard emitters” we mean the emitters commonly used in the tertiary sector, such as mainly fan-coils. The efficiency of the radiant panels may be lower than fan-coils, but they require lower operating temperature, and consequently less energy during the generation phase. Therefore, we consider them as efficient.

Summarizing, in this methodology we assume to consider as inefficient emitters only the fan-coils, with a low quality of control.

3.2.3.3 Market Efficient ($\eta_{e, eff}$)

We propose to consider only emitters characterised by an efficiency $\geq 93\%$ or by low operating temperature (radiant panels) as efficient emitters. We assume 93%, because this is the efficiency value for fan-coils with high quality of control.

3.2.3.4 Level 1 Data Summary

Stock Baseline ($\eta_{e,st.}$) = 78,0 %

Market Inefficient Baseline ($\eta_{e,st.}$) = 89,0 %

Market Efficient System (2008-2009) = 93,0 % (Level 1)

Minimum efficiency for efficient solutions ($\eta_{e,eff.}$) = 93 % or radiant panels

3.2.4 Heat Distribution system

The “distribution system” is defined as the agglomerate of pipe work, fittings, valves, applied insulation, etc. that is necessary to distribute the thermal energy to the heat emitters. The energy losses due to this heating system component are caused by:

- heat losses in the distribution system
- losses due to hydraulic power consumption (possibly due to pumps serving the distribution circuit)

In the following paragraph a clarification regarding the second type of loss is reported.

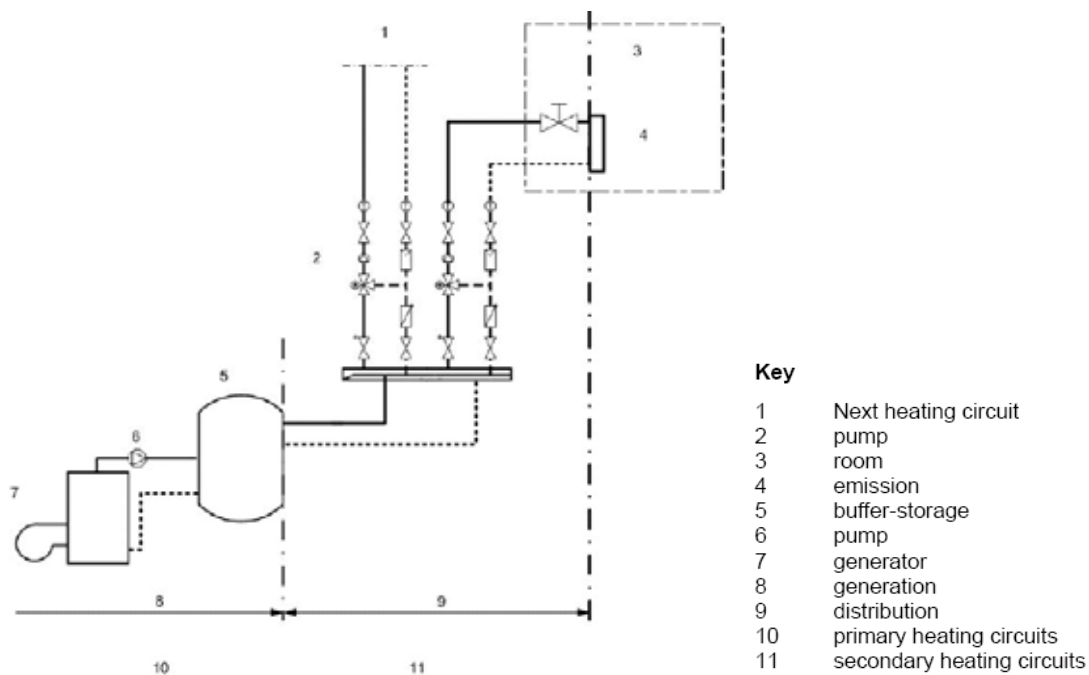


Figure 2 - Scheme distribution and definitions of heating circuits (prEN 15316-2-3)

3.2.4.1 Boundaries between distribution and generation sub-system

Boundaries between generation sub-system and distribution sub-system should be defined according to the following principles (prEN 15316-4-1).

