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

EMEEES bottom-up case application 6: Domestic Hot Water – Solar Water Heaters

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The Project in brief

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

Consortium

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

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

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1 Summary

1.1 Title of the method

Domestic Hot Water – Solar Water Heaters

1.2 Type of EEI activities covered

End-use EEI action	
Sector	Residential, public, tertiary
Energy end-use	Heating of domestic hot water
Efficient solution	Installation of solar water heaters
EEI Facilitating measure	
Types of EEI facilitating measures	• Financial incentives (all kinds of) • Information tools, focused campaigns, advice • Energy performance contractiong • Obligations to install[1]

1.3 Detailed definition of EEI activities covered

Installation of solar collectors (SCs) for provision of hot water in residential, public and tertiary buildings. The *a priori* applicable facilitating measures are: all kinds of financial incentives, information campaigns, energy performance contracting, and possible mandatory measures (cf. also footnote #1). This method is focused on facilitating measures, where EEI programme participants (physical persons or institutions) need to apply individually to obtain support[2]. There is a great number of such promotion schemes[3], which vary country-by-country or even region-by-region within the particular countries, with a common feature, that they require some kind of documentation that has to be presented by an individual participant to be granted the requested support, either before (an application) or after the investment.

Such documentation - if properly designed in a harmonised way across EU – can be a valuable source of information for the bottom-up estimation of the ESD energy savings.

1 If such obligation is introduced (cf. Spanish Renewable Energy Plan 2005-2010), the proposed method based on Level 3 data collection through harmonised questionnaires will still apply. The role of the questionnaires would be replaced by regulations that would have to be specified in the appropriate technical guidelines.

2 This is in line with the approach of Case application No. 14, where the authors state (page 4): *"if one of the* [relevant facilitating] *measures is a selected promotion of* [an EEI measure]*, and thus the number of participants can be derived bottom-up, e.g. through the monitoring* [and/or application procedure]*, this method does apply and is recommended to be chosen"*.

3 The review of such schemes can be found in [18].

The main advantage is that such process of collection of data will not involve much additional administrative work, except for entering them into an EU-harmonised data base, and the data themselves would be statistically meaningful, due to the way they have been collected.

On the other hand, the *ex post* monitoring (after the investment has been completed) typically requires significant additional work, which would also lead to additional costs.

Therefore, in this contribution it is proposed to combine the case-by-case *ex ante* data (provided by the participant) with the appropriate default or averaged values (EU-wide, national or regional, as applicable), using the same algorithm of processing data towards estimating the ESD savings.

In this way one will avoid the, usually tedious, labour-intensive and – at the same time – (often uncertain or biased) *ex post* measurements or monitoring.

The *ex ante* data that will be required to assess the ESD savings in the proposed approach are limited in number and easy to report by an individual applicant (either a physical person or institution that owns or administers the premises under consideration). As explained in more detail later, these would include:

1. number (or average number) of occupants (or users) that will determine the average volume of domestic hot water used annually[4] in the house (facility) where the solar system is installed. The proposed approach is to take the national *per capita* default values, whenever available (cf. Figs. 1 and 2 in Appendix I).
2. the description of existing hot water delivery system that would include only some basic and easy to identify data:
   - (i) fuel replaced (gas, oil, solid fuel, district heat),
   - (ii) model of the boiler (condensing or traditional, manufacturer),
   - (iii) rated capacity of the boiler,
   - (iv) year of production and installation in the building,
   - (v) other installed hot water sources eligible under ESD (heat pumps, biomass boilers),
   - (vi) information about other energy efficiency improvement programmes, the participant might have benefited from before (or applied for) for the same solar water heater[5].

4 In case of hotels, schools etc., other uses (like swimming pools) will have to be reported separately.

5 For example, in Poland there *a priori* exists a possibility to obtain an investment subsidy and, independently, include the same investment in the package of measures eligible under Thermo Modernisation Act.

3. basic data about the building (facility) where the solar collector is installed:

   (i) size of the building (dimensions), number of floors & rooms
   (ii) number of hot water taps,
   (iii) year of construction

   Those data would enable the evaluator to assign the default values for the in-house installation losses, and enter them into the computer model (see the proposal in Appendix I) to estimate the ESD savings.

4. Parameters of the engineering design (surface, zenith and azimuth angles, efficiency of the collector, all preferably given by the installer). Description of the surrounding area should also be included according to the Table in Appendix II.

1.4 General specifications

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

- Installation of the solar water heater system in the premises of the EEI programme participant.
- Compliance with the respective EU norms (EN 12975-1:2006, EN 12975-2:2006, EN 12976-1:2006, EN 12976-2:2006, ENV 12977-1:2001, ENV 12977-2:2001, ENV 12977-3:2001, EN ISO 9488:1999)

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 all three Levels (1, 2 and 3). The focus is on Level 3 (cf. footnote 1), i.e. on the questionnaire to be provided by the EEI programme participant. The questionnaire should contain relevant pre-installation data, such as hot water consumption (determined be the number of occupants or users), the erstwhile boiler characteristics, etc.

For a given EEI measure, the questionnaire should be harmonised across the EU.

Given that the applications are anyhow evaluated by a *"support-granting institution"* (usually regional), it would entail a little additional cost (if any) and little additional effort. This would boil down to entering the individual data into a computer model. This would be particulary easy if the questionnaires were provided in the electronic form.

The computer model will use a Level 1 (EU wide) algorithm with region-specific (Level 2) subroutines, such as climatological functions, I_d, I_{iso} and I_r, defined in Appendix II.

The most essential Level 2 (regional) parameters are:

- Grid (cold) water temperature, averaged over defined time intervals of the year. The proposal is: March 21 - September 22 (for "summer" season) and September 23 – March 20 (for "winter" season)
- the average *per capita* domestic hot water consumption or, preferrably, an EU-wide default value (to be decided by the European Commission with the ESD Committee)

The Level 1 data would include:

- the default hot water temperature T_1 (see also the second bullet above)
- the values of the parameters characterizing the surrounding (cf. the table in Appendix II).

As mentioned above, EU harmonised procedures of processing the data towards estimating the ESD savings should be elaborated and accepted by all MS. In particular, decision should be made which model for calculating functions I_d, I_{iso} and I_r is used EU-wide.

1.5 Formula for unitary gross annual energy savings

A) The basic assumption is that the ESD savings in provision of domestic hot water are equal to the (physical) amount of *chemical energy, ΔE_0, replaced* by the energy of solar radiation converted by the solar system into heat in the delivered hot water. More specifically, it is the amount of energy used to heat-up the grid water entering the in-house piping system with temperature T_0 (see [14,15]) to increase its temperature to the required hot water temperature T_1 (typically ca 50-60 ^{0}C).

B) The unit considered here for determination of unitary gross annual energy savings is *a participant*, i.e. an individual household (or facility), characterised by the number of occupants, the type of the existing hot water system, the building characteristics and the solar fraction of the solar system installed[6].

