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

Task 4.2: harmonised bottom-up evaluation methods; Method 20, Energy Audits

Final draft for consultation

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evaluate energy savings EU

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)	D
Agence de l'Environnement et de la Maitrise de l'Energie (ADEME)	F
SenterNovem	NL
Energy research Centre of the Netherlands (ECN)	NL
Enerdata sas	F
Fraunhofer-Institut für System- und Innovationsforschung (FhG-ISI)	D
SRC International A/S (SRCI)	DK
Politecnico di Milano, Dipartimento di Energetica, eERG	I
AGH University of Science and Technology (AGH-UST)	PL
Österreichische Energieagentur – Austrian Energy Agency (A.E.A.)	A
Ekodoma	LV
Istituto di Studi per l'Integrazione dei Sistemi (ISIS)	I
Swedish Energy Agency (STEM)	S
Association pour la Recherche et la Développement des Méthodes et Processus §Industriels (ARMINES)	F
Electricité de France (EdF)	F
Enova SF	N
Motiva Oy	FIN
Department for Environment, Food and Rural Affairs (DEFRA)	UK
ISR – University of Coimbra (ISR-UC)	P
KE Marked A/S (KEM)	DK
Centre for Renewable Energy Sources (CRES)	GR

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1 Summary

1.1 Harmonised bottom-up evaluation methods; Method 20, Energy Audits

1.2 Type of EEI activities covered

End-use (EEI) action	
Sector	Industry, tertiary
Energy end-use	Various uses
Efficient solution	Investments in energy efficient technologies or better operation and maintenance due to improved information base. In this report the different End-use (EEI) Actions made in audited facilities are being referred to as “improvement actions”.
(EEI) Facilitating measure	
Types of (EEI) facilitating measures	Energy audit programmes or energy audit obligations (or energy audits provided as commercial energy efficiency services)

1.3 Detailed definition of EEI activities covered

According to ESD Article 3(l), ‘energy audit’ is “a systematic procedure to obtain adequate knowledge of the existing energy consumption profile of a building or group of buildings, of an industrial operation and/or installation or of a private or public service, identify and quantify cost-effective energy savings opportunities, and report the findings.”

There is energy auditing in one form or another in most countries in Europe. However, details vary:

- Some of the activities are pure energy audit programmes run at national, regional or local level by governments, energy agencies, local authorities and energy companies. In some activities, e.g. energy certification of buildings, the certification document may, in practice, be a summary sheet of an energy audit. Energy audits can also be found as one of the core elements in broader schemes, e.g., energy management schemes.
- Several different ways of performing energy audits can be found in Europe. An energy audit may cover a site or a building in various ways – the scope of audits may be different. At the “narrowest” an energy audit covers typically only one specific system (or a process), and at the “widest”, an energy audit covers everything inside the site fence.

- In some cases, the audit client himself carries out the inspection using protocols developed by the Operating Agent/Programme Manager, whereas in some cases audits are carried out by specialists following a protocol or without one. (Audit II, Monitoring and Evaluation)

More detailed information on energy audit types can be found in Appendix II, Taxonomy of energy audit methods and Appendix III, Energy audit programmes in Europe.

1.4 General specifications

1.4.1 Choosing the calculation level

For energy audits, the level of calculation depends on the level of sophistication of the monitoring system and the data it provides. When monitoring is almost non-existent, calculations will be made using default values. If actual monitoring data is available, evaluation can be made at level 2 or 3. Given the highly conservative default values for level 1, there is a clear incentive to opt for levels 2 and 3.

The uncertainties related to the savings achieved can be reduced significantly by quality assurance of the audits. If no quality assurance is done, calculations particularly at level 1 are void. In other levels, at least when estimated savings exceed a certain proportion of national total ESD energy savings target, a national quality assurance program is necessary. It is proposed to set the threshold at 5%.

If the energy savings achieved by the audit programme exceed a certain percentage of the total national ESD savings target, calculations should allways be made at level 2 or 3. It is proposed to establish the threshold at 10% of the indicative ESD national energy saving target.

The overall level of evaluation (level 1 to 3) is principally determined by the calculation method chosen in Step 1.4. For example, if the monitoring system allows level 3 calculations but some data used complies only with level 1 requirements (e.g. lifetimes), the level of evaluations can still be interpreted to conform to level 3.

1.4.2 Calculation formulas for the three levels

The following general calculation formula is used for estimating energy savings by energy audits:

total gross annual energy savings =

$$\sum_{i=1}^{n}[\text{annual energy savings of industrial participant i}] + \sum_{i=1}^{n}[\text{annual energy savings of tertiary participant i}]$$

The total gross annual energy savings are the sum of energy savings of all participants (energy audits) in a given year. The “elementary unit of action” is one energy audit which corresponds to one participant with its energy savings arising from several improvement actions. Separate calculation formulas have been formulated for estimating the annual energy savings by one participant at levels 1, 2 (two approaches) and 3.

Level 1

The annual energy savings (GWh/a) to be realised by one energy audit (participant) are calculated as follows at level 1:

Annual energy savings of one participant [GWh/a] =

$$= DV_{h,f}(\text{heat+fuels}) * AC(\text{heat+fuels}) + DV_e(\text{electricity}) * AC(\text{electricity})$$

where:

- DV_e = EU default value for electricity savings, %
- $DV_{h,f}$ = EU default value for heat and fuel savings, %
- AC = annual energy consumption (GWh)

Level 2, Approach A

The energy savings (GWh/a) to be realised by one energy audit (participant) are calculated as follows at level 2 in Approach A:

Annual energy savings of one participant [GWh/a] = AS(heat+fuels) + AS(electricity)

where:

- AS = annual energy savings of the participant realised as a consequence of the energy audit and collected through a survey of participants (GWh/a)

Note: **we propose that** this method should only be allowed for past but recent energy audit schemes, if Level 2, Approach B or Level 3 is not possible, i.e., no database of energy savings potentials identified in audits exists yet.

Level 2, Approach B

The annual energy savings (GWh/a) to be realised by one energy audit (participant) are calculated as follows at level 2 in Approach B:

Annual energy savings of one participant [GWh/a] =

$$= DV_{h,f}(heat+fuels)*TSP(heat+fuels) + DV_{e}(electricity)*TSP(electricity)$$

where:
- DV_e = EU default value for the share of the electricity savings potential implemented, %
- $DV_{h,f}$ = EU default value for the share of the heat and fuel savings potential implemented, %
- TSP = total annual energy savings potential of the participant identified in the energy audit (GWh/a)

Level 3

The annual energy savings (GWh/a) to be realised by one energy audit (participant) are calculated as follows:

Annual energy savings of one participant [GWh/a] =

$$= DI(heat+fuels)*TSP(heat+fuels) + DI(electricity)*TSP(electricity)$$

where:
- DI = individual degree of implementation of the TSP by the participant, %
- TSP = total annual energy savings potential of the participant identified in the energy audit (GWh/a)

The degree of implementation (DI) by one participant in the above formula is calculated as follows:

$$\text{Degree of implementation } DI\ [\%] = I+D+a*C$$

where:
- I= implemented actions , D=actions decided to be implemented, C=actions under consideration (%)
- a=0.05 for actions in industry
- a=0.3 for actions in the service sector

1.5 Indicative default value for annual unitary energy savings

Energy audits are not one single energy efficiency improvement action. Instead, as a consequence of energy audits, several improvement actions are proposed and some of them are implemented. In EMEEES terminology, an energy audit is an (EEI) facilitating measure which consists of numerous end-use (EEI) actions.

The results achieved through energy audits vary significantly by country depending on the starting level of energy efficiency, the type of energy audit used, the type of audited facility and interaction with other (EEI) facilitating measures. Saving potentials reported by some individual Member Countries range from 3% to 20–30% of the audited facility's energy consumption depending on, e.g. the type of energy concerned (electricity or heat and fuels) and the sector (industry or tertiary). The degree of implementation of the proposed improvement actions (end-use (EEI) actions) varies as well.

