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

EMEEES bottom-up case application 3: Biomass boilers (residential sector)

Authors:

Adam Gula
Anna Barcik
Dominik Jezierski

AGH University of Science and Technology

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coordinated by

Wuppertal Institute for Climate, Environment and Energy

supported by

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The Project in brief

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

Consortium

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

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

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

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Contents

1 Summary

1.1 Title of the method

Biomass boilers (residential sector)

1.2 Type of EEI activities covered

End-use EEI action	
Sector	Residential, public, tertiary
Energy end-use	Space heating
Efficient solution	Conversion from fossil fuels to biomass
EEI Facilitating measure	
Types of EEI facilitating measures	• Financial support to individual beneficiaries • Information tools, focused campaigns, advice • Energy performance contracting

1.3 Detailed definition of EEI activities covered

Replacing or supplementing individual conventional heating boilers fed by fossil fuels (coal, heating oil or gas) by installation of heating boilers using **sustainably grown biomass** as fuel, referred to as BMB below.

Note: the method devised in this case application will only be applicable, if the biomass is not a purchased fuel, or not interpreted as such. If biomass is (treated as) a purchased fuel, the formula in case application 4: Residential condensing boilers in space heating should be used, with the BMB as the energy-efficient boiler instead of the condensing boiler.

Background on whether sustainably grown biomass is a purchased fuel according to article 3a of the EU Directive on energy end-use efficiency and energy services (ESD) or not is discussed in section 1.4 below.

The *a priori* applicable facilitating measures are: all kinds of financial incentives, information campaigns and energy performance contracting. In this method, we focus on facilitating measures, for which EEI programme participants (physical persons or institutions) need to apply individually to obtain support.

The biomass space heating boilers, BMBs, have to be considered either as:

- stand-alone heat source (when it can meet the peak demand) or, if otherwise,

- as a boiler supplementing another heating source.

In both cases, energy savings have to be referred to the other (baseline) source, which is either replaced, or supplemented by the biomass boiler.

A priori the other heat sources are:

1. In-house heating sources:

   a) gas boilers (GB),
   b) oil boilers (OB),
   c) coal boilers (CB),

2. Grid-delivered energy

   d) district (grid) heating (DH) (replacing fossil fuel in DH generation by biomass)
   e) resistance electric heating (RH) or electric heat pumps (HP), (replacing fossil fuels in electricity generation)

or any combinations of (a-e) above. Below, sources (a-e) will be referred to as "*erstwhile sources*", by which we shall mean sources supplemented (substituted) by the BMB system. In case of new buildings, by *erstwhile source* one should understand the source with the lowest emmission factor, the installation of which is technically possible and cost-effective for the participant compared to a fossil-fuel source[1].

1.4 General specifications

Conditions for energy savings to be eligible (e.g. compliance with a quality charter or minimum level of energy performance):

substitution (possibly partial) of fossil fuel-derived heat by heat from combustion of biomass in **dedicated biomass boilers** installed in the premises (residential, public or tertiary) of the programme participant.

By "dedicated" we understand boilers specially designed for combustion of biomass, i.e. boilers in which using solid fossil fuel is impossible, or practically impossible, difficult or inefficient, and/or may lead to equipment damages.

[1] with inclusion of subsidies

The rationale for considering such EEI measures as ESD-eligible is based on Annex III to ESD, which lists as "*examples of eligible energy efficiency improvement measures:*

(a) heating and cooling (e.g. heat pumps, new efficient boilers, instillation/efficient update of district heating/cooling systems)(…)

(…) (g) domestic generation of renewable energy sources, whereby the amount of purchased energy is reduced (e.g. solar thermal applications, domestic hot water, solar-assisted space heating and cooling)".

It may, on one hand, seem rather obvious to assume that conversion of individual space heating systems from fossil fuels to biomass is another example of such measures of *(g) domestic generation of renewable energy sources*, even though it has not been explicitly mentioned in the Annex.

The question may arise whether „(…) the *purchased* [replaced] *fossil fuel*" falls in the category of „*replaced purchased energy*". The argument is that, if the Directive is to be internally consistent, the answer must be positive. Indeed, for instance, the solar water heaters, explicitly enumerated in Annex III, usually reduce the volume of purchased gas or oil, which are (purchased) fossil fuels, rather than "purchased energy". The same applies to solar-assisted space heating, which typically, also reduces the amount of fossil fuels burnt in domestic heating boilers.

On the other hand, the ESD defines in article 3a: "energy": all forms of commercially available energy, including … biomass as defined in Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market[2]; and the conversion table in Annex II of the ESD includes wood (25 % humidity) and wood pellets/bricks. Therefore, biomass that is sold to the final consumer could be counted as a type of energy for ESD purposes, and only ***energy-efficient*** biomass boilers would create ESD energy savings. In that interpretation, biomass produced by the final consumer him-/herself, such as wood cut in an own forest, or straw on a farm, would not be counted as commercially available energy, although, typically, it would save even more commercially available energy than purchased biomass.

The EMEEES project cannot decide, which interpretation is correct. Therefore, it remains to the European Commission with the ESD Committee to decide which one should be applied.