[6] One might consider that the natural choice for a unit would be an individual beneficiary of the progamme (a person). However, such choice would present a distorted picture, because the savings depend on the installation characteristics, which are related to a building rather than to a person.

The formula for unitary gross annual energy savings is then:

$$\Delta E_{0,gross} = \Delta E_0 + \Delta E_b - E_{s1} - E_{s2} =$$

$$= (\eta_{cp} / \eta_b \eta_{bp}) N_{occ} \beta\rho \chi v [T_1 - T_0] + \Delta E_b - E_{s1} - E_{s2}, \qquad \text{(S1)},$$

The notation in Eq. (S1) is:

a) ρ – density of water
ρ = 995,64 kg/m^3, corresponding to 30°C (i.e. average value between 10 and 50 °C)

b) χ - specific heat of water, χ = 4190 J/kgK

c) N_{occ} - the (average) number of occupants (or users) of the given house or facility (provided by the participant)

d) ΔE_b - the energy saved annually by the boiler pump (provided by the participant)

e) T_1 - hot water temperature. The proposal is to use: T_1 = 55°C as a default Level 1 value, determined by hygienic requirements (e.g. according to the Polish Standard)

f) T_0 - grid (cold) water temperature. To be determined as Level 2 (regional) technical constant

The value of T_0 is quite critical in the determination of the savings. For instance, according to [14] in Stockholm the cold water temperature varies from 2.1 to 14.9 °C. Even more significant are regional variations of annual averages reported in [15] for the USA.

g) v - the *per capita* default (annual average) volume of hot water, expressed in [m^3/year], usually quoted in the literature (cf. Fig. 2, where the average is 10,22 m^3/year/cap).

h) η_b – rated efficiency of the erstwhile boiler, assumed to be η_b = const. (provided in the questionnaire)

i) η_{bp}, – losses of heat in the in-house hot water installation, leading from the boiler to the tap (provided in the questionnaire)

j) E_{s1} - annual energy consumption by the working medium pump (based on the documentation of the technical project[7])

[7] If such documentation is not available, aproximate values should be used by experts evaluating the application, using default values corresponding to the size of the building.

k) E_{s2} - annual energy consumption by the additional circulation pump (if installed), based on the documentation of the technical project

l) η_{cp} – pipe losses in the additional piping system needed to distribute water heated (preheated) by the solar collector. Those include losses in pipes leading from the solar collector to the (primary) hot water accumulator and between the primary and the secondary hot water accumulator in a cascade system[8] (based on the documentation of the technical project).

m) β - the solar fraction (see Figure 3, Appendix I)

E_{s1} and E_{s2}, as well as ΔE_b, are typically of the order of 10% of the energy needed to heat up the corresponding volume of water. One should note that ΔE_b may roughly cancel with E_{s1} and/or E_{s2}. Consequently, in the first approximation one may neglect the electrical power corrections, although those can be easily accounted for, if the appropriate data are included in the questionnaires.

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

N/A, because the insolation conditions are dramatically different from region to region.

1.7 Formula for total ESD annual energy savings

The proposed methodology is based on the case-by-case data provided by individual participants. Those data are then entered into a database and supplemented there by the appropriate default/average 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

$$E_{0ESD,\,gross} = \Sigma_j \, \Delta \, E_{00,j} \qquad \text{(S2)}$$

[8] It is a common situation that water preheated by solar collector has to be heated up by an auxiliary energy source (e.g. gas or electric boiler)

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

If all correction factors are included, the formula for the total ESD (net) annual energy savings $Q_{ESD,net}$ (in kWh/year) will read:

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

(equation S2)

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

1.8 Indicative default value for energy savings lifetime

The suggested value is 19 years, taken from CEN 15693:2007 and proposed as a harmonised EU value. It will be replaced, if the European Commission with the ESD Committee publishes a list of harmonised lifetimes.

Energy savings lifetime: **EU default/harmonised values**	
EU default	
EU harmonised	19 years, Taken from CEN 15693:2007

This value is based on

CEN 15693:2007

1.9 Main data to collect

Data needed in calculation for <u>EU</u> values (Level 1)	**Corresponding data sources**
Data 1 Hot water temperature	EU (or national) standard value, e.g. 55C
Data 2 Harmonised average *per capita* hot water consumption	Weighted average of national averages[9]
Data 3 Parameters characterizing the	See Ref. [17].

[9] As seen in Fig. 2 the differences beetwen the national averages of hot water use are dramatic. This would mean that taking national averages would favour a lavish use of hot water, which should not be promoted. Therefore a better solution would be to take as harmonised value the EU average (possibly weighted by the population numbers). One can also consider taking a fraction of that value (say 80%).

surrounding	
Data 4 Time intervals for averaging grid (cold) water temperatures	The proposal is: March 21 - September 22 (for "summer" season) and September 23 – March 20 (for "winter" season)[10]
Data 5 EU standarised model for calculation of functions I_d, I_{iso} and I_r of Level 2 (cf. Appendix II)	E.g. anisotropic or isotropic model [16,19]

Data to be collected national values (Level 2)	**Corresponding data sources**
Data 1 Grid water (cold water) temperature averaged over defined periods of time (e.g.months)	Data exist in many cases. If not, they are very easy to collect, see e.g. [14,15]
Data 2 Average *per capita* hot water consumption (if Data 2 in Level 1 is not accepted)	See above
Data 3 Functions I_d, I_{iso} and I_r	Simulation on meteorological files

Data to be collected measure-specific (or participants-specific) (Level 3)	**Corresponding data sources**
Data 1 Number of occupants (or users of building/facility)	Data in the EU-harmonised questionnaire provided by an EEI programme participant (for Data 4 see Ref. [17])
Data 2 Erstwhile boiler characteristics	
Data 3 Building characteristics to include in-door hot water distribution system losses	
Data 4 Characteristic of surroundings for inserting in calculation of I_r function	

Apart from the data, the proposed method heavily relies on the EU harmonised calculation procedures (algorithms).

[10] One could also consider an equivalent to degree-days for the difference between hot water temperature and daily (or weekly) average cold water temperature.