Despite the above difficulties, very conservative European default values for level 1 calculation (see Table 1) have been proposed in this report as a percentage of energy consumption of the audited facilities (or of the audited processes in the case of System Specific Energy Audit). The default values are based on the results achieved in the Finnish Energy Audit Programme. The proposed default values amount to approximately one third of the actual savings achieved in Finland

Table 1 – Proposed level 1 default values for average energy savings achieved by energy audits (% of annual energy consumption)

Sector	Savings % of annual consumption	
	Electricity	Heat and fuels
Buildings in the municipal services sector (residential buildings not included)	2%	3%
Buildings in the private services sector (residential buildings not included)	1.5%	4%
Industry (energy-intensive process industry not included)	1%	2%

In level 2 calculations two different approaches are possible. One (approach A) does not require the use of any default values because data on implemented actions is collected nationally. In another approach (B) at level 2, default values can be used to estimate how much of the potential savings have been realised (see Table 2).

Table 2 – Proposed percentages for realised savings out of potential savings to be used as default value in level 2 energy saving calculations

Sector	**Proportion of realised savings of potential savings %**			
	Finnish Energy Audit Programme[1]		**Percentages to be used as default value in level 2 calculations**	
	Electricity	**Heat and fuels**	**Electricity**	**Heat and fuels**
Buildings in the municipal services sector (residential buildings not included)	76%[2]	73%[2]	25%	25%
Buildings in the private services sector (residential buildings not included)	71%[2]	79%[2]	25%	25%
Industry (energy-intensive process industry not included)	59%[3]	52%[3]	20%	15%

[1] Source: Motiva Oy, 2006.

[2] Includes all implemented improvement actions (I), all decided ones (D) and one third of those under consideration (C).

[3] Includes all implemented improvement actions (I), all decided ones (D) and 5% of those under consideration (C).

1.6 Formula for Total ESD annual energy savings

Several correction factors may need to be applied to calculate the annual energy savings that can be counted towards a Member State's ESD target. If the ESD Committee decides to correct for the free-rider effect, the formula for the Total Esd annual energy savings will read:

Total ESD annual energy savings =
total gross annual energy savings - double counting estimate - technical interactions + multiplier energy savings - free-rider savings

1.7 Indicative default value for Savings lifetime

The proposed EU default value for the lifetime of the annual energy savings is presented in the following table. It is based on the method used in Finland. Note: this value can be used with all levels presented above for calculating annual energy savings from one participant. On levels 2 and 3, national average values or values specific to an energy audit scheme or a type of end-use actions proposed by energy audits can be developed (cf. chapter 6.1).

Energy savings lifetime: **EU default/harmonised values**	
EU default	6-year sliding average lifetime
EU harmonised	Not available yet

1.8 Main data to collect

The resources required for the evaluation consist of two components: establishing and operating the monitoring system and the evaluation itself.

Rough monitoring resource estimates have been made for larger schemes with a minimum of 100 audits per year. At level 2, the operating costs of the monitoring system range from a week to one person-month per year. At level 3, the operating costs of the monitoring system are in the range of 4 person-months per year. The cost of establishing the database needed for level 3 calculations and in some cases also level 2 calculations is approximately 6 person-months.

Table 3 – Data needs for level 1, 2 and 3 calculations.

Data needed in calculation for EU values (level 1)	Examples of corresponding data sources
Eu default values for annual energy savings (% of annual energy consumption of the audited facility)	This report
Audit volumes (annual energy consumption of the audited facilities or building volumes or floor area by building type in the service sector)	Audit or investment subsidy decisions, number of vouchers issued for energy audits
Average specific consumption by building type in the service sector and by energy type (electricity and heat). This information is needed if calculations are based on building volumes or floor area.	National statistics or other sources

Data to be collected National method (level 2)	Examples of corresponding data sources
Approach A Audit programme participants Implemented actions with savings	 Audit or investment subsidy decisions, vouchers issued for energy audits, audit reports filed Questionnaires/interviews
Approach B Proposed actions with savings Implemented actions with savings Audit programme participants	 Monitoring database with national data onenergy efficiency potential Default values given in this report for the degree of realisation If questionnaires/interviews are used, this conforms with level 3 requirements)

Data to be collected Specific method (level 3)	Examples of corresponding data sources
Proposed improvement actions with saving potential	Monitoring database of energy audit results
Implemented actions with savings	Annual reports or periodical questionnaires/interviews to collect follow-up data on the implementation rate

Furthermore, on levels 2 and 3, national average values or values specific to an energy audit scheme or a type of end-use actions proposed by energy audits can be developed.

2 Introduction

2.1 Twenty bottom-up evaluation methods

Within EMEEES, task 4.1 provided methodological materials in “Definition of the process to develop harmonised bottom-up evaluation methods”, version 20 April 2007. Based on this draft report, concrete bottom-up evaluation methods are developed by EMEEES partners within task 4.2, and reference values will be specified within task 4.3.

This report deals with bottom-up evaluation method for energy audits and it has been drafted by Motiva Oy.

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

It was decided to start with 15 methods. These are presented in the table written in normal characters. Methods written in italics are for the second batch of 5 methods, completing the number of 20. A final decision on these 5 will be taken later on in 2007.

	Responsible organisation	**End-use or end-use action, technology, or facilitating measure**	**Sector**
1	A.E.A	2 Building envelope improvement (residential buildings)	Residential
2	Ademe	4 Energy-efficient white goods (appliance purchased anyway)	Residential
3	AGH-UST	3 (Rest) Improvement of heating system (including circulator?)	Residential
4	*AGH-UST*	*5 Hot water: solar water heaters, heat pumps, water-saving faucets*	*Residential*
5	Armines	10 Improvement of ventilation/air conditioning system, including heat recovery, free cooling (non-residential buildings)	Tertiary
6	*Armines*	*10a Improvement of ventilation/air conditioning system, including heat recovery, free cooling (non-residential buildings)*	*Industry (buildings)*
7	Armines	3b: Condensing Boilers	Residential; (tertiary)
8	eERG	9 Improvement of lighting system	Tertiary (industry)
9	eERG	Heating system circulators	Residential, tertiary
10	Fraunhofer	11 Office equipment	Tertiary
11	ISR-UC	13a High efficiency electric motors	Industry
12	ISR-UC	13b Variable speed drives separate, including for industrial pumping systems	Industry

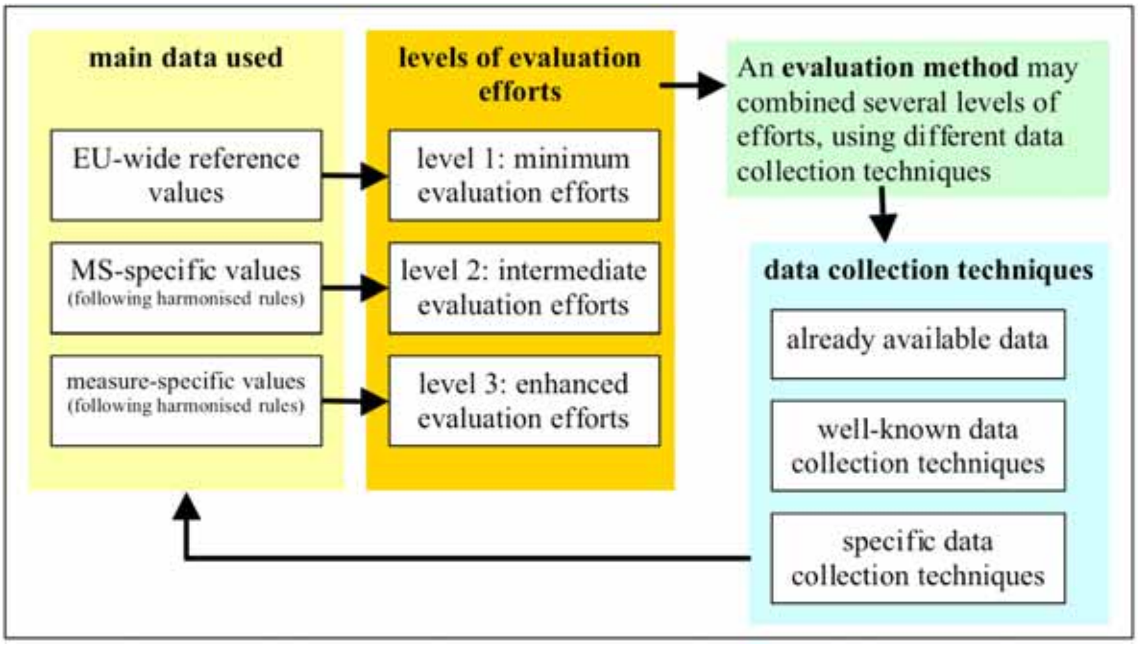
13	Motiva	20 Energy audit programmes (or energy audits conducted as commercial energy efficiency service)	Tertiary industry
14	SenterNovem	1 Energy performance of new buildings	Residential
15	SenterNovem	21 Voluntary agreements with end use sectors	Tertiary industry
16	*SenterNovem*	*6 Energy performance of new non-residential buildings*	*Tertiary*
16 alt	*SenterNovem*	*17 Eco-driving*	*transport*
17	Stem	19 Energy performance contracting	Tertiary industry
18	*Stem*	*18 Combination of agreement with individual companies in combination with tax reduction*	*Industry tertiary*
19	Wuppertal Institute	15 Vehicle (car, bus, truck) energy efficiency (engines, tyres, lubricants)	Transport
20	Wuppertal Institute	16 Modal shifts in passenger traffic, including towards non-motorised traffic	Transport

2.2 Three levels of harmonisation

To be as practicable as possible and stimulate continued improvement, the harmonised reporting on bottom up evaluation is structured on three levels (see figure 1). So the bottom/up evaluation methods will produce:

- 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.