[2] OJ L 283, 27.10.2001, p. 33. Directive as amended by the 2003 Act of Accession.

Conditions requiring level 2 and 3 efforts for a particular point or for the whole evaluation (e.g. special conditions on a parameter responsible of major uncertainties):

The proposed method combines data from Levels 2 and 3, with parameters and procedures defined/harmonised at Level 1.

The proposed method <u>is not a requirement, but a recommended evaluation approach.</u>

The pre-installation and installation design data would be collected individually and would correspond to Level 3. They would be provided by the applicant in an EU-harmonised questionnaire. The institution evaluating the applications would enter the data into an EU-harmonised database and would either process them further towards estimating the ESD saving, or (preferably) transfer them to a national centre (e.g., the authority according to article 4(4) ESD, cf. case application 12: Energy-Efficient Motors), where the evaluation would be done for the whole country. It would be particularly easy to enter and process further the data, if the questionnaires are submitted in an electronic form.

The savings would best be evaluated by using an EU harmonised procedure[3]. The region-specific (Level 2) parameters would be the degree days (with possibly EU-wide, Level 1, indoor temperature assumed) and meteorological parameters (solar gain, average wind exposure...), in cases when the energy audit that takes them into account is not available. In this latter case, Level 2 data would be region-specific average heat consumption (per area or volume) data, determined for defined classes of buildings. Energy Performance Certificates (EPCerts) from a sample of buildings equipped with biomass boilers could be a statistical basis for these level 2 values of region-specific average heat consumption.

In principle, it could also be possible to use Level 1 values for the average annual heat consumption per m^2 from the EcoBoiler study, as proposed in the method 3b for natural gas condensing boilers.

[3] One can possibly consider suggesting an EU-common computer programme for energy auditing of buildings and common guidelines for estimating the heat demand using simple formulae taking into account building characteristics.

1.5 Formula for unitary gross annual energy savings

For this method, the unit used in the formula for the unitary gross annual energy savings is an individual EEI programme participant.

Annual energy savings are determined using the engineering calculation described below:

The direct unitary gross annual energy savings Q_{dir} should be corrected for:

(i) energy embedded in fuel preparation, ε_{emb} , in % of the energy content of the biomass fuel,
(ii) energy embedded in transportation of fuel from production site to the consumer, α_{transp} , in % of the energy content of the biomass fuel.

Then the formula for unitary gross annual energy savings is given by:

$$Q_U = Q_{dir} * [\frac{1}{\eta_{FFB}} - \frac{1}{\eta_{BMB}}(\varepsilon_{emb} + \alpha_{transp})]$$

(equation S1)

where:

η_{FFB} - is the efficiency of fossil fuel boiler, and
η_{BMB} - is efficiency of biomass boiler, and
Q_{dir} - is defined in Eq. 1.2 in chapter 1.

Note: if the aim is to calculate all energy savings, η_{FFB} is the efficiency of the replaced old fossil fuel boiler. If the aim is to calculate energy savings additional to autonomous progress, η_{FFB} is the efficiency of a new, average energy efficiency fossil fuel boiler.

In all cases, the number of regional heating degree days (Level 2) averaged over N (Level 1) previous years[4] will be used in the calculations. Since, the region-by-region variation of the values of degree days is usually significant regional level of averaging should be used rather than the national ones.

[4] The value of N will need to be agreed upon, we propose N=5 years.

Alternatively, for level 1, the normalised energy demand for space heating defined in the ecoboiler study (for the EcoDesign Directive), as recommended by Jérôme Adnot for the method for condensing boilers could be used.

The proposed approach is (i) relative simple, (ii) does not entail significant additional costs and is (iii) pragmatic as regards the determination of heat demand.

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

In calculation of the unitary gross annual energy savings, default values for two parameters could be applied, as defined in the case application 4 on gas-fired condensing boilers. One is the average annual energy consumption per m^2, **E = 86 kWh/m^2/year** on EU average, or using national averages (cf. case application 4 on gas-fired condensing boilers). The other one is the energy efficiency of the replaced boiler (i.e., the baseline), as provided in table S1.

Table S1 level 1 average energy efficiency of replaced gas-fired boiler – value for EU average conditions

	boiler efficiency for regular replacement°	boiler efficiency for early replacement*
Replaced boiler	89%	82%

° if the aim is to calculate energy savings **additional** to autonomous progress

* also for regular replacement, if the aim is to calculate **all** energy savings

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 $Q_{ESD,net}$ (in kWh/year) will read:

$$\Delta Q_{ESD,net}^{(BMB)} = \Delta Q_{ESD,gross}^{(BMB)} * \left(1 - \alpha_{fr} + \omega_{me}\right) * \zeta_{dc}$$

(equation S2)

where α and ζ are in the interval (0, 1), and $\omega \geq 0$, and represent the free rider, double counting and multiflier effect, respectively.

1.8 Indicative default value for energy savings lifetime

The following value is suggested as a default or a harmonised value.