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 6 "Domestic Hot Water – Solar Water Heaters" 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:

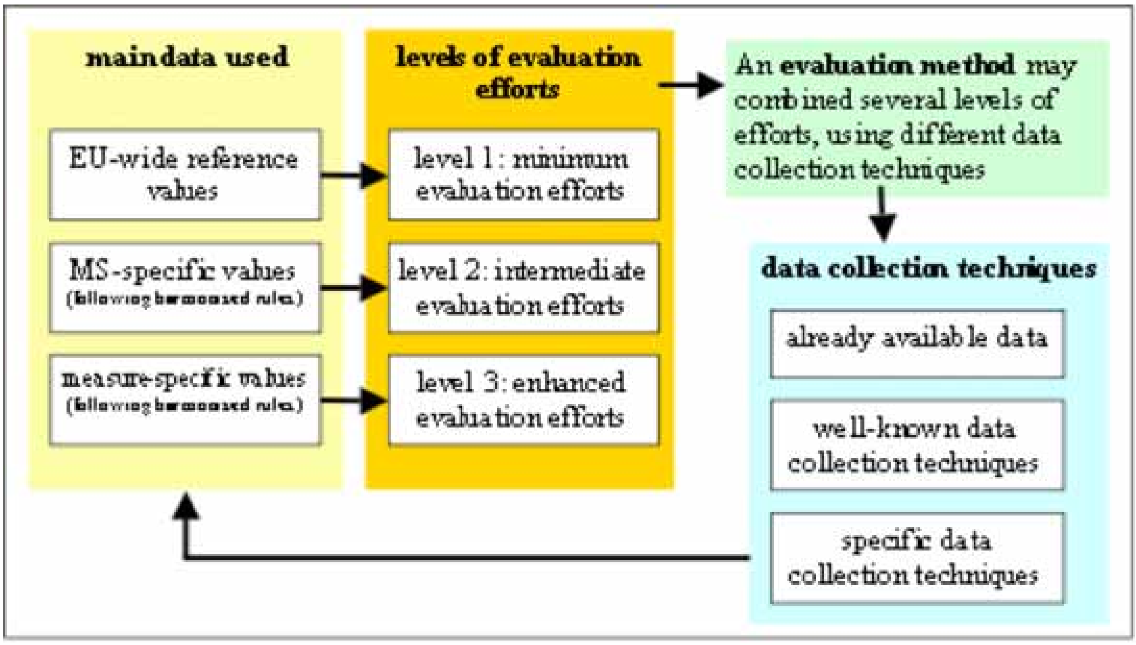
N°	End-use or end-use action, technology, or facilitating measure	Sector	Responsible organisation
1	Building regulations for new residential buildings	Residential	SenterNovem
2	Improvement of the building envelope of residential buildings	Residential	AEA
3	Biomass boilers	Residential	AGH-UST
4	Residential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



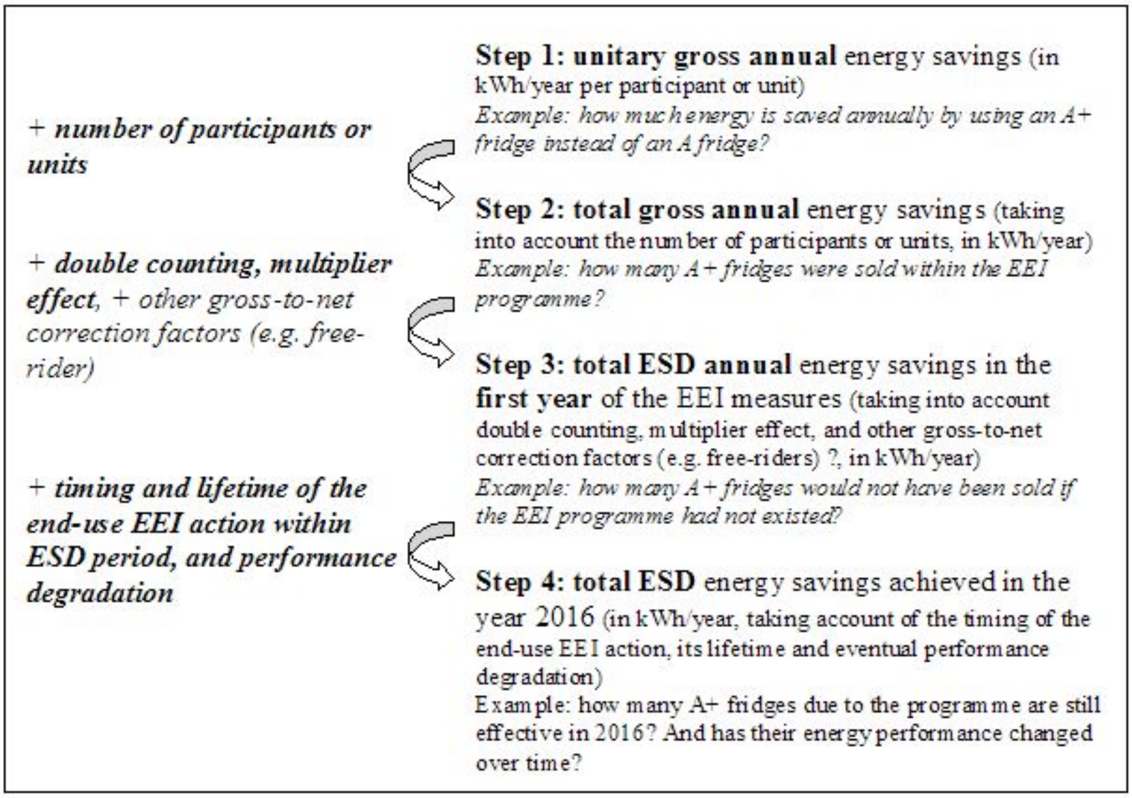
As a consequence, the EMEEES case applications for bottom-up evaluation methods present:

- 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 *Domestic Hot Water – Solar Water Heaters*, the unit is an EEI programme participant (a family living in a given house; public/tertiary building of a specified function; etc.).

unitary gross annual energy savings =

$$\Delta E_{0,gross} = \Delta E_0 + \Delta E_b - E_{s1} + E_{s2} \qquad \text{(equation 1)}$$

with

$$\Delta E_{0,gross} = (\eta_{cp} / \eta_b \eta_{bp}) N_{occ} \beta\rho \chi v [T_1 - T_0] + \Delta E_b - E_{s1} - E_{s2}$$

The notation in Eq. (S1) is:

n) ρ – density of water
ρ = 995,64 kg/m^3, corresponding to 30°C (i.e. average value between 10 and 50 °C)

o) χ - specific heat of water, χ = 4190 J/kgK

p) N_{occ} - the (average) number of occupants (or users) of the given house or facility (provided by the participant)

q) ΔE_b - the energy saved annually by the boiler pump (provided by the participant)

r) T_1 - hot water temperature. The proposal is to use: T_1 = 55°C as a default Level 1 value, determined by hygienic requirements (e.g. according to the Polish Standard)

s) T_0 - grid (cold) water temperature. To be determined as Level 2 (regional) technical constant

The value of T_0 is quite critical in the determination of the savings. For instance, according to [14] in Stockholm the cold water temperature varies from 2.1 to 14.9 °C. Even more significant are regional variations of annual averages reported in [15] for the USA.

t) v - the *per capita* default (annual average) volume of hot water, expressed in [m^3/year], usually quoted in the literature (cf. Fig. 2, where the average is 10,22 m^3/year/cap).

u) η_b – rated efficiency of the erstwhile boiler, assumed to be η_b = const. (provided in the questionnaire)

v) $\eta_{bp,}$ – losses of heat in the in-house hot water installation, leading from the boiler to the tap (provided in the questionnaire)

w) E_{s1} - annual energy consumption by the working medium pump (based on the documentation of the technical project[11])

x) E_{s2} - annual energy consumption by the additional circulation pump (if installed), based on the documentation of the technical project

y) η_{cp} – pipe losses in the additional piping system needed to distribute water heated (preheated) by the solar collector. Those include losses in pipes leading from the solar collector to the (primary) hot water accumulator and between the primary and the secondary hot water accumulator in a cascade system[12] (based on the documentation of the technical project).

z) β - the solar fraction (see Figure 3, Appendix I)

E_{s1} and E_{s2}, as well as ΔE_b, are typically of the order of 10% of the energy needed to heat up the corresponding volume of water. One should note that ΔE_b may roughly cancel with E_{s1} and/or E_{s2}. Consequently, in the first approximation one may neglect the electrical power corrections, although those can be easily accounted for, if the appropriate data are included in the questionnaires.