Figure 1: Three levels of harmonisation



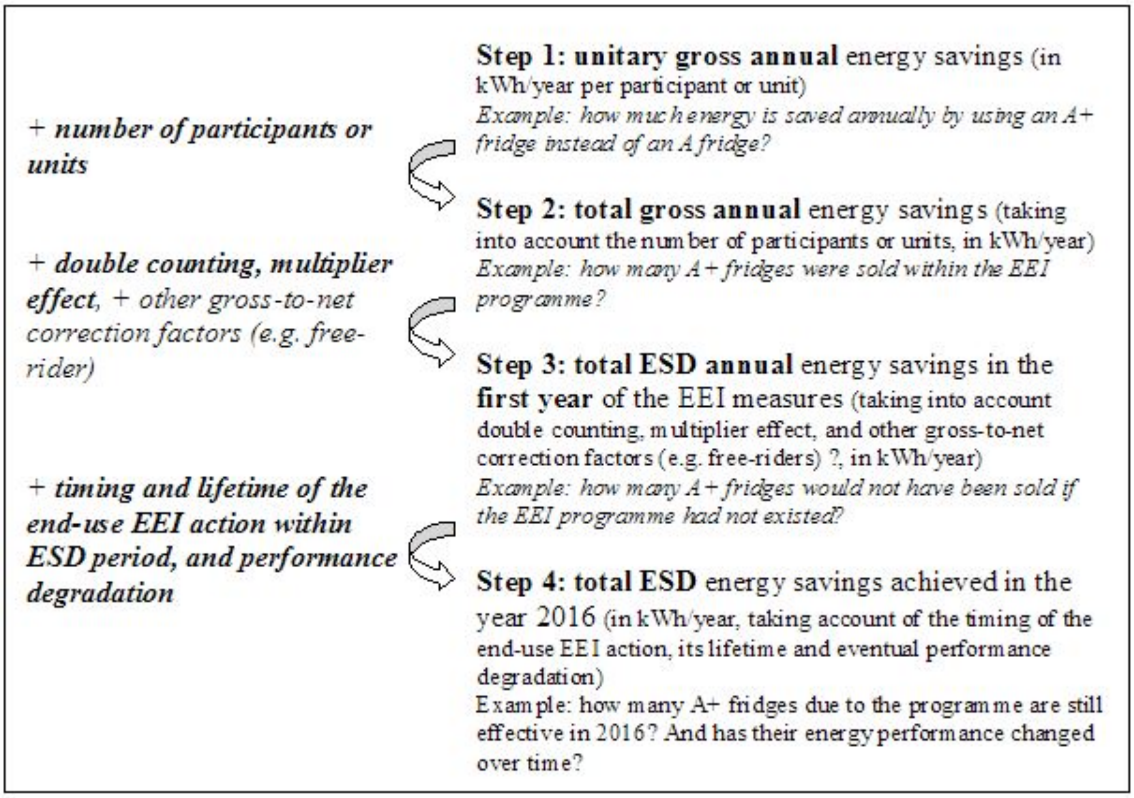
2.3 Four steps in the calculation process

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

The reports on the bottom-up evaluation methods will follow the format of these four steps and hold six chapters and 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”

Figure 2: Four steps in the calculation process



2.4 Six pilot projects

Additional to the 20 bottom-up evaluation methods, six organisations will test the methods in practice (WP 8). The foreseen case examples are:

	Sector	Pilot project	Organisation
1	Public and non-residential buildings	Energy Efficiency Investment Programme for Public Buildings (2005-2008)	STEM
2	households , public sector and partly business sector	Rebate programme of Elsparefonden for electricity savings	SRCI
3	Residential	Schemes under the French White Certificates system	EDF/ARMINES/ ADEME
4	Tbd	Own programme	ADEME
5	Residential, industrial, tertiary, cross-cutting	Schemes under the Italian White Certificates system	eERG
6	Non residential	Energy efficiency services for energy-efficient ventilation in non-residential buildings	KEM

3 Step 1: Unitary gross annual energy savings

3.1 Step 1.1: General formula and calculation model

For energy audits, candidates for an “elementary calculation unit” are one energy audit and one improvement action (in EMEEES terms End-use (EEI) Action) implemented by the audited facility. Because of the huge number of possible improvement actions (several thousands, each with different associated savings) it is practically impossible to take them as the “elementary calculation unit”. Also the magnitude of energy savings resulting from an energy audit may vary greatly making it difficult to use it as an “elementary calculation unit” either. Therefore, being a more practical alternative, particularly for level 1 calculation, single audits themselves will serve as an “elementary calculation unit” in the method developed here.

For some individual improvement actions it is possible to define default gross annual energy savings but for many of them it is not possible because they are very specific to the site, process or building. Although guidelines and templates have been prepared, each audit needs to be tailored to take into account the characteristics of the audited facility. Despite these concerns, this report proposes extremely conservative default values for energy audits for level 1 calculation.

Given the specific features of energy audits, a monitoring system is paramount to reliably assess the savings. However, there are a number of ways to monitor the audits and their results. For energy audits, the calculation method (see Step 1.4, Chapter 3.4) and its three levels are defined in terms of the sophistication of the monitoring system used.

The formulas for calculating the annual energy savings per energy audit participant are provided in the summary, chapter 1.4, and in chapter 3.4.

The better the level of information gathered, the higher are the monitoring costs. Therefore, compromises have to be made between the monitoring data desired and what is practically possible to gather. This is illustrated in Figure 3.

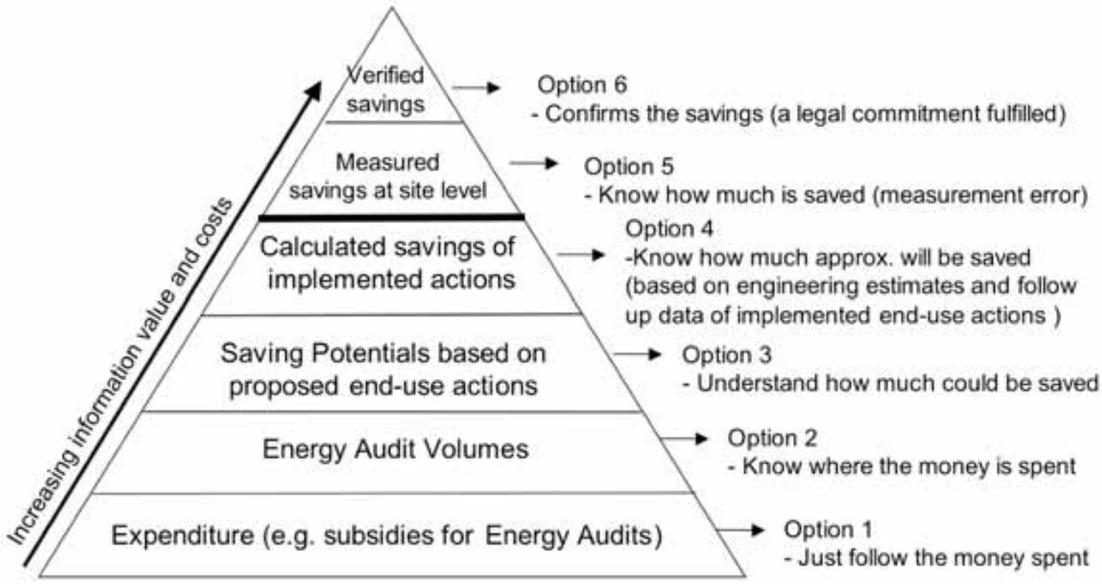


Figure 3: – Relations between monitoring, information value and costs in energy audit programmes (Audit II Project, 2001-3003, modified by Motiva Oy)

For example, administration costs of Option 1 are low if only the amount of subsidies is monitored (see Figure 3). The administration costs of Option 2 are still quite low but it is also known where the money is spent – for example, how the number of audits has been divided to sectors, if the information from the applications is monitored. Nonetheless, when the data from audit reports is not monitored, the energy efficiency improvement actions and their savings remain unknown.