Energy savings lifetime: **EU default/harmonised values**	
EU default	
EU harmonised	17 years, Taken from CEN 15693:2007 for small boilers

This value is based on

CEN 15693:2007

1.9 Main data to collect

Data needed in calculation for EU values (level 1)	**Corresponding data sources**
Data 1 Calorific value of different kinds of biomass and other parameters determining the values of ε and α in Eq. S1 (embedded energy in production of pellets, briquettes, and wood chips and biomass transportation losses) m2 of building floor space when using the values from table S1 and E = 86 kWh/m^2/year	Appendix to this Summary and references therein monitoring of participants
Data 2 Biomass boilers efficiencies for dominant classes of models in the EU market	EN 303-5 Heating boilers–part 5. “Heating boilers for solid fuels, hand and automatically stocked, nominal heat output of up to 300kW- terminology, requirements, testing and marking”
Data 3 Erstwhile boiler efficiency	Default values provided above in section 1.6, taken from case application 4 on gas-fired condensing boilers

Data to be collected national values (level 2)	**Corresponding data sources**
Data 1 Degree days	Appropriate meterological statistics from the regioal meterological station. Cf. Statistical aspects of the energy economy in 2005 - Issue number 13/2006” , Authors: Antigone Gikas, Rita Keenan and analogous national/regional sources
Data 2 Region-specific characteristics of classes of buildings and their average parameters enabling the experts to assign heat demand for a particular building based on this information	Averaged over a sample of buildings of a given type, size and construction date (engineering estimate). See also below (Level 3 data)
Data 3 Data on domestic (national) production of solid biomass fuel for	tbd

individual space heating and the corresponding data for imports[5]	
Data 4 Erstwhile boiler efficiency	As above for level 1 or national averages

Data to be collected measure-specific (or participants-specific) (level 3)	Corresponding data sources
Data 1 Energy audit or building characteristics needed for assessment of heat demand	Provided by the participant in the questionnaire accompanying the application form
Data 2 Installation design data, including model and capacity of the boiler, and in house heat distribution system, kind of biomass to be used and source (local, national, potentially imported, if purchased from wholesale dealers)	input parameters provided by the participant or installer in the questionnaire or assigned by the programme evaluation expert (Level 2) based on default values and information in the questionnaire
Data 3 Erstwhile boiler efficiency	As above for level 1 or 2, or boiler replaced in the individual case

[5] These data will be needed only if the proposal to take into account the transportation energy losses is accepted

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 3 "Biomass boilers" developed by AGH University of Science and Technology.

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

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

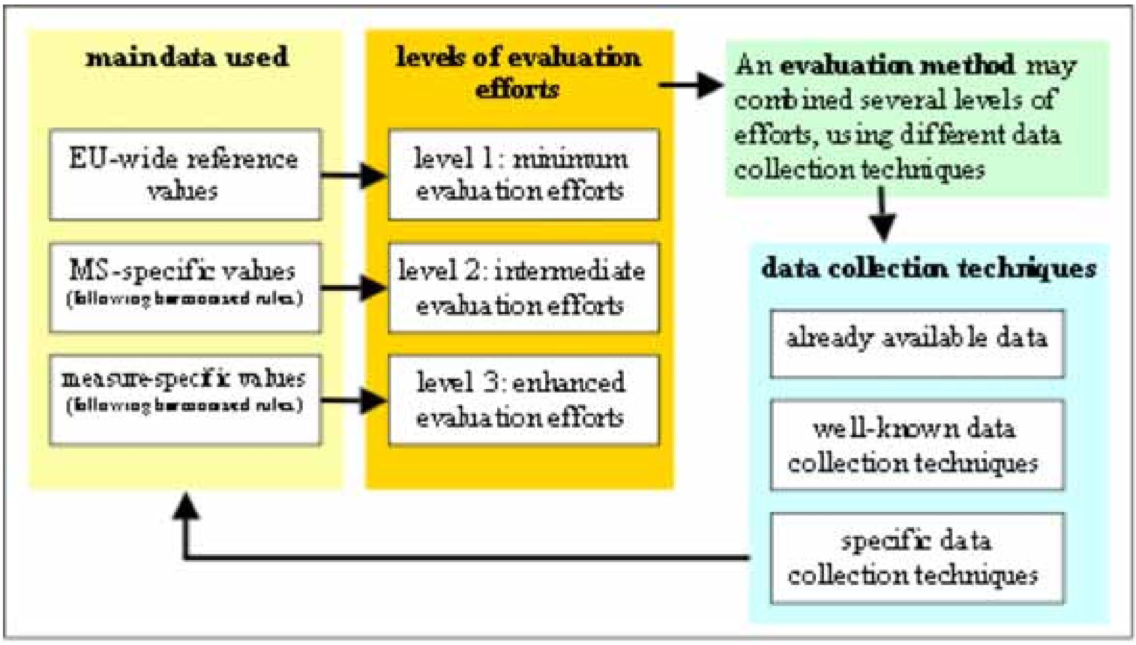
N°	End-use or end-use action, technology, or facilitating measure	Sector	Responsible organisation
1	Building regulations for new residential buildings	Residential	SenterNovem
2	Improvement of the building envelope of residential buildings	Residential	AEA
3	Biomass boilers	Residential	AGH-UST
4	Residential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