3.2 Step 1.2: Baseline

The baseline is the individual situatiuon before the installation of a solar water heater, determined basically by the erstwhile boiler, with taking into account Level 1 or Level 2 values when appropriate (as indicated in the table below).

There will be no difference between the baseline for all and additional energy savings. The baseline will also be dynamic automatically, if the individual baseline is taken. If national averages are used (e.g., for erstwhile boiler efficiency), they should be adapted to changes from time to time.

level 1	EU default baseline: • *Per capita* hot water consumption: 10 m^3/year/cap • EU-standard hot water temperature of 55C (or 60C – proposed for consideration); grid (cold) water temperature to be determined at Level 2

11 If such documentation is not available, aproximate values should be used by experts evaluating the application, using default values corresponding to the size of the building.

12 It is a common situation that water preheated by solar collector has to be heated up by an auxiliary energy source (e.g., gas or electric boiler)

level 2	guidelines: *(how to define a MS-specific baseline)* data required: see section 1.9
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: see section 1.9

3.3 Step 1.3: Requirements for normalisation factors

(new) normalisation factor 1a – Seasonal averages of grid (cold) water	
level 1	Averaging cold water temperature over “winter” and “summer” season (see section 1.9).
level 2	n.a.
level 3	n.a.

(new) normalisation factor 1b – Degree-days (or degree-weeks) for domestic hot water	
level 1	n.a.
level 2	guidelines: *(how to include the normalisation factor in calculation model or how to calculate a level 2 coefficient of normalisation)* Either average cold water temperature averaged in two time intervals: March 21 - September 22 (for “summer” season) and September 23 – March 20 (for “winter” season). Else, one could consider use a number equivalent to degree-days, calculated for the difference between standarised hot water temperature and daily (or weekly) average cold water temperature. data required: as specified in 1.9
level 3	n.a.

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 based on Level 2 and <u>aggregated</u> Level 3 data, with level 1 harmonised value for hot water use per year.
level 2	Mix of deemed and ex-post: national average values for some parameters (cf. section 1) based on the creation of national databases of: • ESD savings results, corresponding to a particular EEI facilitating measure for evaluation, planning and possible improvement • input values, reported in the questionnaires for research and planning
level 3	Enhanced engineering calculation, with the use of EU harmonised questionnaire

3.4.1 Conversion factors

n.a. (no special conversion factors needed, ESD Annex II is valid for the replaced fuels)

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 direct rebound effect is automatically eliminated by referring the savings to the average annual *per capita* consumption of hot water defined at the EU-standard level. In this way, any savings that would otherwise be attributed to the excess hot water above this ceiling will not be counted as ESD savings.

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

- *Per capita* hot water consumption: 10 m^3/year/cap (proposed)
- Standard hot water temperature (T_1) of 55C (or 60C – proposed for consideration); grid (cold) water temperature (T_0) determined at Level 2

3.4.3.2 Requirements to define level 2 and level 3 values

As described in the Table in Section 1.9.

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:

$$E0_{ESD,\ gross} = \Sigma_j \Delta E0_{0,gross,j} \qquad \textbf{(2)}$$

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 methodology is based on the case-by-case data provided by individual participants. Therefore, the accounting for the number of actions is trivial. Those data are then entered into a database and supplemented there by the appropriate default/average values needed for Eq.(1).

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 (Eq.(2) above).

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 annual savings

If all correction factors are included, the formula for total net ESD annual energy savings, corrected for the free-rider, α_{fr}, multiplier effect, ω_{me}, and double-counting, ζ_{dc}, factors will read:

$$\Delta E_{ESD,net} = \Delta E_{0,gross,total} * (1 - \alpha_{fr} + \omega_{me}) * \zeta_{dc} \quad (3)$$

where α, ω, ζ are in the interval (0, 1). Their particular values are discussed below following the approach of case application 12 on electric motors.

5.2 Step 3.2: Requirements for avoiding double counting

EMEEES case application 12 suggests the following approach:

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

This approach will be perfectly applicable in the method proposed here. As it is suggested, the Level 3 data should converge at the "*National ESD Evaluation Centres*" (one per MS, e.g., the authorities according to article 4(4) ESD), where corrections for ω and ζ could be estimated. Otherwise, following again the case application 12:

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 favoured. 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

$$\zeta = 1$$

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

$$\Delta E_{ESD,net} = \Delta E_{0,gross,total}$$

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

5.3 Ste p 3.3: Requirements for taking account of technical interactions

The candidates for technical interaction eligible in ESD according to its Annex III are:

- under item (a) - heat pumps
- under item (g) - solar systems (mentioned explicitly as examples) and – one should understand, based on the same underlying principle – water saving faucets, individual hot water meters in multifamily blocks of flats, hotels etc, resistance heating of domestic hot water based on wind or small (micro) hydro electricity, or notably, domestic biomass boilers providing also domestic hot water.

Those, however, can be easily accounted for on the basis of information provided by the program participant in the questionnaire in the evaluation procedure outlined above and in Annex I.

According to Polish experience, e.g., it would be particularly valuable to include as examples, the programs targeting installation of individual grid water metering and biomass boilers.

5.4 Step 3.4: Requirements for multiplier energy savings

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

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.

The proposal is to make an *ex post* anonymous inquiry asking one “YES/NO” question whether the participant would have installed the collector without the EEI programme. Technically, it could be done by mailing a small questionnaire to a sample of participants (possibly to all, the cost wouldn’t be high) with an addressed and prepaid return envelope. The questionnaire could also include questions helping to evaluate the multiplier effect, e.g. : “if you moved to another house would you install a solar collector in absence of the programme?” “Why?”

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 19 years and proposed to be taken as a harmonised EU value according to CEN 15693:2007. It will be replaced, if the European Commission with the ESD Committee publishes a list of harmonised lifetimes.

However, the estimates of the lifetime of the solar water heaters vary significantly from ca. 10-15 years [20] to 20 years [21].

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.

If early savings are admited they could be counted as from

$$T<T_{i-19} \qquad (6)$$

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

6.3 Reminder to treat uncertainties

In general, evaluation of savings involves uncertainties on imput parameters except for physicall constants or 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 procedures. 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.