For Option 3, administrative costs are higher and at least in this stage a monitoring database to file information, e.g., from the audit reports is needed. Information on proposed energy efficiency improvement actions is now available making it possible to calculate the saving potentials. In Option 4, information on implemented improvement actions is gathered from the sites and it is combined with the proposed improvement actions data from the audit reports to get a calculated estimate of the realised savings.

Option 5 needs much more resources because measurements and good energy monitoring systems on the site level are needed; applying measurements on a large enough sample of participants or end-use actions may be sufficient. Still, the difficulty can be to measure the effect of one implemented energy efficiency improvement action due to many other changes at the same time, e.g., in the running hours, production mix, volume etc. In Option 6 improvement actions are individually monitored/verified by a third party. Administrative costs are furthermore higher and there will also be other costs, e.g., for measurement instruments. The costs of monitoring energy savings are similar to those for Energy Performance Contracting in this option.

The amount of work needed to maintain a monitoring system should not be underestimated. The required resources depend naturally on the volumes but also on how much time is spent to carry out the analysis for various purposes and how actively this type of information service is marketed to various bodies like the media etc. Table 4 shows the characteristics of the monitoring schemes.

Table 4 – Different options for monitoring energy audits (Audit II Project, 2001-2003, Option names modified by Motiva Oy)

Options	**Coverage**	**Complexity**	**Rough cost estimates**		**Information gained from**
			< 100 audits/year	**> 100 audits/year**	
1. Expenditure	All audits	Easily achieved	No extra costs	No extra costs	Application
2. Energy audit volumes	All audits	Easily achieved	Negligible extra costs	Minor extra costs – 0.25 man-months/year	Application
3. Saving potentials	All audits	More complex. Tool necessary , i.e. database	Minor extra costs. Need spreadsheet – 0.5 man-month	Development costs: 6 man-months/year Operation costs: 1 man-months/year	Audit report
4. Calculated savings of implemented action	All audits/ samples	More complex. Need tool (database) and feedback from clients.	Operating costs in the range of 2 man-months/year	Operating costs in the range of 4 man-months/year	Questionnaire/ site visits
5. Measured savings at site level	All audits/ samples	Complex. Need tool, feedback from clients and analytical expertise.	Costs in the range of 4 man-months/year	Costs in the range of 1 man-year	Questionnaire (annually)
6. Verified results	Samples	Complex. Need tool, feedback from clients and analytical expertise.	Costs in the range of 6 man-months/year (based on representative samples)	Costs in the range of 1 man-year (based on representative samples)	Monitoring on-site level

3.2 Step 1.2: Baseline

European (level 1), national (level 2) or action-specific (level 3) average baseline values cannot be formulated for energy audits. Due to the character of energy audits, a different approach - in line with ESD definitions - is followed.

In practice, auditors usually calculate the "before the improvement action" and "after the action" energy consumptions for each audited technical system with proposed improvement actions. Their difference is the savings achieved through the action. This conforms to the ESD definitions of calculating energy savings. According to this definition: "… an amount of saved energy determined by measuring and/or estimating consumption before and after implementation of one or more energy efficiency improvement measures, whilst ensuring normalisation for external conditions that affect energy consumption."

Table 5 – Three levels for baselines for energy audits

level 1	Not applicable
level 2	Not applicable
level 3	Not applicable

3.3 Step 1.3: Requirements for normalisation factors

The ESD mentions the following normalisation factors:

a) weather conditions, such as degree days;
b) occupancy levels;
c) opening or operation hours for non-domestic buildings;
d) installed equipment intensity (plant throughput); product mix;
e) plant throughput, level of production, volume or added value, including changes in GDP level;
f) schedules for installation and vehicles;
g) relationship with other units

The above normalisation factors are not used when total savings by energy audit programmes are calculated, as the individual audits are producing enhanced engineering estimates. However, some of them can be taken into account in calculations made within an individual energy audit for the individual baselines of the energy consumption for the equipment analysed or the whole building or facility. For example, temperature corrections are usually made for the total heat consumption (excluding the use of hot water) of the audited facility. Furthermore, several factors (b-g) can be taken into account when calculating the savings by individual improvement actions. Equipment operating times are an important source of potential savings when improvement actions are proposed. Known forthcoming changes in the installed equipment intensity (plant throughput) or product mix should also be taken into account.

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

The objective of the evaluation is to produce quantitative data on energy savings achieved by energy audits. This establishes the minimum requirements for the monitoring system.

The three levels of calculation (Table 6) are defined on the basis of the sophistication of the monitoring system:

Level1: Using EU-default values (although not recommended)

Level 2: Using national data or national data supplemented by EU-default values following Option 2 or Option 3 (Table 4/Figure 3)

Level 3: Option 4 (Table 4/Figure 3) is quite rare but is used by some Member States. This, together with the virtually non-existent Options 5 and 6, represent level 3 calculations.

Option 1 in Table 4/Figure 3 does not provide adequate information for evaluations at any other level but the first one using default values.

Option 2 in Table 4/Figure 3 does not enable saving estimates without additional effort. One approach could be by interviews/questionnaires among the audited facilities either by addressing a sample or all audited facilities. The approach is quite resource-intensive and requires special skills (in practice, a consultant). However, if a monitoring database has not been established from the outset of the audit programme, questionnaires/interviews may be the only possibility to enable ex-post evaluation with real-life information instead of default values.

Option 4 is more sophisticated than Options 1 to 3 but due to its complexity and higher cost it may not be realistic for all Member States. It also takes considerable time to establish the necessary monitoring system.

Without additional data collection efforts, only Option 3 or higher (see Table 4/Figure 3) can produce adequate data. Basically, Option 3 means that at least a simple database has been established for data collection.

The formulas for calculating the annual energy savings per energy audit participant are provided in the summary, chapter 1.4, and in chapter 3.4.

Table 6 – Three calculation levels for energy audits defined on the basis of the sophistication of the monitoring system

level 1	Using EU-default values
level 2	A) Monitoring of expenditure and/or audit volumes accompanied by additional interviews/questionnaires to the participants in national level (Options 1 and 2 in Table 4/Figure 3) B) Filing the savings potentials from audit reports into a database in national level (Option 3 in Table 4/Figure 3)
level 3	Option 4 in Table 4/Figure 3 (or Options 5 and 6 if available)

3.4.1 Conversion factors

All energy savings are to be reported in GWh or equivalent.

Annex II of the ESD contains a conversion table for various fuels. However, at present auditors in the Member States use national conversion factors which may differ from those in Annex II. In the monitoring systems usually only aggregated fuel (heat) consumption data is reported for each audited facility. The same applies to fuel (heat) savings. This makes it practically impossible to make ex-post conversions to accommodate Annex II conversion factors. In the future, the problem could be avoided by obliging all auditors to use Annex II factors.

3.4.2 The direct rebound effect

The ESD does not require the evaluation of the direct rebound effect. Neither is there any other need to take it into consideration in energy audits in industry and the tertiary sector.

For energy audits, direct rebound effect is rather unlikely to occur. Industrial facilities and businesses are not likely to increase room temperatures, lighting etc. due to improved energy efficiency. In some cases, energy savings may be small or even negative, if with the new lighting system the lighting levels are in conformity with the norms, while they were not with the old system. However, this is not a rebound effect.

In calculations, there are no real possibilities for ex post evaluation of the direct rebound effect. It can only be estimated by the auditor who should calculate and report net savings.

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

3.4.3.1 Preconditions for the use of the calculation method at all levels

The uncertainties related to the savings achieved can be reduced significantly by quality assurance of the audits. If no quality assurance is done, calculations particularly at level 1 are void. In other levels, at least when estimated savings exceed a certain proportion of national total ESD energy savings target, a national quality assurance program is necessary. It is proposed to set the threshold at 5%.