If the generation-subsystem includes the generator only (i.e. there is no pump within the generator), the boundary with the distribution sub-system is represented by the hydraulic connection of the boiler (fig. 5).

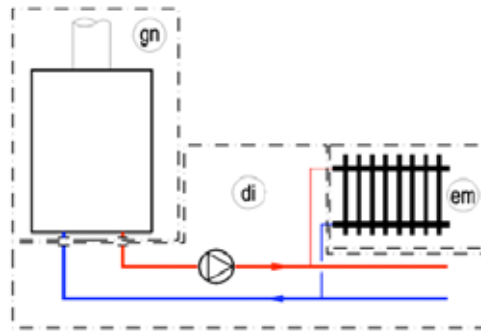


Figure 3 - Sample boundaries (gn = generation, di = distribution, em = emission)

A pump physically within the boiler is however considered part of the distribution sub-system if it contributes to the flow of heating medium to the emitters (fig. 6).

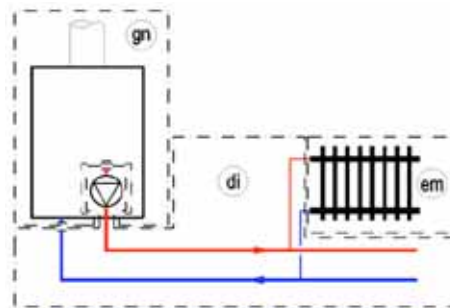


Figure 4 - Sample boundaries (gn = generation, di = distribution, em = emission)

Only pumps dedicated to generator requirements may be considered within the generation sub-system (fig. 7).

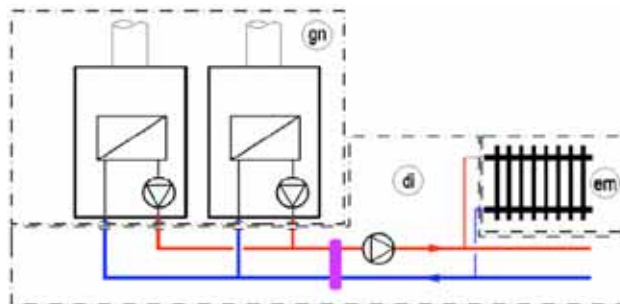


Figure 5 - Sample boundaries (gn = generation, di = distribution, em = emission)

3.2.4.2 Efficiency of heating distribution systems and baselines

We consider the most common distribution systems in the tertiary sector, together with their efficiency values as defined by the Standard prEN 15316-2-3 and we make conservative hypotheses to estimate baseline efficiency values as described below.

The values specified for distribution range from 93 to 97%. 93% for a poorly insulated

distribution system can be referred to a standard old (existing) building. However, modern well-insulated systems (especially if served by condensing equipment) presently can even achieve efficiencies of about 99.5%.

Correction factor depending on the emitter:

Type of emitter	η_d corrected
Radiators (90 / 70°C)	-
Radiators (70 / 55°C)	$1-(1-\eta_d)\cdot 0,85$
Fan-coil (55 / 45°C)	$1-(1-\eta_d)\cdot 0,60$
Radiant panels (35 / 28°C)	$1-(1-\eta_d)\cdot 0,25$

This factor has been introduced in order to take into account the advantage of operating with lower average temperature (45÷50°C) with respect to the temperatures of traditional radiators (75÷80°C).

3.2.4.2.1 Stock Inefficient Baseline ($\eta_{d,st}$)

Level 1 data can be considered only for buildings not larger than 5000 m³ in this case. For larger buildings more detailed data are necessary (i.e. level 3 evaluation effort), especially because the tertiary sector includes a wide variety of building types and sizes (height > 4 m for example). Therefore we have:

> Level 1

The **Stock Inefficient Baseline** ($\eta_{d,st}$) is taken as the minimum efficiency value referred to the buildings not larger than 5,000 m³ in the distribution reported in Fehler! Verweisquelle konnte nicht gefunden werden., namely

93,0 % (2008-9)

> Level 3 is required for all buildings bigger than 5,000 m³

3.2.4.2.2 Market Inefficient Baseline ($\eta_{d,st}$)

As regards the market inefficient baseline, we think that it is not realistic to evaluate a level 1 market inefficient baseline, because the distribution system inefficiency essentially depends on the thickness of the insulation material and on the pipe positioning, but also on the size of the buildings (volume, number of floors). These factors may vary from building to building, and it is not easy to determine which distribution system can be considered as efficient or inefficient in the current construction standards. These evaluations can be carried out only at a level of effort 3, by considering to the prEN 15316-2-3 Standard.