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

2.2 Three levels of harmonisation

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

Figure 1: Three levels of harmonisation



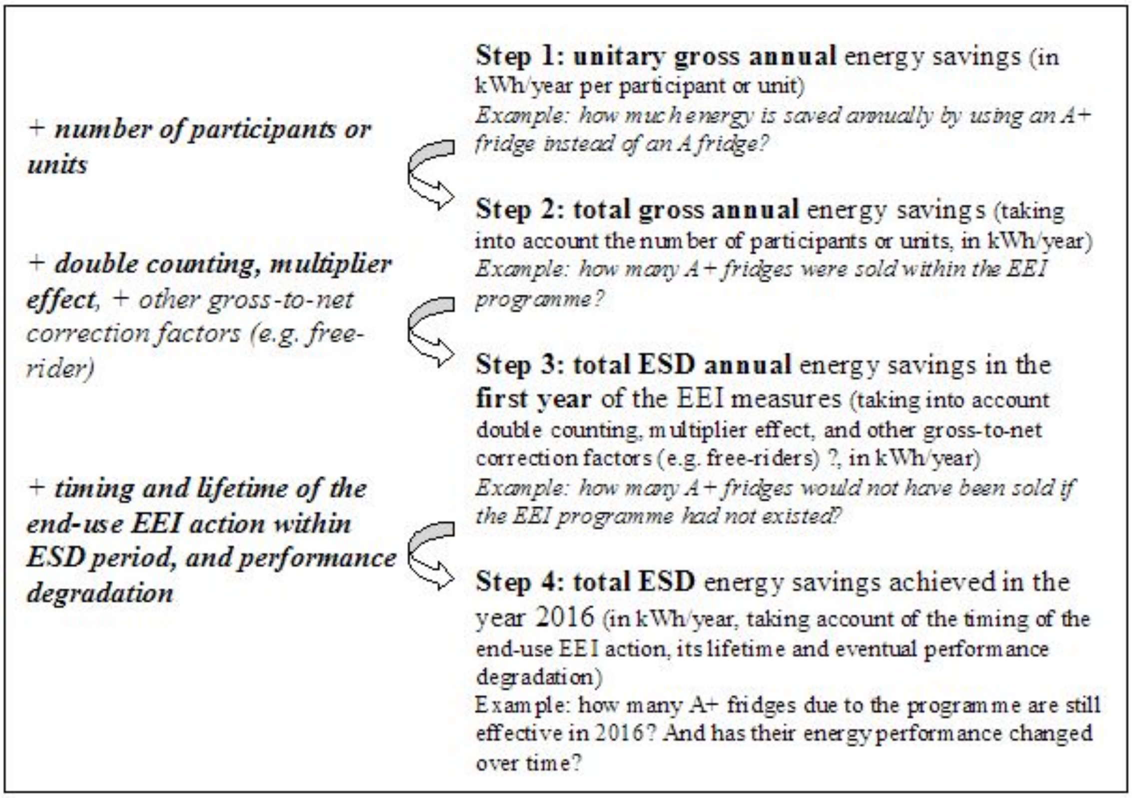
As a consequence, the EMEEES case applications for bottom-up evaluation methods present:

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

2.3 Four steps in the calculation process

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

Figure 2: Four steps in the calculation process



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

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

2.4 Pilot tests

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

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

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

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

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

3 Step 1: Unitary gross annual energy savings

3.1 Step 1.1: General formula and calculation model

For this method on *Improvement of heating system: biomass boilers*, the unit is an EEI programme participant (a family living in a given house; public/tertiary building of a specified function; etc.).

Annual energy savings are determined using the engineering calculation described below:

First, two cases on peak demand/capacity are distinguished:

1. The biomass boiler meets the peak demand (fossil fuel boiler, FFB, is removed, or the BMB boiler is installed as a sole heat source in a new building)
2. The FFB of rated capacity Y [kW] is supplemented by a biomass boiler (BMB) of capacity X [kW]

In the first case the "direct" (uncorrected) savings Q_{dir} are equal to average annual heat consumption Q determined by:

b) the energy audit, EPCert, or, possibly, simplified energy assessment, e.g. based on past energy bills (Level 3), attached to the application provided by the applicants in an EU-harmonised questionnaire, or

c) by an expert, on the basis of the appropriate Level 2 data on aveage annual heating energy consumption for particular classes of buildings characterised by year of construction, size of the building, heated area and other relevant building characteristics (detached, semi-detached, etc).

In the second case, the annual heat consumption Q, will be divided into two parts, according to the ratio of heat production[6] or, if it is difficult to be assesed, according to the ratio of the rated capacities of the two heat boilers

$$X'_{BMB} + Y'_{FFB} = Z, \qquad (1.1)$$

where, X' and Y' correspond to the annual heat generation of the BMB and FFB, respectively (or of their rated capacities), Z being the calculated (or estimated) annual heating energy consumption of the building, Q, or the peak demand determined on the basis of the rated capacities.
If the heating system is assisted by a solar collector, the contribution from solar energy should be subtracted from the annual heat consumption, Q (or peak heat demand, Z)

[6] usually: BMB = base load; FFB = peak load/backup

The raw ESD (uncorrected) savings will then be determined by the fraction of Q corresponding to the biomass boiler:

$$Q_{dir} = X'_{BMB} / Z \qquad (1.2)$$

The direct unitary gross annual energy savings Q_{dir} should be corrected for:

(i) energy embedded in fuel preparation, ε_{emb} , in % of the energy content of the biomass fuel,
(ii) energy embedded in transportation of fuel from production site to the consumer, α_{transp} , in % of the energy content of the biomass fuel.