Using the standard approach, the uncertainty of the total savings can be estimated as:

$$\delta\Delta E_{0,gross,total} = \sqrt{\frac{\sum_{j}^{N_p} \left(\delta\Delta E_{0,gross,j}\right)^2}{N_p(N_p - 1)}} \quad \textbf{(7)}$$

where N_p is the number of EEI programme participants and $\delta\Delta E_{0,gross,j}$ can be calculated by using the standard error propagation (cf. Method 5 b, section 6.3).

The biggest uncertainty is then asociated with the solar fraction β.

Following the remarks in sections 3.4.2 and 5.2, the errors related to the direct rebound effect and the double counting effect in the proposed method are eliminated or reduced to a negligible level.

Concerning 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 is to be included or not. The problem is that too big uncertainties may discredit the whole ESD evaluation effort, and negatively influence the public perception of the relevance of the ESD directive in general.

Concerning the double counting, it is recommended, (cf. Section 5.2.2. above) to associate installation of the solar water heater with the facilitating measure in which EEI programme participants must file individual applications (cf. Case application 14), and allocate the corresponding energy savings only to this measure (cf. also Case application 12).

7 Appendix I:

The exact formulae for calculation the unitary gross annual savings involve a number of factors and parameters, which are difficult to be reliably identified/quantified by the individual applicant or even to be found in the literature. However, bearing in mind that the ESD reporting has to be a compromise between accuracy and feasibility, it is enough to use simplified formulae and simplifying assumptions, provided they are clearly specified and possibly well understood.

In order to understand those simplifying assumptions, leading to the final formula, let us first start with a rather general equation for the chemical energy used for heating of domestic water over a year by the existing boiler (that will be substituted or supplemented by a solar system). It is given by the integral over instantaneous time, τ, covering one full year:

$$E_0 = \int \varepsilon(\tau)/\eta(\tau)\, d\tau,$$

where

$$\varepsilon(\tau) = \rho\, \chi\, V(\tau)\, [T_1 - T_0(\tau)]; \qquad (1)$$

with $V(\tau)$ being the instantaneous flux of water in m^3/s, and ρ and χ are density and specific heat of water, respectively.

One should note that T_0 varies seasonally and with the location of the source feeding the grid, while T_1 is determined by the normative values that vary between Member States.

$\eta_1(\tau)$ is the efficiency of the system (including the boiler and the in-house distribution installation)

$$\eta_1(\tau) = \eta_b\, \eta_{pb}(\tau) \qquad (2)$$

η_b being the rated efficiency of the boiler, which one can reliably assume to be η_b = const over the year under consideration.

$\eta_{pb}(\tau)$ reflects the losses of heat in the in-house hot water installation, leading from the boiler to the tap, which may, in principle, vary with outdoor temperature (i.e. with time τ) in poorly insulated systems. However, in practice, one can assume with a good approximation, that the fluctuations are relatively small and $\eta_{pb}(\tau)$ can be replaced by its annual average $<\eta_{pb}(\tau)>$ = const = η_{pb}, to be determined by experts in the particular countries or regions. The table below taken from [3] shows the examples for the Netherlands. The Member States should be encouraged to propose their default values for given categories of buildings[13] .

Table 1. Sanitary hot water distribution efficiency (MEN 5128:2004)

Length of pipe [m]	0-2	2-4	4-6	6-8	8-10	10-12	12-14	>14
kitchen								
Piping =< 8mm internal diameter over 2/3 of its length	1,00	0,86	0,75	0,67	0,60	0,55	0,50	0,46
Piping =< 10mm internal diameter over 2/3 of its length	1,00	0,79	0,65	0,55	0,48	0,43	0,38	0,35
Piping > 10mm internal diameter over 2/3 of its length	1,00	0,69	0,53	0,43	0,36	0,31	0,27	0,24
bathroom								
all	1,00	0,95	0,90	0,86	0,82	0,78	0,75	0,72

If one assumes additionally that the fluctuations of $V(\tau)$ and $T_0(\tau)$ are small, which is an acceptable approximation, Eq. 1 becomes

$$E_0 = \rho\, \chi\, V\, [T_1 - T_0]/\eta_1, \qquad (3)$$

V being the total volume of hot water used annually by a participant

$$V = \langle V(\tau)\rangle\, \Delta\tau \qquad (4)$$

The brackets <> representing the average over time and $\Delta\tau$ the 365 days of the year. In the present contribution it is assumed that V is equal to

$$V = v\, N_{occ} \qquad (5)$$

where v is the *per capita* default (annual average) volume of hot water, expressed in [m^3/year], usually quoted in the literature (cf. Fig. 2).

N_{occ} is the number (possibly an average number) of occupants of the given house or facility.

The number needed for the ESD savings is the amount of energy, ΔE_0, replaced by the of the solar radiation. It is primarily determined by the *solar fraction,* β, which is given by (cf. Fig 3):

$$\beta = \left[\int_{\tau 0}^{\tau 1}\varphi(\tau)\eta_2(\tau)\, d\tau + \int_{\tau 2}^{\tau 365}\varphi(\tau)\eta_2(\tau)\, d\tau + (\tau_2 - \tau_1)D\right] / \left[D(\tau_0 - \tau_{365})\right] \qquad (6)$$

[13] This assumption has been implicit in the EMEEES bottom-up case application on condensing boilers, where it is largely justified, because as a rule the space heating pipes are typically well insulated. This is not necessarily the case for the hot tap water in the older buildings, especially in the New Member States.

where:

D is the average demand for hot water expressed in kilowatts [kW] needed for heating the grid water

$$D = \rho \chi V [T_1 - T_0] / \Delta\tau \quad (7)$$

$\varphi(\tau)$ is the instantaneous energy flux of solar radiation - (method of calculation is explained in Annex II).

$\eta_2(\tau)$ is defined as in Eq. (2) of this Appendix with the difference being that $\eta_b(\tau)$ is now understood to be the analogous efficiency for the solar collector, $\eta_c(\tau)$ (including the geometry, positioning, material; and design characteristics of the collector).

$$\eta_s(\tau) = \eta_c(\tau)\, \eta_{cp}, \quad (8)$$

η_{cp} describes the losses corresponding to η_{bp} in Eq. 2 which need not to be the same as for the boiler system, because additional losses appear on the way from the collector to the solar hot water tank (accumulator) and when the boiler and the accumulator are significantly separated and an additional circulation system has to be added.

Fig. 3 illustrates a typical situation in most of the EU countries. As it is seen,

$$\beta \le 1 \quad (9)$$

In other words, with a given demand for hot water, some of the solar energy is not used (usually, or mostly, in summer time). Increasing β (bigger, i.e. more expensive collector) increases the blank area above the D = const line, which in fact, means stranded costs for the investor. This situation is illustrated in Fig. 4, which shows the physical efficiency of the solar system (fraction of solar energy converted into heat, relative to total solar energy impinging on the collector) versus solar fraction β. The higher the β, the lower the system efficiency defined as above. The solar fraction β varies depending on insolation (see Annex II) and the pattern of use of domestic hot water. Some representative vales are given in [12, 13].