In order to simplify the calculation methodology, we assume to skip the evaluation of this baseline, and prefer to refer only to the efficiency related to a good practice of construction as that able to achieve a minimum value of efficiency determined as reported in the next paragraph.

3.2.4.2.3 Market Efficient Values ($\eta_{d,eff}$)

We propose to consider only end-use actions promoting the installation of efficient distribution systems characterised by efficiency at least equal to the maximum values achievable by considering well-insulated, corrected for taking into account low operating temperatures. The efficiency value proposed is 97,0%..

3.2.4.3 Level 1 Data Summary

Stock and Market Inefficient Baseline ($\eta_{d,st.}$) = 93,0 %
Minimum efficiency for efficient solutions ($\eta_{d,eff.}$) = 97,0 %

- Level 3 is required for all buildings bigger than 5,000 m³

3.3 Step 1.3: Normalisation factors

We consider Normalisation Factors in respect of the following variables of Equation 1:

- Size of the building --> S (m²)
- Location of the building --> Heating Degree Days --> Thermal Demand (kWh/m²/y)

To determine the effect of latitude on operating hours we consider climate data reported in Eurostat, providing average Degree Days for each European Country, and building envelopes characteristics, related to the Heating Loads (by VHK).

The specific parameter used to take into account the climate and the characteristics of the building envelopes is expressed in **kWh/(m²·DD·y)**.

Level 1	Normalisation included in national modification factors to be take either from table 6 or 7 (to be decided by European Commission and ESD Committee)
Level 2	Climatic zones defined at a national scale
Level 3	Registering of the participants' location and use of local HDD

3.4 Step 1.4: Calculation method and its three related levels

3.4.1 Default values and levels of effort

3.4.1.1 Default values for energy consumption and related parameters (level 1)

In Step 1.2 (cf. chapter 3.2), we defined unitary Level 1 values for the following end-use actions

- replacement of standard boilers with condensing boilers (energy savings per boiler)
- improvement of the emitter system and the control strategy (also together with condensing boiler)
- improvement of the distribution system

Determining total energy savings from individual end-use actions requires simply multiplying the unitary savings by the number of units sold or otherwise distributed under the given Action. This would be a deemed savings approach)

Energy saving estimates for the above mentioned end-use actions may require Level 2 (deemed) or Level 3 (mix of deemed and ex-post) data for some of the parameters used in Equation 1.

Making saving evaluations at level 1 by using default values is the easiest way to apply the methodology, but it provides conservative estimations. However, in the absence of adequately accurate National or measure specific data enabling level 2 or level 3 evaluation, level 1 data provided are recommended for conservative evaluations for buildings with less than 1,000 m² of floor area.

The same calculation procedure based on Equation 1 can be used either for level 1, 2 or 3 evaluation efforts. Under certain circumstances it may prove possible to complement, rather than completely substitute, Level 1 data with more specific level 2 or level 3 data.

EMEEES recommends to require Level 3 for buildings above 1,000 m² of floor area. Doing individual calculations for each building with equation (1) will be an enhanced engineering approach.

3.4.2 Definition of level 2 and level 3 values

As previously underlined, level 1 is the only viable option when no resources are available to collect additional data for buildings with less than 1,000 m² of floor area.

If actual stock/market data is available at the national level, evaluation can be made at level 2 or 3. Given the extremely conservative default values for level 1, there is a clear incentive to opt for levels 2 and 3. By the way, it is worth specifying that Level 1 values are "extremely" conservative because the assumptions done in order to estimate the reference values for energy savings evaluations have been penalized with the aim to stimulate the MS to achieve at least a level 2 of effort.