Then the formula for unitary gross annual energy savings is given by:

unitary gross annual energy savings =

$$Q_U = Q_{dir} * [\frac{1}{\eta_{FFB}} - \frac{1}{\eta_{BMB}}(\varepsilon_{emb} + \alpha_{transp})]$$

(equation 1)

where:

η_{FFB} - is the efficiency of fossil fuel boiler, and

η_{BMB} - is efficiency of biomass boiler, and

Q_{dir} - is defined in Eq. 1.2

The assumptions behind Eq. S1 are the following:
Sustainably grown biomass used for heating purposes is not purchased (fossil) energy. Under this assumption, the efficiency of the biomass boiler needs not to be taken into consideration, as far as reduction of purchased fossil fuels is concerned[7]. Here it is assumed that energy embedded in biomass preparation (processing and transportation to the destination place) is fossil fuel based. This is reflected by the rightmost term, which has to be corrected for the biomass boiler efficiency, as the amount of biomass fuel needed to provide a given heat output is inverse proportional to its value.

[7] A less efficient biomass boiler will provide a given (needed) amount of heat still with zero CO2 emissionsfossil fuel.

Note: if the aim is to calculate all energy savings, η_{FFB} is the efficiency of the replaced old fossil fuel boiler. If the aim is to calculate energy savings additional to autonomous progress, η_{FFB} is the efficiency of a new, average energy efficiency fossil fuel boiler.

In all cases, the number of regional heating degree days (Level 2) averaged over N (Level 1) previous years[8] will be used in the calculations. Since the region-by-region variation of the values of degree days is usually significant, the regional level of averaging should be used rather than the national ones.

Alternatively, for level 1, the normalised energy demand for space heating defined in the ecoboiler study (for the EcoDesign Directive), as recommended by Jérôme Adnot for the method for condensing boilers could be used.

The proposed approach is (i) relative simple, (ii) does not entail significant additional costs and is (iii) pragmatic as regards the determination of heat demand.

3.2 Step 1.2: Baseline

- *before/after or current market inefficient?*

level 1	a) default indoor temperature for calculation of degree-days (national average) b) default average efficiency of heating systems substituted by BMB (e.g. data from EMEEES case application 4 on gas-fired condensing boilers or from Eco Boiler study): (i) *for all energy savings:* stock average, (ii) *for additional energy savings:* inefficient market average.
level 2	a) national level 2 baseline should be the average efficiency of substituted heating systems for a given MS b) (i) *for all energy savings:* stock average, (ii) *for additional energy savings:* inefficient market average. Data required: as in section 1.9. Examples of data sources: national statistics about heating systems, national survey on a sample of dwellings where heating systems were substituted.
level 3	guidelines how to define a measure-specific baseline: EU harmonised questionnaire and a common computer model for processing the input data into ESD energy savings Data required: as in section 1.9. Data sources: (i) *for all energy savings:* (database of) participants' reported data on *erstwhile* boilers and participants' annual heat consumption; (ii) *for additional energy savings:* participants' annual heat consumption, but market average of inefficient fossil fuel boiler efficiency

[8] The value of N will need to be agreed upon, we propose N=5 years.

3.3 Step 1.3: Requirements for normalisation factors

Reference to appendix for normalisation factors already addressed in existing methods.

normalisation factor 1: degree-days	
level 1	default indoor temperature for calculation of degree-days (national average)
level 2	National meterological data for main climatic zones and corresponding correction factors
level 3	registered participants' data (e.g. location in term of climatic zone)

It is assumed that in case of substitution between heating systems, there is no change in dwelling surface. Otherwise, correction for the change in the surface area should be made: if it is increased, the baseline for the additional area should correspond to the new standards in terms of GJ/m2 (kWh/m2).

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

level 1	Mix of deemed and ex-post: the use of the EU common computer model evaluating ESD savings per building. The input data to the model will include also Level 2 and aggregated Level 3 data, together with possible default Level 1 values. (e.g. a default relative gain (in %) to be applied to default energy consumption ratio (in kWh/m²) based on, e.g., the Eco Boiler study, cf. section 1.6, or default national average value for surface of the participants' dwellings)
level 2	Mix of deemed and ex-post: Based on metereological data, default parameters for building classes, Creation of EU harmonised national databases of: (i) ESD savings results, corresponding to a particular (EEI) facilitating measure (ii) input values (tbd which) reported in the questionnaires or national average values, e.g., for surface of the participants' dwellings, based on samples of buildings (iii) average efficiency of heating systems per energy carrier
level 3	Mix of deemed and ex-post: Based on the use of EU harmonised questionnaire. Input can come from an enhanced engineering estimate performed in an energy audit The same data as for level 2 taken at level 3

3.4.1 Conversion factors (when relevant)

Conversion factors for biomass are provided in Annex II ESD and in table A3 in the Annex to this case application. Justified national values can also be used.