The solar fraction β could be, in principle, determined in the technical project of the installation, which, however, would be a too complicated task for the individual installer (see Annex I). Moreover, one can assume that installers may tend to overestimate β, which may lead to over sizing the collectors. In the opinion of the authors, the ESD evaluation methodology should not favour such situations, as it would lead to excessive use of hot water or to the waste of absorbed heat.

According to ESD, the total annual unitary raw gross energy savings are given by the energy substituted by the solar system

$$\Delta E_0 = \beta \; D \, \Delta\tau / \eta_1 = N_{occ} \, \beta\rho \, \chi \, v \, [T_1 - T_0] / \eta_1 \, , \qquad (10)$$

The efficiency η_1 in the denominator of Eq. 10 accounts for the fact that the existing boiler uses more input energy than the energy transferred into water, and these are exactly the ESD savings one is looking for. If the solar fraction β is not given in the application form, or if it only refers to the given type of collector, i.e. without taking into account the in-house distribution losses (while taking into account only the physical conversion efficiency of the collector itself), the final equation (10) becomes

$$\Delta E_0 = \beta \; D \, \Delta\tau / \eta_1 = (\eta_{cp} / \eta_1) \, N_{occ} \, \beta\rho \, \chi \, v \, [T_1 - T_0] \, , \qquad (11)$$

In this contribution it is proposed that the annual *per capita* value, v, is the national (or EU) default value, which reflects the average *per capita* use of domestic hot water prior to installation of the solar system[14].

The raw savings have to be corrected for the electrical energy needed to operate the solar system, which is the energy needed to pump the working medium from the solar collector to the accumulation tank, and – possibly – the additional pump for circulation of the heated water. If the erstwhile boiler requires some kind of electrical support, this should also be taken into account.

Consequently,

$$\Delta E_{0,gross} = \Delta E_0 + \Delta E_b - E_{s1} - E_{s2} =$$

$$= (\eta_{cp} / \eta_b \, \eta_{bp}) \, N_{occ} \, \beta\rho \, \chi \, v \, [T_1 - T_0] + \Delta E_b - E_{s1} - E_{s2} \, , \qquad (12),$$

where ΔE_b is the energy saved annually by the boiler pump; E_{s1} and E_{s2} reflect annual energy consumption by: working medium pump and the additional circulation pump (if installed), respectively.

One should note that, typically, E_{s1} and E_{s2}, as well as ΔE_b, are of the order of magnitude of 10% of the energy needed to heat the corresponding amount of water. One should note that ΔE_b may roughly cancel with E_{s1} and/or E_{s2}. Consequently, in the first approximation one may neglect the electrical power corrections, although those can be easily accounted for, if the

[14] As explained in chapter 3 under the disturbing effects section, such an assumption means, in particular, that the direct rebound effect is automatically taken into account.

appropriate pieces of data are included in the questionnaire provided by the participants.

The above equation determines the data needs, which are the following:

aa) ρ, χ - physical constants
ρ = 995,64 kg/m^3, corresponding to 30°C (i.e. average value between 10 and 50 °C)
χ = 4190 J/kgK

bb) N_{occ} , E_b - provided by the participant

cc) T_1 - default Level 1 value. We propose T_1 = 55°C as determined by hygienic requirements (e.g. according to the Polish Standard)

dd) T_0 - regional/national technical constant

The value of T_0 is quite critical in the determination of the savings. For instance, according to [14] in Stockholm the cold water temperature varies from 2.1 to 14.9 °C. Even more significant are regional variations of annual averages reported in [15] for the USA.

Therefore, considering high sensitivity of ESD savings to this parameter, our proposal is to determine those values at level 2 (regional), as it is proposed in Annex I

ee) v - per capita national default or average value (alternatively an EU common default value)

ff) η_b, η_{bp}, - drawn from data provided by the participant about the boiler and building

gg) E_{s1}, E_{s2}, η_{cp} – based on the documentation of the technical project

hh) β - calculated from eq. (6) (see also Annex I)

CONCLUSION:

The proposed evaluation approach is relatively accurate and cost-effective, mainly because it does not require individual, *ex post* measurements or monitoring. It is also feasible, provided a EU wide system is designed, based on:

- mandatory, harmonised questionnaires
- provision (elaboration) of EU-wide computer Level 1 algorithm/model for evaluation of ESD savings, with regionally defined parameters or functions (like the *I-functions* of Annex II to this Appendix)

Those would be facilitated by establishing ESD Savings Evaluation Centres that would proceed the collected data towards ESD savings. Those, in fact, need not be any new structures, as the support granting institutions do most of such work anyhow. However, in the age of internet, we would support the idea of having one such dedicated centre per MS[15], and one "umbrella" EU centre. Indeed, such harmonised estimates would be of great value for the EU and National decision-making, not to mention its value for research.

[15] There are reports that some of the investments in solar water heating are grossly ineffective and will never pay back, despite of significant public subsidies, nor will they lead to any remarkable CO_2 emission reduction. Realization of the concepts outlined above based on more centralised and specialised project evaluation would help to eliminate such cases and reduce the waste of public money.

8 References (and sources):

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9 Figures to the Appendix

Fig. 1 – *per capita* hot water demand defined in the selected national building standards (NL, UK, DE, ES, PT, FR) [3]

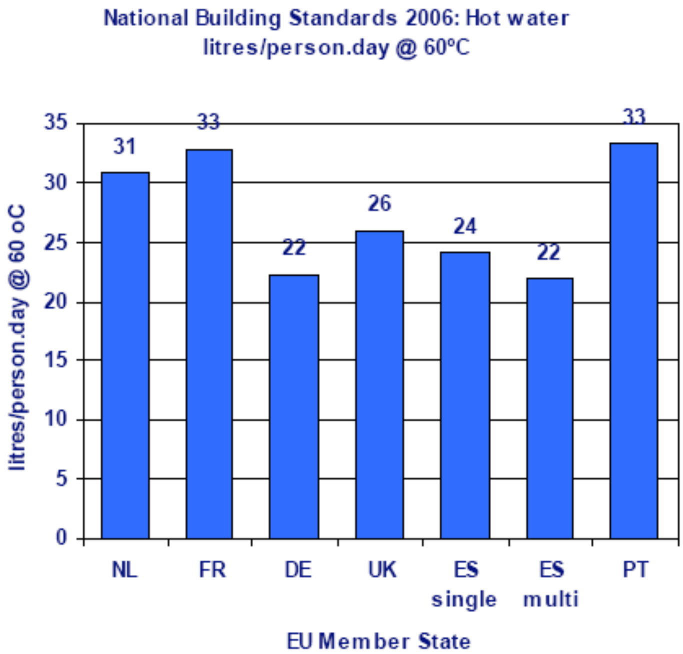


Fig. 2 – estimated *per capita* demand for domestic hot water in the EU-25 countries showing great differences between Member States [3]