Specific Level 2 data: → National Data

Specific Level 3 data: → Installation Specific Data

- Measurement issues: To determine energy savings with reasonable accuracy and repeatability, good measurement practices should be followed.
- Sampling issues: Samples of the measures selected for monitoring at a particular site shall be representative of all measures at the site and shall be selected at random.
- Modelling issues: Unit energy savings and engineering parameters collected during the M&V analysis should include a reference indicating their source, uncertainty estimates (when available), and limits of their applicability. These data should be delivered and stored in a standard format.

3.4.3 Direct rebound effect

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.

It is difficult to foresee a rebound effect from improving the efficiency of heating systems in tertiary sector. In most cases (for example in offices) the decision to switch heating systems on or off is not taken by the heating system user. Such decision is a function of a number of factors (first of all the energy regulations and then, obviously, the climatic conditions and the number of working hours) and energy costs are usually not one of them. Economic savings provided by end-use actions in most cases will not lead to direct signals to users and hence no change in behaviour will be stimulated.

For these reasons, we consider that direct rebound effects for heating system EEI actions in tertiary sector may be neglected.

4 Step 2: Total gross annual energy savings

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

The total gross energy savings are the sum of energy savings of all participants in a given year. The “elementary unit of action” is one EEI action which corresponds to one participant with its energy savings arising from several improvement measures. The calculation of the savings by one participant as described in chapter 2 .

$$\text{Total Gross Annual Energy Savings} = \sum_{i=1}^{N_p} \Delta E_i \quad (2)$$

where:

N_p = total number of participants

ΔE = Unitary Gross Annual Energy Savings from an end-use Action (Equation 1)

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

Financial incentive schemes, e.g., under White certificates, plans for renovation of building stock, application of article 6 of EPBD, etc. give all the necessary data. They just need to be monitored.

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 ESD energy savings

If all correction factors are included, the formula for calculating total ESD annual energy savings will be:

$$\begin{aligned} \text{Total ESD Annual Energy Savings} = & \text{average energy savings per unit} \\ & * \text{gross number of units (actions)} \\ & * (1 - \text{free-rider ratio} + \text{multiplier ratio}) \\ & * \text{double-counting factor} \end{aligned}$$

or, in brief

$$\text{TEAES} = \text{equation (1)} \cdot \text{gross number of units} \cdot (1 - \text{FR} + \text{MR}) \cdot \text{DOC} \quad (3)$$

Coefficients definition:

TEAES: Total ESD Annual Energy Savings

Free-rider (FR): share [0,1]

Multiplier ratio (MR): ≥ 0

Double Counting (DOC): coefficient [0,1]

5.2 Step 3.2: Avoiding double counting

When several EEI measures/programmes are related to same sector or end-use, it is best to evaluate them as a package.

In case of overlap, the decision to allocate the corresponding energy savings to one or another EEI measure is up to the Member-States. Possible overlaps include:

- Overlap of national EEI measures using different types of (EEI) facilitating measures and addressing the same types of end-use actions
- Overlap among different EEI measures implemented at local, national or EU level.

In order to avoid double-counting issues we suggest the following approach:

Level 1	Not possible
Level 2	evaluating one consistent package of measures related to a specific action
Level 3	sharing results according to priority rules

Table 15 - Risk of overlap

	Energy Performance Contracting	White Certificates Schemes	Energy Taxations	Subsidies schemes	Risk of Overlap
Energy Efficient Boilers	X	X	X	X	X
Heating system losses reduction (e.g. by insulation)	X	X	X	X	X
Improved Control	X			X	X

Double counting can best be avoided by cross-cutting information available in a central database of registered participants.

How to address double counting:

- to group facilitating measures targeting the same type of end-use action in a single package, reporting one global result by type of end-use action, or
- to associate each targeted end-use with a particular facilitating measure or programme, allocating the corresponding energy savings only to this measure.

5.3 Step 3.3: Technical interactions

Technical interactions are possible with end-use actions addressing Variable speed drives, because of the potential reduction of energy consumption due to the adoption of VSD to improve control of circulation pumps.