3.4.2 Considering the 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.

In the proposed method, the rebound effect is eliminated by using the value of heat demand determined in an audit (or by using harmonised simplified estimation guidelines) with an EU-standard indoor temperature.[9]

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

3.4.3.1 Default values for energy consumption and/or related parameters

Using European studies such as Eco-Boiler (as done, e.g., in EMEEES case application 8 about heating in the tertiary sector or case application 4 about condensing boilers)

The other Level 1 default values would include:

- the EU-standard indoor temprature (tbd) for calculation of Level 2 degree-days, and
- the correction factors for energy embedded in biomass processing into final fuel (pellets, briquettes, chips), with exclusion of logging/harvesting and transportation to the biomass processing plant. As seen in Table A1 in the Appendix, the embedded energy is significant, especially for wood pellets and briquettes.

The correction for transportation is also explained in the Appendix. Considering the ambiguity in the determination of transportation distances it is suggested to consider the following:

- if the biomass is produced locally (e.g. self-supply or source within ca. 50 km for woody biomass and 30 km for straw or hay), assume zero transportation losses
- if the biomass is of national origin but outside the radius of 50 or 30 km, respectively, a default distance: 300km will be used[10].

[9] The rebound may take place in a situation where, say, a farmer having surplus straw may use it for heating just to get rid of it, rather than achieve the required thermal comfort.

For the fraction of imported biomass (if such statistics is made available), it is proposed to use a default distance: 800km. Then, the value of α will be a weighted average of the latter two values (see footnote 16)

It should be noted that, by the very nature of the coefficients ε and α, only very rough estimates can be used. Table A1 in the Appendix presents estimates obtained under the assumptions specified therein, which have been chosen arbitrarily from among a range of plausible parameters or values.

3.4.3.2 Requirements to define level 2 and level 3 values

The most important Level 2 default values are:

- the efficiency of the erstwhile fossil fuel boiler which will be either given in the questionnaire provided by the applicant (then it will be level 3), or estimated by an expert (ESD Evaluation Centre) on the basis of information therein (type, capacity, year of production and installation; level 2 average values can be used here).
- metereological data for calculation of degree-days or directly degree-days or other equivalent normalisation factor
- default parameters for building classes, if no energy audit is enclosed in the application or national building typology + national average energy consumption per building type.

[10] The reason is to discourage the practice of long-distance tranportation of solid biomass, which is much more energy intensive per GJ of carried fuel due to a much lower energy density per unit volume.

4 Step 2: Total gross annual energy savings

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

For this method, the unit used in the formula for the unitary gross annual energy savings is an EEI programme participant (a family living in a given house; public/tertiary building of a specified function; etc.). The formula for summing up the number of actions is:

$$Q_{ESD,\ gross} = \sum_j Q_{U,j} \qquad \text{(Eq. 2)}$$

where the sum runs over all EEI programme participants.

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

The proposed method is based on the case-by-case data provided by individual participants, so that the number of actions can be readily obtained. Those level 3 data are then entered into a database and supplemented there by the appropriate default (level 1)/average (level 2) values needed for Eq.(S1).

Subsequently, the evaluation of the total annual gross energy savings becomes straightforward (automatic) and easy, as it does not require any post-investment measurements or monitoring. The gross annual savings are then given by a sum over all participants. If not all participants have been entered into the database, the missing values should be determined by using national average (level 2) or by the averages over the registered participants' data (level 3).

The additional benefit of the proposed method, apart from the ESD reporting simplicity, is its potential usefulness for introducing corrections to the promotion schemes that may increase their efficiency.

(compare Section 3.4.3.2, where it is recommend what data are the most useful to be reported at level 2 or 3)

5 Step 3: Total ESD annual energy savings

5.1 Step 3.1: Formula for ESD annual savings

The formula for total net ESD annual energy savings, corrected for the free-rider, α_{fr} (only to be applied when calculating energy savings additional to the autonomous changes), multiplier effect, ω_{me}, and double-counting, ζ_{dc}, factors reads:

$$\Delta Q_{ESD,net}^{(BMB)} = \Delta Q_{ESD,gross}^{(BMB)} * \left(1 - \alpha_{fr} + \omega_{me}\right) * \zeta_{dc} \qquad \text{(S3)}$$

The particular values of α, ω, ζ are discussed below, following the approach of EMEEES case application 12 (Energy Efficient Motors).

5.2 Step 3.2: Requirements for avoiding double counting

EMEEES case application 12 (Energy Efficient Motors) suggests the following approach:

5.2.1 *“double counting can best be avoided by cross-cutting available information in a central database of registered participants and the equipment (…) installed (…).”*

This approach would be perfectly feasible in the method proposed here. As we suggest, the Level 3 data should converge in the “*National ESD Evaluation Centres*” (one per MS, e.g., the authorities according to article 4(4) ESD), where corrections for ω and ς could possibly be estimated based on country-specific data. Otherwise, following the EMEEES bottom-up methodology:

“5.2.2 *(…) How to address double counting when reporting results:*

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

In this method, the latter solution should be favored. If one of the facilitating measures is a financial support of any kind, it is most likely that all people intending to invest in an EEI measure, who have been reached by an information, education or advice campaign will apply for such support, which practically means

$$\zeta = 1 \qquad \text{(S4)}$$

Assuming additionally that α and ω roughly compensate with each other or/and are both small Eq.(3) will read

$$\Delta Q^{(BMB)}_{ESD,net} = \Delta Q^{(BMB)}_{ESD,gross} \qquad \text{(S5)}$$

which should be a sufficient approximation of the net ESD savings. For further remarks concerning ω see step 3.4.