There are two factors to consider: the competence of the auditors and the quality of the audit reports. The former can be enhanced by a national training and authorization programme for the auditors. Such a scheme does not only enhance more reliable ESD saving calculations but also increases the credibility of the audit scheme among the audit clients.

3.4.3.2 Requirements to define level 2 and level 3 values

Firstly, the significance of the energy audit programme in meeting the national total ESD target requires consideration in the choice of the calculation level. If the energy savings achieved by the audit programme exceed a certain percentage of the target, saving calculations should be made at level 2 or 3. It is proposed to establish the threshold at 10% of the indicative ESD national energy saving target. The higher the proportion of audit-induced savings in the total national target, the more likely the Member State is to have a monitoring system enabling level 2 or level 3 calculations.

Secondly, the applied level depends on the availability of monitoring data. If only the audit volumes are known and there are no resources for collecting additional data, level 1 is the only option. If actual monitoring data is available, evaluation can be made at level 2 or 3. Given the extremely conservative default values for level 1, there is a clear incentive to opt for levels 2 and 3.

3.4.3.3 Level 1 calculations

Making evaluations at level 1 using default values is not recommended. However, in the absence of an adequately sophisticated monitoring system enabling level 2 or level 3 evaluation it may be the only possibility for quantitative evaluation.

Hereunder, some very conservative default values are given based on the results achieved in the Finnish Energy Audit Programme. The Programme was launched in 1992 and the monitoring system has been running since 1994. The monitoring system created for the Programme follows Option 4/Calculated savings of implemented actions (see Table 4/Figure 3) and is among the most sophisticated in Europe.

The Finnish monitoring system uses an Access®-based database where all relevant data from energy audit reports is filed. The data is used, e.g., for the annual impact assessment of the Programme. Information on an individual energy audit is filed into the database in three phases:

- The first phase occurs when an audit subsidy is granted.
- The second phase takes place when the audit report containing information on all proposed improvement actions is submitted to Motiva, which operates the database. The data is presented in standard tables that are submitted also in digital format in order to simplify the filing of the data.
- In the third phase follow-up data on implemented improvement actions is gathered and filed. Initially, the follow-up data was collected via questionnaires. Since 2000, it has been collected via annual reporting by the companies and municipalities joined the voluntary agreements. The purpose of the follow-up data is to monitor the implementation rate of the suggested improvement actions to enable calculation of the realised savings.

The average realised savings for each sector (non-energy intensive industry, private services, municipal services) are calculated using the saving potentials found in the energy audits and the implementation data gathered via annual reporting in the voluntary agreement scheme. The calculated average realised savings differ by sector and are shown in Table 7.

Table 7 –Average energy savings achieved in the Finnish Energy Audit Programme (Motiva Oy, 2006)

Sector	**Savings % of annual consumption**	
	Electricity	**Heat and fuels**
Buildings in the municipal services sector (residential buildings not included)	5.5%	9%
Buildings in the private services sector (residential buildings not included)	4%	12%
Industry (energy-intensive process industry not included)	3…5%	6…9%

Proposed conservative default values for level 1 calculation are given in Table 8. The prerequisite for using them is that the volume of energy consumption of the audited facilities (or the audited processes in the case of System Specific Energy Audit) is known. Furthermore, the significance of the energy audit programme in meeting the national ESD target may necessitate at least level 2 calculations (see Chapter 3.4.3.2).

The proposed default values amount to approximately one third of the lower estimates of the actual savings achieved in Finland (see Table 7). It can easily be argued that the default values should be either much lower or even multiple (up to 3-fold or 4-fold) compared to the Finnish results. The higher end would apply to countries with a very low starting level of energy efficiency. The lower end would represent an extremely conservative estimate or very pessimistic view of the effectiveness of energy audits. It could also apply to countries with energy efficiency levels exceeding those in Finland. In the absence of analytical evidence a cautious, simple and practical choice (i.e., accepting one third) has been made. Given the large uncertainties associated with the default value approach, it does not appear adequately conservative to take even half of the Finnish savings as the default value.

The prerequisite for using the default values proposed in Table 8 is that the annual energy consumption of the audited facility (or process) is known. If it is not known, it may be possible to use an alternative approach in the service sector buildings. In this approach, the required data are an inventory of the audited building volumes (m^2 or m^3) by building type and average specific consumption (kWh/m^2 or kWh/m^3) by building type. The latter can be taken or derived from national statistics or other sources. With these data and the default values in Table 8, savings can be estimated. The approach cannot be applied in industry where consumption does not correlate well with building volumes.

Table 8 – Proposed level 1 default values for average energy savings achieved by energy audits (% of annual energy consumption)

Sector	**Savings % of annual consumption**	
	Electricity	**Heat and fuels**
Buildings in the municipal services sector (residential buildings not included)	2%	3%
Buildings in the private services sector (residential buildings not included)	1.5%	4%
Industry (energy-intensive process industry not included)	1%	2%

The annual energy savings (GWh/a) to be realised by one energy audit (participant) are calculated as follows (Level 1):

annual energy savings of one participant [GWh/a] =
$= DV_{h,f}$ *(heat+fuels)*AC(heat+fuels) +* DV_e *(electricity)*AC(electricity)*

where:
- DV_e = EU default value for electricity savings, % (Table 8)
- $DV_{h,f}$ = EU default value for heat and fuel savings, % (Table 8)
- AC = annual energy consumption (GWh)

3.4.3.4 Level 2 calculations

Calculations are made at level 2 when national data on audit volumes (alternative A) is known and additional data on implemented actions can be collected or when savings potentials (alternative B) are known. However, at level 2 the degree of implementation of the proposed improvement actions is not known from monitoring of participants.

Two different approaches are proposed for level 2 calculations:

A. Monitoring of audit participants who are addressed by interviews/questionnaires/etc. regarding their implemented actions and associated savings proposed by the energy audit (Option 2 in Table 4/Figure 3)

B. Filing the savings potentials from audit reports into a database (Option 3 in Table 4/Figure 3)

<u>Approach A at level 2</u>

In this approach, the monitoring system provides information on audit programme participants and possibly on their annual energy consumption and building volumes. Information on implemented improvement actions and associated savings is collected by additional questions asked from all or some of the participants.

In this approach, additional information shall be collected by interviews, questionnaires etc. on the implemented improvement actions and associated savings. In practice, questionnaires have proven to be quite inefficient. The respondents can easily discard them for various reasons such as lack of time or lack of competence. The desired response rate for questionnaires is at least 50% of the energy audits implemented in one sector during, e.g., the last three years. An alternative to questionnaires are telephone interviews, which have been used by some Member States.

The approach is rather resource-intensive. Furthermore, it is likely to produce limited information on the improvement actions taken and savings acquired.

Therefore, **we propose that** this method should only be allowed for past but recent energy audit schemes, if Level 2, Approach B or Level 3 is not possible, i.e., no database of energy savings potentials identified in audits exists yet.

The energy savings (GWh/a) to be realised by one energy audit (participant) are calculated as follows (Level 2 A):

Annual energy savings of one participant [GWh/a] = AS(heat+fuels) + AS(electricity)

where:
- AS=annual energy savings of the participant realised as a consequence of the energy audit and collected through a survey of participants (GWh/a)

Approach B at level 2

In this approach a relatively sophisticated monitoring system is required. The data which such a system would normally contain is listed hereunder. However, it should be noted that in the saving calculations only information on proposed and implemented improvement actions by sector is used.

- Basic information (building volume, year of construction, building type, participation in the voluntary agreements etc.)
- Energy consumption in the year preceding the audit
- For each proposed improvement action:
    - short description/name (technical/operational actions)
    - savings of heat and electricity in energy units (kWh/a)

Saving potential does not equal actual energy savings. Not all proposed improvement actions, even economically viable ones, are implemented. Therefore, effort needs to be taken in order to study which actions have actually been implemented.

Default values for estimating the actual savings can be used. The improvement actions proposed in an audit can be divided into four categories based on their status: implemented (I), decided to be implemented (D), under consideration (C) and not to be implemented (N). Without actual monitoring data, the problem is how to allocate the savings potential into the four categories. The default values given are based on the results of the Finnish Energy Audit Programme (see

Table 9). To play it safe, it is proposed to include only approximately one third of the results achieved in Finland.