Difficulties: monitoring the cases where it occurs. This is likely to have to be dealt with at level 3, e.g., through building simulation. Further study is needed to analyse whether level 2 national average values for technical interaction factors can be developed.

5.4 Step 3.4: Multiplier energy savings

It is relevant to evaluate the multiplier potential of EEI measures targeting energy-efficient heating systems.

Assessment of the Multiplier effect:

Ex-post evaluation of multiplier effect should be considered, through the following indicators:

- Sales data analysis.
- Surveys among representative samples of (non-)participants.

- Surveys with trade allies and/or other relevant stakeholders.

In order to carry out a more accurate assessment of the multiplier effect (level of effort 2 and 3) we suggest applying the procedure reported in “Statewide Market Assessment and Evaluation Non-Residential New Construction Program Area Building Efficiency Assessment Quarterly Report, 2001” (<http://www.calmac.org>).

5.5 Step 3.5: 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.

Energy savings as determined in Step 1 are adjusted to take account of the fraction of participants in EEI measures that would have purchased the energy efficient solutions in absence of the programme.

The Free Rider effect depends on the situation that is prevailing in a specific EEI measure and what would have happened in the absence of the EEI measure.

- Anticipated replacement supposes that in the absence of the EEI measure the user would have continued to use the standard inefficient equipment without changing. In the case we use (inefficient) **Stock Baseline** and there is **NO Free Rider** effect.
- Programmed replacement supposes the user would have proceeded with some kind of replacement even in the absence of the EEI measure. In this case we use the **Inefficient Market Baseline** and a **Free Rider effect**, if the aim is to calculate ‘additional’ energy savings. For calculating ‘all’ energy savings, we use the **Stock Baseline** and **no Free Rider effect**.

We define the Free Rider Factor (F_{FR}) such that (cf. equation (3)):

- where there is no Free Rider effect $F_{FR} = 0$
- where all savings can be distributed to Free Riders $F_{FR} = 1$

The present section aims to determine the Free Rider effect in respect of Programmed Substitution. In all cases we propose that the amount of energy saving (Equation 2) be reduced by the F_{FR} (Free Rider Factor). A separate Free Rider Factor is defined for each of the types of energy efficient solution described in Step 1, except for the distribution systems, for which we consider the free-rider effect not applicable.

5.5.1 Heat generators: Replacing standard boilers with condensing boilers: Free Riders

Data from VHK shows that condensing boilers in stock can be estimated for less than 10% of total,

while market sales allow us to estimate a market free-rider of 20%. However, this value will be very much dependent on the maturity of the national markets. The market shares of condensing boilers differ a lot throughout the EU. Not level 1 default value for the free-rider effect can therefore be defined.

5.5.2 Emitter systems: Free Riders

It is not easy to estimate how many efficient emitters would be installed in absence of EEI measures.

Here we estimate a market free-rider of 50% (Table 16) by considering that at least half of the currently installed emitters (fan-coils, floor-heating) can operate at low temperature (35-45°C) and can be considered already as efficient emitters. Actually, fan-coils require additional electricity for the fans, so other less energy intensive emitters should be promoted (e.g. radiant panels).

In order to estimate the free-riders we elaborated on VHK data regarding emitters sold in EU. According to VHK data, 75% of all central heating systems in the EU have radiator systems, while floor heating and fan-coil systems are 12% and 13% respectively (VHK, 2007). The figures include commercial systems, since fan-coil systems are very rare as domestic systems. So we assumed that all fan-coils and radiant panels are referred only to tertiary sector. This conservative assumption allowed us to estimate a percentage of efficient emitters currently sold in EU (Table 16).

Table 16 – Free Rider Factor for market emitter systems

Year	Free riders from the efficient control systems as % of total	F _{FR}
2008	60	0,6
2009	60	0,6

5.5.3 Levels of effort 2 and 3

In order to carry out an accurate assessment of the free-ridership (level 2 and 3) we suggest applying the procedure reported in “Statewide Market Assessment and Evaluation Non-Residential New Construction Program Area Building Efficiency Assessment Quarterly Report, 2001” (<http://www.calmac.org>).