5.3 Step 3.3: Requirements for taking account of technical interactions

As far as the ESD energy savings are concerned there exist obvious technical interactions, which may, *a priori,* lead to double counting:

i. Improvement of building envelope
ii. Temperature controls
iii. Upgrading in–house heating distribution system
iv. Replacing the FF boiler by a more efficient one, when the biomass boiler is not fully substituting the old boiler
v. Solar assisted heating
vi. Heat pump (assisted) heating
vii. Geothermal (assisted) heating

Those, however, can be, in principle, accounted for in the evaluation procedure on the basis of information provided by the program participant in the questionnaire outlined above, and/or cross-cutting available information in a central database of registered participants (c.f. Method 13A) using some kind of modelling (worked out only once for the whole period of evaluation). One should note, that only the three first kinds of interactions seem to be the really likely to happen.

5.4 Step 3.4: Requirements for multiplier energy savings

If the idea of the active National ESD Evaluation Centres is accepted and implemented, the trend of the time variation of the number of EEI programme participants can be followed and extrapolated into the future by numerical fitting of the observed data to an assumed analytical formula for the time dependence of the trend. Those results can be verified by ex-post evaluation through e.g. sales data analyses or surveys among representative samples of (non-participants)[11].

5.5 Step 3.5: Requirements for the free-rider effect

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

One could make an *ex post* anonymous inquiry asking one “YES/NO” question whether the participant would have installed the biomass boiler in absence of the EEI programme. Technically, it could be done by mailing a small questionnaire to a sample of participants (possibly even to all, the cost wouldn’t be high) with an addressed and prepaid return envelope. Considering large uncertainties involved, the corrections would be very significant but could be largely arbitrary. Therefore, and because of the costs involved with the surveys and their evaluation, it is recommended to only evaluate both multiplier and free-rider effects for larger EEI programmes, e.g., exceeding 50 million kWh of annual energy savings.

Alternatively, for BMB, the free-rider effect could also be evaluated by using market analysis (e.g. by studying what was the market trend for this equipment before the facilitating measure started, e.g. if available in the Eco Boiler study).

[11] Multiplier effects can be over time, but can also occur in other ways at the same time with the facilitating measure. When multiplier effects are considered over time, it should be remembered that for ESD, only savings achieved in 2016 count. So multiplier effects after 2016 can not be accounted for the ESD target. However, it is to the European Commission and the Committee to decide if the multiplier effects can be evaluated through ex-ante assessments, or only ex-post.

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

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

6.1 Requirements for the energy saving lifetime

The suggested value is to be taken as a harmonised EU value according to CEN 15693:2007 (CWA 27), i.e., the value of 17 years provided for small boilers.

6.2 Special requirements for early actions

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

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

OR

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

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.

The lifetime of a typical biomass boiler exceeds 15 years. Therefore, savings due to installations realised before 2010 (T_{2010}) or 2016 (T_{2016}) can be included by the Member States in their reported ESD savings. If early savings are admitted, they could eligible as from

$$T < T_{i-15} \qquad (6)$$

where i= 2010, or i=2016, respectively.

6.3 Possibilities to treat uncertainties

In general, evaluation of energy savings involves uncertainties on all input parameters, except for physical constants and rigidly assumed default values. In the proposed method, the most relevant data are obtained directly from the EEI programme participant (Level 3), entered into national databases (Level 2), and then processed according to the EU harmonised (common) calculation procedure. Therefore, assuming coherence and uniformity of algorithms in national centres across EU, the level of uncertainties in the calculation of savings will be relatively low, as compared with other evaluation methods.

Once the algorithm for calculation of $Q_{dir,j}$ is agreed upon, the formula for $Q_{U,j}$ (Eq. S1) can be, in principle, written in an analytical form. Then, the associated uncertainty can be expressed by the standard formula for propagation of the errors:

$$\Delta Q_{U,j}(\xi_1,\xi_2...\xi_3,\eta_B,\eta_F,\alpha,\varepsilon) = \sum_1^k \left| \frac{\partial \Delta Q_{dir,j}}{\partial \xi_i} \delta\xi_i \right| + Q_{dir} * \left[\frac{\delta\eta_B}{\eta_B^2} + \frac{\delta\eta_F}{\eta_F^2} + \frac{\delta\alpha + \delta\varepsilon}{\eta_B} \right]$$

(7)

where:

ξ_i and $\delta\xi_i$ are parameters defining Q_{dir} and their errors, respectively and other values are analogously defined via Eq. S1.