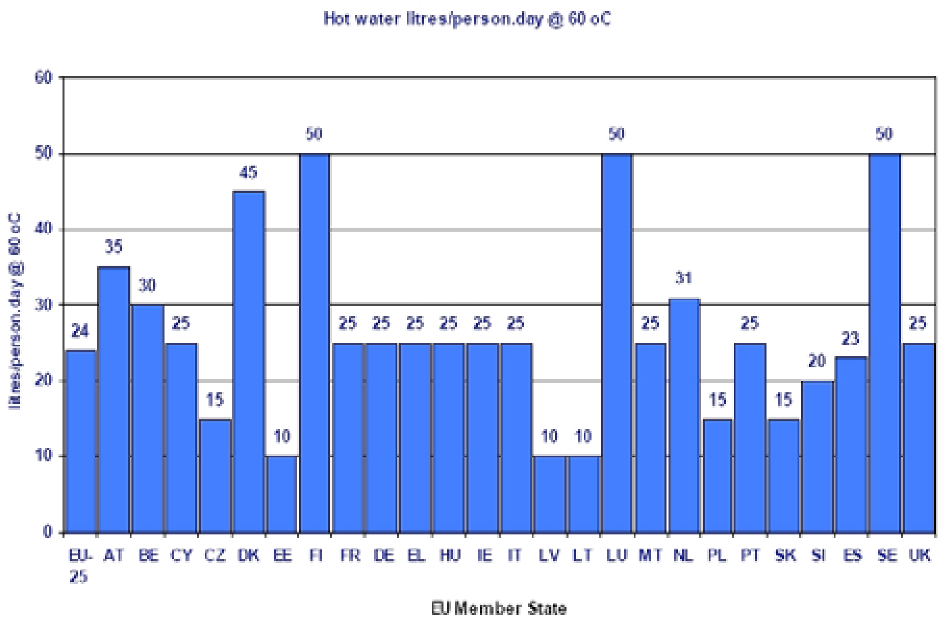


Fig. 3 – solar energy yield for different temperatures (illustrative)

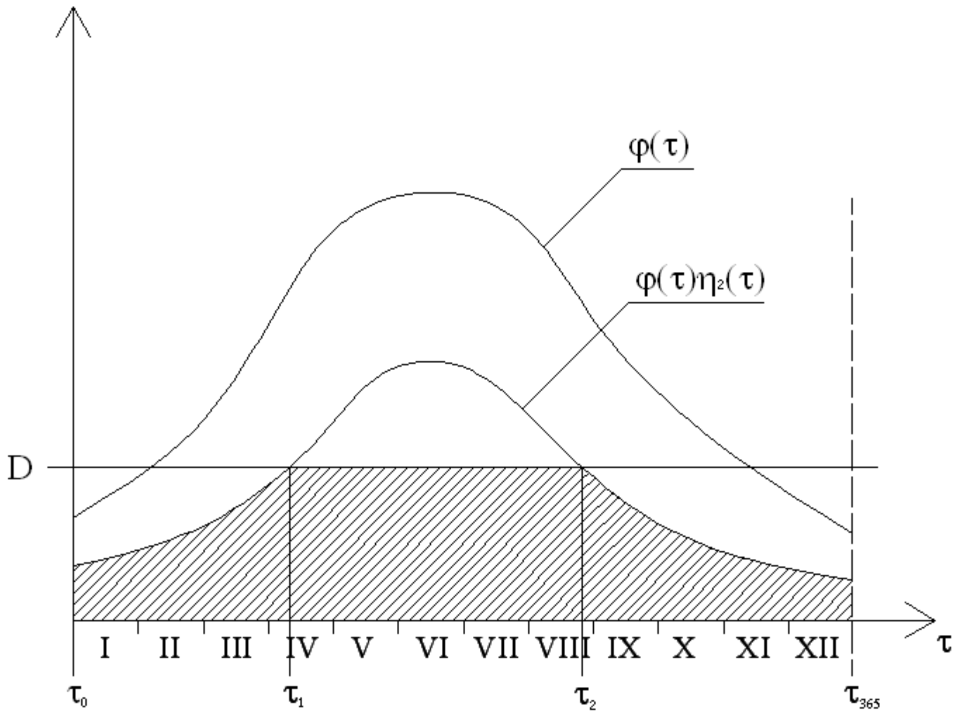


Fig. 4 – solar system efficiency vs. solar fraction [11]

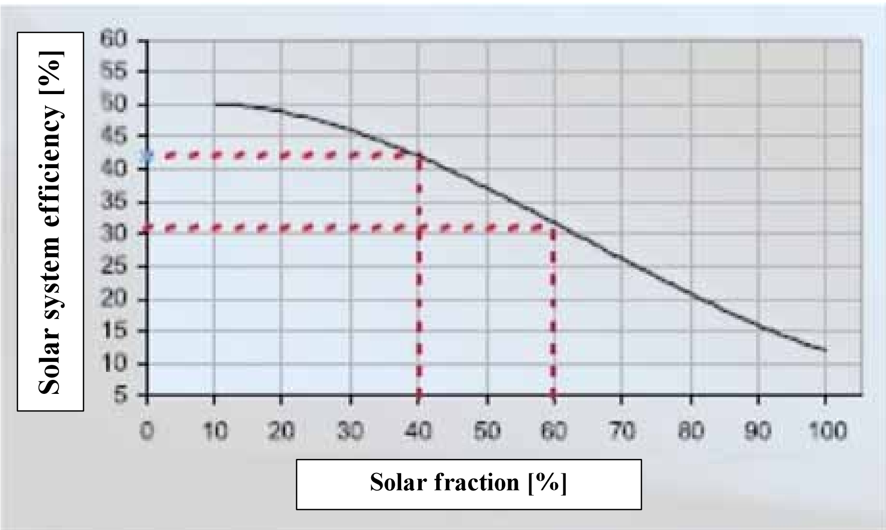
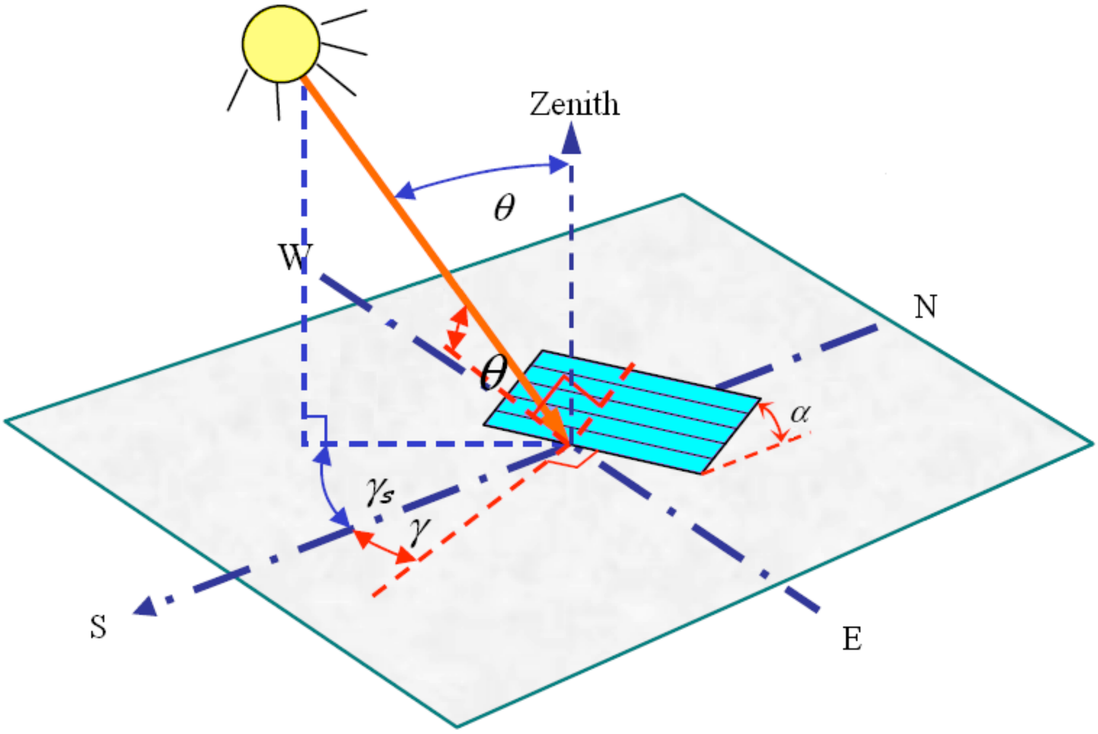