6 Step 4: total ESD energy savings for year “i” (2010 and 2016)

6.1 Step 4.1: Energy saving lifetimes and early energy savings

For the energy saving lifetimes of the heating energy efficiency actions analysed here, CWA values from CWA27 are proposed, until the Commission will revise the list of life times in the Directive.

Table 17 - List of values defined within the CWA27 for heating systems

Category	End-use EEI action	EU Savings Lifetime values	First year for eligibility
Heat generator	Large boilers*	17 years (default value)	2000
Heat generator	Heat pumps (commercial sector)	20 years (harmonised)	1997
Control system	Heating control*	5 years (default value)**	2012**
Heating load	Heat recovery systems	17 years (harmonised)	2000

* The CWA27 proposes this value for the residential sector. We propose to consider this default value also for the energy efficient boilers considered in the present application case.

** can be extended by repeated analysis of a sample, provided control system efficiency remains unchanged with time.

Therefore, only EEI measures implemented in or after the years indicated in the last column should be considered as eligible, if early energy savings are allowed to count towards a Member State’s ESD target:

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. This needs to be proven. The same holds, respectively, for the intermediate target in 2010.

6.2 Timing and Lifetime of End-Use actions

Harmonised saving lifetimes (conservative estimate) of heating systems are provided in Table 26.

However, persistence of savings is also a potential issue.

Persistence of savings = f (measure retention, performance degradation);

Definitions:

- Measure Retention is the degree to which measures are retained in use after they are installed.
- Performance Degradation is any over time degradation that includes both technical operational characteristics of the measures.

6.2.1 Measure Retention

Measure retention studies collect data to determine the proportion of measures that are in place and operational. The primary evaluation components of a measure retention study are research design, survey-site visit instrument design, establishing the definition of an operable status condition, identifying how this condition will be measured, and establishing the data collection and analysis approach.

The withdrawal of the installed heat generators, although not recommended, is easily done. Hence, ex-post verification to a sample of participants is recommended to evaluate what is the status of the factors that influence the lifetime of a heating system:

- Rate of effective installation
- Risk of failures
- Operation conditions and maintenance
- Removal: economical and technical reason

The reasons for lack of retention, and the rates of non-retention, should be gathered when feasible for use in developing Effective Useful Life (EUL) values and in future retention studies.

6.2.2 Performance Degradation

A progressive reduction of the heating systems performance during the lifetime is likely to happen, especially for heat generators. But it depends on various factors, in particular:

- Control system
- Conditions of operation and maintenance

Power input control (modulation) of the boiler to a large extent determines the on and off cycling of the boiler. If the power input is higher than the heat demand, the boiler switches on and off in its attempt to deliver the requested amount of heat or (depending on the room temperature control system) requested supply temperature. This results in lower generator efficiencies, and also higher emissions. But it also influences the lifetime expectancy of the product. In most cases, the minimal power input of the boiler is considerably higher than the minimal and average heat demand of the building. In these cases, the improvement potential is considerable.

However, even if performance degradation causes a progressive reduction of efficiency of the heating systems, this aspect may be neglected.

In fact, a similar performance degradation would happen also for the standard (inefficient) systems that would have been used in the place of the efficient ones without the EEI measure.

Otherwise, for more detailed evaluations, an indication of the levels of degradation may be given by the following values of efficiency reduction depending on the age or the insulation level of the heat generator.

Boiler insulation level	Corresponding estimated energy efficient heat generator age	Seasonal Efficiency reduction [%]
Well insulated, high efficiency new boiler	< 3 years	$1,72 - 0,44 \cdot \log (P_n)$
Well insulated and maintained	3 - 5 years	$3,45 - 0,88 \cdot \log (P_n)$
Old boiler with average insulation	5 – 8 years	$6,9 - 1,76 \cdot \log (P_n)$
Old boiler with poor insulation	8 – 12 years	$8,36 - 2,2 \cdot \log (P_n)$
No insulation	> 12 years	$10,35 - 2,64 \cdot \log (P_n)$

P_n is the nominal power of the heat generator

Source: prEN 15316-4.1, eq. C1, table C.3. Heat generator ages reported in the table are not indicated in prEN15316-4.1 and represent eERG estimates. These estimates are based on the assumption that the seasonal efficiency reduction rates that can be associated to different insulation levels correspond to the seasonal efficiency reduction rates for energy-efficient heat generators that are observed in the age ranges reported. However, it remains to be tested in practice, if really a new, high efficiency boiler will degrade to the level of an old boiler with poor insulation by aging 8 to 12 years.