Contrary to what may seem at a first glance, using Eq. 7 will be straightforward, since it can be done by using a single formula, accepted once for the whole EU.

Analogously, using the standard approach, the uncertainty of the gross savings can be estimated as:

$$\Delta Q_{ESD,gross} = \sqrt{\frac{\sum_j^N (\Delta Q_{U,j})^2}{N_p(N_p - 1)}} \qquad (8)$$

where N_p is the number of EEI programme participants.

As to the evaluation of the uncertainty of the free-rider fraction (its magnitude and arbitrary nature of its assesment) it should be decided by the Commission, whether it should be included or not.

Concerning the double counting, it is recommended, (cf. Section 5.2.2. above) to associate the biomass boiler instalation with the facilitating measure in which EEI programme participants must file individual applications (cf. Method 15), and allocate the corresponding energy savings only to this measure (cf. also Method 13a).

One should note that another essential uncertainty is related to Q. In some cases, it will be defined by using intermediate parameters (such as building envelope, building age, etc.).

Selected references

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[4] P. McKendry, "Energy production from biomass (part2): conversion technologies", Bioresource Technology vol. 83 pp. 47 – 54, Elsevier Science Ltd. 2002.

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[7] Paweł Drobnik, "Embedded energy in woody biomass processing", Thesis, AGH, 2007

[8] Antigone Gikas, Rita Keenan, "Statistical aspects of the energy economy in 2005 - Issue number 13/2006"

[9] EcoBoiler study, VHK for European Commission, 2007

Appendix I

Table A1. Correction factors for Eq. 1. The numbers in the Table are in [%]. All are very rough estimates chosen arbitrarily from a range of plausible values.

	ε	α			
		30km	50km	300km	800km
Log wood[12]	0	0	0	6.3	9.6
Wood chips[13]	1.3	0	0	5.8	8.2
Wood briquettes[14]	20.0	0	0	4.1	5.8
Wood pellets[15]	23.2	0	0	4	5.7
Hard pressed straw[16]	0	2.1	3.6	21	56
Medium pressed straw[17]	0	2.9	4.8	28.8	76

The following tables are only included here for the purpose of information.

Table A2a. Energy losses in pellets production in MJ per 1 Mg of manufactured fuel.

Technology [Mg/h]	Electricity consumption [MJ/Mg]	Heat consumption, and chemical energy loses [MJ/Mg]
Pelleting machine 0.25	1106	3460
Pelleting machine 1	1063	3333
Pelleting machine 3	1022	3200

[12] For heating value (HV) 12 GJ/t corresponding to typical season wood. Energy embedded in transportation for shorter distances (up to 300 km) corresponds to trucks with MTW=12t while those for 800km correspond to 27 ton trailer towing trucks. The underlying assumption is that log wood is transported only for energy use.

[13] Corresponding to embedded energy for wet wood (dry wood is seldom chip). Wood chips with heating value of 9 GJ/t.

[14] Corresponds to HV=18GJ/t

[15] Corresponds to HV=19GJ/t

[16] Hard pressed straw corresponds to 110kg per cubic meter and HV=14 GJ/t

[17] Hard pressed straw corresponds to 90kg per cubic meter and HV=14 GJ/t as stated above

Source: Thesis of Mr. Pawel Drobnik “Embedded energy in woody biomass processing”, 2007

Table A2b. Energy losses in briquette production in MJ per 1 Mg of manufactured fuel.

Technology [Mg/h]	Electricity consumption [MJ/Mg]	Heat consumption, and chemical energy loses [MJ/Mg]
Briquetting machine 0.25	1008	2923
Briquetting machine 1	869	2809
Briquetting machine 3	827	2700

Source: Thesis of Mr. Pawel Drobnik, as above

Table A3. Heat value of biomass fuels as possible examples for establishing conversion factor

Fuel	**Moisture content in %**	**Heating value in MJ/kg**	**Heating value in MW/tone**	**Dust content in %**	**Sulfur content in %**
Wet chips	45	9,5	2,6	1,5	0,05
Dry chips	12	16,6	4,6	0,8	0,03
Bark	55	7,3	2,0	3,0	0,05
Willow chips	50	7,9	2,2	2,2	0,02
Wood pellets	10	17,7	4,7	1,5	0,03
Wood briquettes	10	17,7	4,7	2,0	0,03
Straw	15	14,4	4,0	7,0	0,15

Source: http://www.econatura.pl/ date of modification: 5th April 2008

Table A4. Averaged energy consumption in transportation of main kinds of final biomass fuel by road vehicles.

	Truck MTW>3.5t [MJ/Mg*100km]	Truck MTW>7t [MJ/Mg*100km]	Lorre MTW>12t [MJ/Mg*100km]	Trailer towing truck MTW>27t [MJ/Mg*100km]
Log wood	493	362	252	134
Chips<15mm	658	482	337	179
Chips<10mm	617	452	316	168
Chips<8mm	548	402	280	149
Straw-hard compressed	1962	1437	1005	534
Straw-medium compressed	2699	1977	1382	735
Briquette and pellets	493	362	252	134
Averaged fuel demand [dm^3/100km]	14	22	29	40

Source: Thesis of Mr. Pawel Drobnik, as above