The annual energy savings (GWh/a) to be realised by one energy audit (participant) are calculated as follows (Level 2 B):

Annual energy savings of one participant [GWh/a] =

$$= DV_{h,f}(heat+fuels)*TSP(heat+fuels) + DV_{e}(electricity)*TSP(electricity)$$

where:

- DV_e = EU default value for the share of the electricity savings potential implemented, % (Table 9)
- $DV_{h,f}$ = EU default value for the share of the heat and fuel savings potential implemented, % (Table 9)
- TSP=total annual energy savings potential of the participant identified in the energy audit (GWh/a)

Table 9 – Proposed percentages for realised savings out of potential savings to be used as default value in level 2 energy saving calculations

Sector	Proportion of realised savings of potential savings %			
	Finnish Energy Audit Programme[1]		Percentages to be used as default value in level 2 calculations	
	Electricity	Heat and fuels	Electricity	Heat and fuels
Buildings in the municipal services sector (residential buildings not included)	76%[2]	73%[2]	25%	25%
Buildings in the private services sector (residential buildings not included)	71%[2]	79%[2]	25%	25%
Industry (energy-intensive process industry not included)	59%[3]	52%[3]	20%	15%

[1] Source: Motiva Oy, 2006.

[2] Includes all implemented improvement actions (I), all decided ones (D) and one third of those under consideration (C).

[3] Includes all implemented improvement actions (I), all decided ones (D) and 5% of those under consideration (C).

If a monitoring system following Option 3 exists, it might enable evaluations even at level 3 if more detailed information on implemented improvement actions can be collected. One possibility is to periodically collect additional information, e.g., by interviews or questionnaires. The desired response rate is at least 50% of the energy audits implemented during, e.g., the last three years. A practical example of this approach can be found from Finland where information was collected through follow-up questionnaires before annual reporting started in the context of the voluntary agreement scheme.

3.4.3.5 Level 3 calculations

When information on the actions implemented is available, calculations can be made at level 3. This is the case when monitoring is conducted following Option 4 or higher (Table 4).

In Option 4, data collected into the monitoring database(s) usually includes at least those listed hereunder. Data sources can be audit subsidy applications and subsidy decisions, audit reports and other reports/information from the audited facilities (e.g. interviews or questionnaires; or reports in the context of voluntary energy efficiency agreements). However, all the data listed hereunder is not mandatory for the saving calculations. Those used have been highlighted in ***bold italics***.

- Basic information (building volume, year of construction, building type, participation in the voluntary agreements etc.)
- Audit subsidies given, audit costs
- Energy (and water) consumption in the year preceding the audit
- For each proposed improvement action:
    - short description/name
    - ***savings of heat, electricity (and water) in energy units (kWh/a)***
    - cost savings for heat, electricity (and water) (€/a) and possible other cost savings
    - savings in CO_2 emissions (tonnes of CO_2/a)
    - estimate of the investment cost and pay-back period (€, a)
    - ***the updated degree of implementation (acquired by the degree of implementation at the time of finalisation of the audit report, by questionnaires/interviews or by reporting by the audited facility if it participates in voluntary agreements). The minimum level of information on the degree of information required which actions have been implemented. If possible, the improvement actions could be classified into the following categories: implemented (I), decided to be implemented (D), under consideration (C), not to be implemented (N).***

The auditor makes a site visit and based on collected data, interviews and measurements makes a list of recommended improvement actions with priority ranking. When calculating the savings due to each improvement action their sequence is taken into account so that technical interaction (see Chapter 5.3) is removed. For example, if the first proposed improvement action is regulation of ventilation and the second one a new heat recovery system, in the saving calculations for the heat recovery system air flows are based on improved ventilation.

When data is imported into the database, some check-ups should be made to spot possible errors.

Saving potential does not equal actual energy savings. Not all proposed improvement actions, even economically viable ones, get implemented. Therefore, effort needs to be taken in order to study which actions have actually been implemented.

The very first improvement actions may be implemented during the audit (e.g. instant improvements in regulation). Also, the feed-back provided by the audited facility to the audit report is part of the first phase of implementation data input. There may be a small delay between the audit visit and submission of the report during which the client already may have implemented some improvement actions. These can be updated into the audit report and put into the database.

The collection of the second phase of implementation data is more complicated but several different options exist:

- If audits are subsidised, the audited facility can be obliged to report the actions taken, e.g., within one to three years from the audit.
- If the Member State runs a voluntary agreement programme, the participants can be obliged to annually report the improvement actions taken and the data can be used to update the savings.
- Data can be collected by interviews and questionnaires after the audit.

Four different alternatives exist for the status of an improvement action: implemented (I), decided to be implemented (D), under consideration (C) and not to be implemented (N). A decision needs to be made to what extent each of them will be taken into account in the saving calculations. For two of the categories the decision is simple; the implemented actions (I) will be fully included and the rejected actions (N) fully excluded. If an implementation decision exists (D), it is recommended to include the action. Because part of the actions under consideration (C) will be implemented but many rejected, it is recommended to include only a small share of these actions. For example, in Finland only 5% is accepted in industry and one third in the services sector. The percentages have been formed based on information collected through the audit follow-up process. The same percentages are proposed to be used in level 3 calculations. Therefore, the degree of implementation (DI) is calculated using the following formula. DI should be calculated separately for electricity and heat:

*Degree of implementation DI [%] = I+D+a*C*

where:
- I= implemented actions , D=actions decided to be implementation, C=actions under consideration (%)
- a=0.05 for actions in industry
- a=0.3 for actions in the service sector

The energy savings (GWh/a) to be realised by one energy audit (participant) are calculated as follows (Level 3):

Annual energy savings of one participant [GWh/a] =

*= DI(heat+fuels)*TSP(heat+fuels) + DI(electricity)*TSP(electricity)*

where:
- DI = individual degree of implementation of the TSP by the participant, %
- TSP=total annual energy savings potential of the participant identified in the energy audit (GWh/a)

4 Step 2: Total gross annual energy savings

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

The EMEEES Task 4.1 report "The developing process for harmonised bottom-up methods" provides a calculation formula for energy savings by energy audits. The formula has been edited hereunder to take account of the differences between industrial and tertiary sector participants.

total gross annual energy savings =

$$\sum_{i=1}^{n}[\text{annual energy savings of industrial participant i}] + \sum_{i=1}^{n}[\text{annual energy savings of tertiary participant i}]$$

The total gross annual energy savings are the sum of the annual energy savings of all participants (energy audits) in a given year. The "elementary unit of action" is one energy audit, which corresponds to one participant with its energy savings arising from several improvement actions. The calculation of the savings by one participant has been described in Chapter 3.4.3.

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

Normally, the number of participants can be acquired through the monitoring system thus complying with level 3 requirements. Possible sources of data include the energy audit monitoring database, number of subsidised audits, number of investment subsidy decisions if audits are a prerequisite, number of vouchers issued for energy audits or number of audit reports filed.

The evaluation methods developed for the energy audits at the three levels do not require information on the number of individual improvement actions proposed in energy audits. Instead, they rely on other information such as audit volumes, savings potential or realised savings. However, more sophisticated monitoring systems can naturally produce reports on the number of different actions.

5 Step 3: Total ESD annual energy savings

5.1 Step 3.1: Formula for ESD savings

The EMEEES Task 4.1 report "The developing process for harmonised bottom-up methods" provides a generic calculation formula for ESD savings. The formula has been adjusted to accommodate the special features of energy audits:

Total ESD annual energy savings =
total gross annual energy savings - double counting estimate - technical interactions + multiplier energy savings - free-rider savings

where:

- **double counting** takes in account whether energy savings have to be shared between several (EEI) facilitating measures
- **technical interactions** take into account the situation when a (EEI) facilitating measure encourages several end-use (EEI) actions (improvement actions) having an impact on the same technical system
- **multiplier energy savings** are additional energy savings, as indirect results of an end-use (EEI) action or facilitating measure, when "*the market will implement a measure automatically without any further involvement from the authorities or agencies (…) or any private-sector energy services provider*"
- **free-rider energy savings** are the amount of energy saved by free riders. Free riders are participants or consumers who would have implemented the end-use (EEI) action also in absence of the (EEI) facilitating measure being evaluated

Each of the elements included in the formula and the way they have been taken into account in the developed method are discussed in more detail in Chapters 5.2-5.5.