6.2.3 Effective Useful Life (EUL)

Main factors which may affect the lifetime of a heating system EEI measure:

- Installation quality

- Performance or efficiency decay
- Operating conditions
- Maintenance
- Removal
- Changes in operation profile

6.2.4 Skills Required to Conduct Retention, EUL, and Technical Degradation Evaluations

EUL analysis evaluation efforts need to have the specific skills and experience in regression and statistics proving an ability to be able to conduct classic survival analysis and handle EUL functional form and issue analysis.

Technical degradation studies require senior experienced engineers that are quite familiar with the equipment to be studied, with best practice procedures, and the components, mode of operation, and effects of changes in the operational conditions on the components and function of the equipment.

Surveys and interviews need to be conducted by experienced personnel. These studies and their instruments must be designed with personnel with experience in energy efficiency markets, and interview and survey instrument design, implementation and analysis.

Behavioural degradation studies could be based upon survey and interview analysis methods and/or statistical/econometric methods.

6.3 Uncertainties

The main parameters influencing the EU25 totals are:

1. uncertainty regarding the average annual heating load in the tertiary sector;
2. uncertainty regarding the efficiency values;
3. uncertainty regarding annual operating hours (relevant for level 3 calculations of E of individual buildings, cf. equation (1)).

▪ Uncertainties

for average heating load (E) we estimate: $\pm 20\%$ (VHK source)

for heat generators seasonal efficiency we estimate:

For efficiency : $\pm 2\%$

For unitary energy savings: $\pm 10\%$

for emitter systems we estimate:

For efficiency : $\pm 2\%$

For unitary energy savings: $\pm 10\%$

for distribution systems we estimate:

For efficiency : $\pm 2 \%$

For unitary energy savings: $\pm 10 \%$

for operating hours: $\pm 10 \%$

Appendix I: Justifications and sources

Legislation

- Directive 2005/32/EC on eco-design requirements for energy-using products.
- Directive 2006/32/EC on energy end-use efficiency and energy services
- SAVE II Labelling & other measures for heating systems in dwellings, 1999. Contract no. 4.1031/Z/99-283.
- Odyssee database (<http://www.odyssee-indicators.org>).
- Eurostat "Energy Consumption in the Services Sector" project (data 1995-1999). ec.europa.eu/eurostat
- VHK Preparatory Study on Eco-Design of Boilers (2007) (<http://www.ecoboiler.org>).
- prEN 15316-2-1 - Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies
- prEN 15316-4-1 – Space heating generation systems – Combustion systems
- prEN 15316-4-2 – Space heating generation systems – Heat pump systems
- prEN 15316-4-4 – Space heating generation systems - CHP
- prEN 15316-4-5 – Space heating generation systems – District heating
- prEN 15316-4-7 – Space heating generation systems – Biomass combustion systems
- prEN 15316-4-3 – Space heating generation systems – Thermal solar systems
- prEN 15316-2-3 – Space heating distribution systems
- BED - Boiler Efficiency Directive (92/42/EC)
- EPBD – Energy Performance of Buildings Directive (2002/91/EC)
- MD – Machinery Directive (98/37/EC + 98/79/EC + 89/392/EEC + 91/368EEC + 93/44/EEC + 93/68/EEC)
- Construction Products Directive (89/106/EEC)
- GAD – Gas Appliance Directive (90/396/EEG + 93/68/EC)
- LVD – Low Voltage Directive (73/23/EEC + 93/68/EC)
- EMC-D – Electromagnetic Compatibility (92/31/EC + 93/68/EC + 2004/108/EC)
- PED – Pressure Equipment Directive (97/23/EEC)
- Packaging Directive (2004/12/EEC)