Fig. 5 – basic relations between position of the Sun and defined surface



Annex I to Appendix I

In its essence, the proposed evaluation method applies to all kinds of EEI facilitating measures, which consist of giving support to individual EEI programme beneficiaries.

The basic rationale is that such support is granted on the basis of an application of the candidate beneficiary, whereby it is very easy and cost effective to gather the essential data that will enable the evaluator (ESD savings "estimator") to make relatively reliable estimates, based on those individual data, combined with the appropriate default data or parameters.

The method relies basically on the Level 3 data collected from each programme participant by the way of a questionnaire that will be a mandatory attachment to the application for the support. For the solar collectors the data to be collected are listed in Section 1 above.

For a given end-use Action the questionnaire can and should be harmonised across the EU, in other words, it should be the same questionnaire.

Given that the applications are anyhow evaluated by a "support granting institution" (usually regional) it is a little-cost effort (or no additional cost effort) to enter those individual data into a computer data base, and a dedicated computer model (see below), especially if the questionnaires are provided (also) in an electronic form.

The computer model will be a Level 2 (regional) model based on the formulae which will typically contain regional parameters or regionally defined functions.

In our case the functions in need of regional definition are functions I_d, I_{iso} and $I_{r,,}$ Those should be made available to the (regional or national) ESD savings evaluation centres (or responsible units), wherever they exist, while in regions they do not exist yet, they should be determined, which is important also for several other reasons.

The most essential Level 2 (regional) parameter is grid water temperature. The other Level 2 (national) parameter is the average *per capita* domestic hot water consumption.

The Level 1 data and procedures would include in our case:

- the default hot water temperature T_1
- the values of the parameters in the table in the Appendix II
- decision on which model for calculating functions I_d, I_{iso} and I_r is used EU-wide.

Annex II to Appendix I

The instantaneous energy flux of solar radiation, $\varphi(\tau)$, is a product of energy of solar radiation I, falling on 1 m^2 in a given time (hour, day, etc.), and area of the solar collector A.

$$\varphi(\tau) = I(\tau) \cdot A$$

Solar radiation consists of: direct radiation I_d, dispersed isotropic radiation I_{iso}, dispersed circumsolar radiation I_c, dispersed bright horizon radiation I_{bh}, and reflected radiation I_r.

$$I(\tau) = I_d(\tau) + I_{iso}(\tau) + I_c(\tau) + I_{bh}(\tau) + I_r(\tau).$$

In literature, there is a great number of various, more or less complicated, mathematical models, which allow one to calculate solar radiation impinging on a defined area, characterised by surface and orientation (zenith and azimuth angle – see Fig. 5). One of the first methodologies – isotropic model of radiation – was proposed by Liu and Jordan in 1963 [19], who took into consideration only I_d, I_{iso} and I_r, and introduced appropriate correction factors *R*.

$$I(\tau) = I_d(\tau) \cdot R_d(\tau) + I_{iso}(\tau) \cdot R_{iso} + (I_d(\tau) + I_{iso}(\tau)) \cdot \rho_r \cdot R_r,$$

where: $R_d(\tau)$, R_{iso}, R_r – are correction factors for, respectively, direct, dispersed and reflected radiation; ρ_r – reflectivity of basis (non-dimensional coefficient of reflection).

R_{iso} and R_r are function of inclination angle α of surface (solar collector), while R_d is a function of latitude ϕ, inclination angle α, azimuth angle γ, solar declination $\delta(\tau)$ and meridian angle $\omega(\tau)$.

$$R_{iso} = \frac{1+\cos\alpha}{2},$$

$$R_r = \frac{1-\cos\alpha}{2},$$

$$R_b(\tau) = f(\phi, \alpha, \gamma, \delta(\tau), \omega(\tau)).$$

The general formula for correction factor for direct radiation is:

$$R_b(t) = \frac{\sin(\delta(t))[\sin(\phi)\cos(\alpha) - \cos(\phi)\sin(\alpha)\cos(\gamma)]}{\sin(\delta(t))\sin(\phi) + \cos(\delta(t))\cos(\phi)\cos(\omega(t))} +$$

$$+ \frac{\cos(\delta(t))[\cos(\phi)\cos(\alpha)\cos(\omega(t)) + \sin(\phi)\sin(\alpha)\cos(\gamma)\cos(\omega(t)) + \sin(\alpha)\sin(\gamma)\sin(\omega(t))]}{\sin(\delta(t))\sin(\phi) + \cos(\delta(t))\cos(\phi)\cos(\omega(t))}$$

Exemplary values of coefficient of reflection ρ_r are listed in the table below:

Surrounding	Coefficient of reflection ρ_r
Forest	0,03-0,10
Grass	0,14-0,37
Ground	0,07-0,20
Black Soil	0,08-0,14
Sand (dry)	0,18
Sand (wet)	0,09
Concrete	0,25
Asphalt	0,10
Snow/ice	0,46-0,87

Source: [17]

I_d, I_{iso} and I_r are influenced by local/regional conditions (mainly meteorological) and must be defined as appropriate local/regional default values.

Our proposal is to have those values determined for every region under consideration and use them to calculate φ and hence the solar fraction β.

In fact, such data do often exist and the only problem would be to make them available and usable for the purposes of ESD evaluation, preferably by specialised regional units dealing with the applications.