5.2 Step 3.2: Requirements for double counting

In the case of energy audits, double counting cannot be estimated as a coefficient factor (ref. generic calculation formula, WP 4.1 report). Instead, it should be estimated in absolute terms.

Regarding energy audits, possible sources of double counting are other (EEI) facilitating measures such as voluntary agreements, investment subsidies and white certificates addressing the same energy users and end-uses/end-use actions.

In case of overlap, the decision how to allocate the corresponding energy savings to each (EEI) facilitating measure is up to the Member States.

Preferably, the information systems built for monitoring the different (EEI) facilitating measures should work together in such a way that double counting can either be avoided or reliably quantified. For example, in the monitoring systems established for energy audits and voluntary agreements in Finland, double counting can be avoided because information is exchanged between the two systems.

Alternatively, it might be possible to evaluate energy savings from a package of (EEI) facilitating measures targeting a sector and/or end-use through an integrated monitoring and evaluation process.

According to the EMEEES WP2 report “Briefing on existing evaluation practice and experience” double counting is an important consideration in the tertiary sector because building energy efficiency is often influenced by many different programs, building codes etc. However, most evaluations take a qualitative approach. This applies also to industry.

5.3 Step 3.3: Requirements for technical interactions

The ESD does not require the evaluation of technical interactions as such. However, in order to avoid overlap in an individual energy audit, technical interactions should be paid due attention during the audit.

Technical interactions - in itself a positive phenomenon - may take place when a (EEI) facilitating measure encourages several (EEI) end-use actions (improvement actions) having an impact on the same technical system. This may occur in energy audits. For example, as a result of an energy audit in a building, improvements both in insulation and heating system could be proposed. When two efficient solutions overlap, the resulting energy savings may be smaller or bigger than the sum of both individual solutions.

An auditor proposes a package of solutions. In this process (s)he should rank the proposed improvement actions according to their priority. When the savings of a lower ranking improvement action (n+1) are being calculated, the impact of a higher ranking action (n) should be taken into account in order to avoid overlap due to technical interactions.

5.4 Step 3.4: Requirements for multiplier energy savings

There is some possibility for multiplier effect to take place. This can occur, for example, in companies which run several identical or almost identical facilities. If an energy audit is conducted in one facility, some recommendations given in the audit may be implemented in other ones without separate energy audits. There is anecdotal evidence that in some cases international companies have copied effective approaches proposed in an energy audit in one country in other overseas facilities.

It is not known, how common a multiplier effect is or how significant it is in the proportion to energy audit volumes. However, it is not likely to be very significant because industrial sites and most tertiary buildings have quite individual characteristics making separate audits necessary in each facility. The most likely facilities for multiplier effect to take place are businesses running in chains and operating rather identical facilities (e.g. very small supermarkets). In the absence of analytical evidence, no assumptions should be made.

EMEEES WP2 report “Briefing on existing evaluation practice and experience” states that both in industry and in the tertiary sector multiplier effect is usually dealt with in qualitative terms. Due to the practical difficulty and cost of evaluation, it is not proposed to evaluate the multiplier effect in every case. However, if data can be acquired, e.g., through interviews and questionnaires, the impact of the multiplier effect could be added to the savings.

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.

Who are the possible free-riders? When energy audits are provided as fully commercial energy service, free-riders do not exist. In energy audit programmes, free-riders can emerge because the programmes include subsidies and some participants could have implemented audits or end-use actions by themselves in any case but nevertheless apply for subsidies. This is implied by the fact that some (but not many) facilities fully pay for the audits in the existence of subsidies. However, even their decision-making process probably has been influenced by the information dissemination made in the context of the audit programme or by the increased credibility created by a certification scheme for auditors.

The actual evaluation of the free-rider effect can be costly and difficult particularly for energy audit schemes with the many different end-use actions involved. There is, hence, little practical experience with this for energy audits. According to the EMEEES WP2 report “Briefing on existing evaluation practice and experience”, the free-rider effect is usually dealt with in qualitative terms or based on assumptions. In Finland, it has been estimated by the energy auditors that about 10–15% of the improvement actions would have been implemented also without the audit subsidies (Khan 2006).

The free-rider effect and multiplier effect are not mutually exclusive. Whereas the impact of free-riders theoretically should be extracted from the savings, the multiplier effect should be added on. Therefore, it can be considered that they compensate each other at least to some extent. Furthermore, if the lifetime of energy savings is cautiously chosen as proposed in the next chapter, it will be likely that few actions would have been taken anyway during that period.

6 Step 4: total ESD energy savings for year "i"

6.1 Requirements for the energy saving lifetime

Only the annual energy savings achieved and still existing in 2016 are accounted for. WP4/Task 4.1 report recommends this to be the first question to consider. Second, it recommends considering whether the (EEI) facilitating measure or end-use (EEI) action is reversible.

There is a wide range of saving lifetimes of the improvement action. Some improvement actions have lifetimes much shorter than 10 years but some have lifetimes exceeding 25 years. At the same time, the number of potential improvement actions is very large (several thousands). Furthermore, some facilities may undergo a follow-up audit with a new set of recommendations before 2016. How to deal with this complex situation given that many countries do not even monitor the total estimated savings for each energy audit not to mention the improvement actions proposed in energy audits?

The practical approach taken by several countries has been to apply the same average lifetime for all improvement actions. In the Italian white certificate scheme, all improvement actions in industry have been assigned a lifetime of five years. In France, lifetimes considered in the white certificate scheme for the industry are typically much longer (10–15 years) but a discount factor of 4% is applied to discount future energy savings.

In Finland, a very conservative 6-year "sliding average" is used in the service sector and 8-year "sliding average" in industry. In the calculation of the "sliding average" the savings from the previous six-year period are summed up. The process is repeated annually. For example, in CEN/CWA27 work, the proposed conservative lifetime for technical actions (as opposed to short-term operational actions) in industry was only eight years. The preliminary list of lifetimes proposed by CEN/CWA27 is subject to further updates.

At level 1 it is proposed to use 6-year sliding average for the lifetimes of the improvement actions. At level 2 it is possible to use sectoral sliding averages. For the service sector and industry the proposal is to use 6-year and 8-year sliding averages, respectively. The reason for the difference is that there are more short-term operational actions in the service sector whereas in industry there are more technical actions that can have quite long lifetimes. For example, in the case of Finland, analysis has shown that over 95% of the proposed actions in industry are technical with lifetimes by far exceeding eight years and it is planned to study what would be an average lifetime better corresponding with reality. As an alternative to the transfer of results from Finland, national justified values per participants can be used, if available.

Due to the big amount of separate improvement actions it is extremely difficult (if not impossible) to use varying lifetimes for each individual improvement action, particularly, when comprehensive energy audits are concerned (see Appendix II). However, for some narrower audit types (e.g. System Specific Energy Audit) this could be possible. Furthermore, it could be possible to estimate lifetimes for groups of actions by technical system (e.g., heating system, cooling systems, ventilation system, use of electricity in different applications, building structures). Given these considerations, using individual lifetimes for improvement actions or groups of actions has been put at level 3 (see Table 10).

Table 10 – Lifetimes of implemented improvement actions

level 1	6-year sliding average lifetime
level 2	If national sectoral information exists: • 6-year sliding average for the services sector or proven national average values per type of participant • 8-year sliding average for industry or proven national average values per type of participant
level 3	Lifetimes for groups of improvement actions (by technical systems) or individual improvement actions if : • the Member State can present justified information or • internationally agreed lifetimes can be formulated

One question to consider is, when the energy savings due to an improvement action take effect. The most conservative option is to assume them taking effect at the beginning of the year succeeding the year of implementation, i.e., the first full year of operation. A less conservative but statistically justifiable option in large masses of data is assuming them to take effect in the middle of the implementation year, i.e., accepting 50% of the annual savings for the implementation year. In some cases, the exact timing of implementation might be known and used. Any of the options can be chosen but should be reported.

Energy audits themselves are not “reversible”. However, some improvement actions are. This applies particularly to operational actions. This is taken into account in the saving calculations by applying short lifetimes.

6.2 Special requirements for early actions

All energy savings arising from energy audits (improvement actions) since 1995 will be taken into account if the savings still exist in 2016. In practice, this appears to mean that if a Member State wishes to include early actions in its ESD savings, it should be able to demonstrate that improvement actions (or which part of them) have a lifetime exceeding 8 years.

If 6-year sliding average is used, only implementation actions realised after 2010 are accounted for, hence excluding all early actions.

6.3 Reminder to treat uncertainties

The uncertainties depend on several factors and should be considered separately for each level of calculation.

The following sources of uncertainties apply to calculations at all levels:

- Type of audit chosen (accuracy of results varies from estimates of the range of magnitude to maximum accuracy achievable in field work)
- Quality of the energy audit (It depends, e.g., on the competence of the auditors and the quality of input data and associated measurements. It can be improved, e.g., by training and a national certification scheme for the auditors.)
- Quality of the audit report (can be improved by standard templates and good guidelines and quality control)
- Errors in data input (error risk can be reduced by automatic of manual check-ups)
- Uncertainties associated with the parameters used for calculations (e.g. energy saving lifetimes)

The accuracy of saving calculations in the audit reports corresponds to normal accuracy levels in field work. Some of the input data are design parameters and estimates because measurements are not always possible. The savings are not normally verified ex-post by measurements due to practical difficulties and extra cost.

To date, saving estimates made by energy auditors have been realistic because neither the client nor the auditor have had motivation to exaggerate savings. However, due to the new pressure created by the ESD, the situation could change and attention needs to be paid on ensuring prudence.

Default values given for level 1 and 2 calculations are conservative estimates based on results achieved in the Finnish Energy Audit Programme. Uncertainties arise from:

- The difference between the default values and the actual situation in the Member State
- Uncertainties associated with the Finnish monitoring system
- The method of formulating the default values from the Finnish results

The following sources of additional uncertainties apply to calculations at level 3:

- Availability of follow-up data on the implemented actions (full coverage improves reliability whereas sampling reduces reliability)

The directive does not mandate quantification of uncertainties. However, to enhance the improvement of the audit programmes as well as their evaluation, it is useful to at least identify and report the sources of uncertainties.

Table 11 – Guidelines for considering the uncertainties associated with the evaluation of energy audits

level 1	Identify and report the sources of uncertainties.
level 2	Identify and report the sources of uncertainties. Estimate range of magnitude for each parameter used (min-max).
level 3	Identify and report the sources of uncertainties. Conduct a sensitivity analysis with pessimistic/optimistic scenarios or quantify uncertainties (confidence intervals).

Appendix I: Justifications and sources

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Appendix II: Taxonomy of energy audit methods

An energy audit is defined as a systematic procedure that:

- Obtains an adequate knowledge of the existing energy consumption profile of a building or an industrial site;
- Identifies and scales the cost-effective energy saving opportunities; and
- Reports the findings.

A list of energy audit activities in Europe can be found in Appendix 1 of the Guidebook for Energy Audit Programme Developers (Väisänen et. al., SAVE-project Audit II, 2003[1]). Although the Guidebook was very comprehensive when it was issued, some more recent data might be missing. Most of the information given in this chapter on the various audit models has been taken from the Guidebook.

Energy audits are used for different purposes, either for pointing out the areas where savings can be found (scanning the areas of possible energy savings) or for describing in detail the actual saving actions so that they can be easily implemented (analysing in detail the individual energy saving actions). The different energy audit models can be classified into two main categories according to their aim: the Scanning Energy Audit Models (A) and the Analysing Energy Audit Models (B). The different models can be categorized according to their scope and thoroughness:

A. Scanning Energy Audit Models

- Walk-through Energy Audit
- Preliminary Energy Audit

B. Analysing Energy Audit Models

- Selective Energy Audit
- Targeted Energy Audit
    - System Specific Energy Audit
    - Comprehensive Energy Audit

[1] http://www.motiva.fi/en/projects/saveiiprogramme/auditiiproject/

A. Scanning Energy Audit Models

The main aim of the Scanning Energy Audit Models is to point out areas, where energy saving possibilities exist (or may exist) and also to point out the most obvious saving actions. The scanning audits do not go deeply into the profitability of the areas pointed out or into the details of the suggested actions. Before any action can be taken, the areas pointed out need to be analysed further.

A Walk-Through Energy Audit is typically used in tertiary buildings where the energy consuming systems are quite simple and the probable areas for potential energy saving actions are known in advance. This model is also suitable for small and medium size industrial sites if the production processes are not very complicated in terms of energy flows. A Walk-Through Energy Audit gives an overview of the energy use of the site, points out the most obvious savings and also points out the needs for next steps (supplementary "second-phase" audits). The Walk-Through Energy Audit has been used by ESCOs in the scanning phase of Third Party Financing projects.

Preliminary Energy Audits are typically used in large sites, e.g., in the process industry. Although the main objectives of the Preliminary Energy Audit are similar to those of the Walk-Through Energy Audit, the size and type of the site requires a different approach. Most of the work in the Preliminary Energy Audit is in building up a reliable breakdown of the present total energy consumption and defining the areas of the significant energy consumption and usually also of the probable energy saving actions. The reporting also points out areas where supplementary "second-phase" audits are needed and how they should be targeted.

B. Analysing Energy Audit Models

The Analysing Energy Audit Models produce detailed specifications for energy saving actions, providing the audit client with enough information for decision-making. Audits of this type are more expensive, require more work and a longer time-schedule but bring concrete suggestions on how to save energy. From the client's point of view the saving potential can be seen and no additional surveys are needed.

For the Selective Energy Audit there are only general guidelines and the auditor is allowed to choose the level of approach, both in coverage and accuracy. The Selective Energy Audit looks mainly for the major savings based on the former experience of the auditor and does not pay attention to minor saving actions.

The content of work in the Targeted Energy Audit is specified by detailed guidelines from the Operating Agent/Programme Manager and this means that most of the systems to be covered by the Targeted Energy Audit are known in advance. The Targeted Energy Audit usually produces a consumption breakdown and includes detailed calculations on energy savings and investments. If the guidelines are adequate, the audit produces a standard report. A tertiary building or a non-energy-intensive industrial facility are examples of compact sites (with more or less standard systems) where this model is a good option but setting very detailed guidelines is not cost-effective in large sites in process industry.

The System Specific Energy Audit is an example of the Targeted Energy Audit at the simplest and smallest. This type of audit has a tightly limited target (one system, device or process e.g. compressed air systems), but the thoroughness of the work is usually very high. The System Specific Energy Audit produces a detailed description of the system and points out all profitable saving actions with alternative options concerning the specific system. Sometimes this kind of audit is carried out in combination with more comprehensive audit models.

The Comprehensive Energy Audit covers all energy usage of the site, including mechanical and electrical systems, process supply systems, all energy using processes, etc. Some minor systems may be excluded if they are non-relevant in ratio to the total energy consumption. The starting point in this type of audit is always a detailed analysis of breakdown of the total consumption but also detailed description of current energy use and systems should be included. The Comprehensive Energy Audit comments on all energy using systems specified by the guidelines - regardless if savings are found or not. It points out all profitable saving actions and includes detailed calculations on energy savings and investment costs. This model also creates a basis for a standardized and detailed reporting.

Appendix III: Energy audit programmes in Europe

Information on energy audit programmes in Europe can be found in at least two on-line databases:

- The MURE (Mesures d'Utilisation Rationnelle de l'Energie) Database has been designed and developed within the framework of the SAVE and 'Intelligent Energy - Europe' Programmes: http://www.isis-it.com/mure/
- The IEA Energy Efficiency Policies and Measures database: http://www.iea.org/textbase/effi/index.asp

There is a free access to the information in the two databases.

The search features of both databases are not very user-friendly in scanning all the audit programmes. For example, in the MURE database a separate search is needed in the industry and tertiary sector. Furthermore, most of the audit programmes are classified under 'information, education and training' but not always under its subcategory 'voluntary audits'. Searching at the higher hierarchical level leads to a long list of facilitating measures other than audit programmes. Furthermore, some of the audit programmes have been classified under 'information' in a sub-category 'grants/subsidies for energy audits'.

The IEA database is equally confusing. In it the most comprehensive list of audits can be found using the search "energy audits". Searches "energy audit" or "auditing" only display few programmes. Searching by 'policy type' can be quite confusing because audit programmes have been classified under various categories such as 'financial' or 'regulatory instruments'.

The national audit programmes were described in the country reports of the Audit II Project (SAVE Programme). It should be noted that they are not necessarily fully update. The reports can be found, e.g., following the link: http://www.motiva.fi/en/projects/saveiiprogramme/auditiiproject/