

## Examples of bottom-up (BU) methods

- **Variable speed drives** (BU 13b)
- **Energy audits** (BU 20)
- **Improvement of lighting systems** (BU 9)



Original slides for the methods by Wuppertal Institute

# Variable Speed Drives

evaluate  
energy savings<sup>EU</sup>

## 5.0 Recalling Elements of Calculation:

### Four steps for calculation

- **step 1:**      **unitary gross annual energy savings**  
 (per end-use action)

(+)      no. of participants or units
- **step 2:**      **total gross annual energy savings**  
 (of a facilitating measure)

(+)      double counting, multiplier effect, free rider effect
- **step 3:**      **total ESD annual energy savings**  
 (of packages of EEI measures)

(+)      timing and lifeline of end-use action within ESD period  
 and performance degradation
- **step 4:**      **total ESD energy savings for year “i”** (i=2010 or 2016)

## 5.2 Recalling Elements of Calculation: Three levels of evaluation efforts

	Data scale	Main data sources	Data processing and documenting
Level 1	<b>European default values</b>	<b>existing/available</b> European regulation, studies and statistics	<b>security factor</b> according to the level of <b>reliability</b> of the default value
Level 2	<b>National representative values</b>	<b>up-to-date</b> national statistics, surveys, samples, registries	requirements = <b>minimum set of information and justifications</b> to be reported
Level 3	<b>Program- or Participant-specific</b>	<b>specific</b> monitoring systems, registries, surveys, measurements	requirements to report on the specific data and justifications <b>in detail</b> (standard report at least available)

→ an evaluation method may combine different levels of efforts, as several parameters are needed in the calculations

## 4.1 Harmonised bottom-up evaluation methods

### Method 13B: Variable Speed Drives

- a method dealing with a type of **end-use action**
- the **unit** is a Variable Speed Drive (VSD) installed
- VSDs are electronic devices for energy-efficient control of electric motors in industry and large buildings
- If the load driven by the motor is fluctuating (as often with, e.g., pumps, fans, compressors, elevators), large energy savings can be made

(method developed by ISR – University of Coimbra, Portugal)

## 4.1 Variable Speed Drives

- **Step 1.1: Basic calculation formula for the unitary savings**

*Annual energy savings of one participant = the participant's energy consumption before installing a VSD – the participant's energy consumption after installing a VSD*

- **Step 1.2: General baseline**

→ The baseline to be considered is EFF2 motors with throttle control

## 4.1 Variable Speed Drives

- **Step 1.3: Normalisation factors**

- Annual Operating hours and Load factors are both an input parameter for the calculation of energy savings, and a potential normalization factor for energy use of motors with VSDs.

## 4.1 Variable Speed Drives

- **Step 1.4: Specifying the calculation method and its three related levels: two options depending on motor size**

A) [savings] are estimated **for motors smaller than 22 kW** using a default % of savings in **level 1** (EU default values for parameters) and **level 2** (national average values for parameters from sample surveys), or a **measure-specific level 3** (average values for parameters from surveys of a sample of participants to the facilitating measure being evaluated).

unitary gross annual energy savings per unit =

$$\left( \frac{P_{mec}}{\eta} * Av.LoadFactor * Av.OperatngHo urs \right) * Av.DefaultSavings$$

**With:**

$P_{mec}$  – Mechanical power taken from nameplate

$\eta$  – Motor efficiency values for motor per power range (taken from reference tables)

## 4.1 Variable Speed Drives

- **Step 1.4: Specifying the calculation method and its three related levels**

B) [savings] are estimated **for motors larger than 22kW with a case-specific level 3 method of evaluation:**

(Method used for White Certificates in **Italy** for motors  $\geq 22\text{kW}$ )

$$\text{unitary gross annual energy savings per unit} = \sum_i \left( (P_T^i - P_{VSD}^i) * h^i \right)$$

**With:**

$P_T^i$  – Electrical Power, with throttle control

$P_{VSD}^i$  – Electrical Power, with VSD

$h^i$  – Number of working hours for each power level

$i$  – Load profile index (Number of hours for each load range)

## 4.1 Variable Speed Drives

- Step 1.4: Specifying the calculation method and its three related levels: motors < 22kW

	Level 1	Level 2	Level 3
	unitary gross annual energy savings per unit = $\left( \frac{P_{mec}}{\eta} * Av.LoadFactor * Av.OperatingHours \right) * Av.DefaultSavings$		
A)	- EU default value for $\eta$ , Av. Load Factor, Av. Operating Hours, % of savings (Av. Default Savings)	- national averages for $\eta$ , Av. Load Factor, Av. Operating Hours, % of savings (Av. Default Savings)	- programme- or service-specific averages for $\eta$ , Av. Load Factor, Av. Operating Hours, % of savings (Av. Default Savings)

## 4.1 Variable Speed Drives

- Step 1.4: Specifying the calculation method and its three related levels: motors  $\geq 22\text{kW}$

	Level 1	Level 2	Level 3
B)	unitary gross annual energy savings per unit = $\sum_i ((P_T^i - P_{VSD}^i) * h^i)$		
	- not applicable	- not applicable	- unit-specific data

## 4.1 Variable Speed Drives

- **Indicative default value** for the unitary savings (1)
- default values for *av. load factor*, *av. operating hours*, **option A (< 22 kW), Level 1:**

Power ranges	Type of Applications	Industry		Tertiary	
		Hours (h)	Load factor	Hours (h)	Load factor
[0,75;4[	Pumps	3861,03	0,55	3800	0,55
[4;10[		4501,94	0,58	3050	0,60
[10;22[		5040,47	0,59	3000	0,60
[0,75;4[	Fans	4910,47	0,53	2250	0,60
[4;10[		4137,76	0,56	2500	0,65
[10;22[		5210,64	0,59	2500	0,65

## 4.1 Variable Speed Drives

- Indicative default value for the unitary savings, < 22 kW, level 1 (2)

[0,75;4[	Air Compressor	2177,99	0,63	1030	0,40
[4;10[		4057,72	0,60	1000	0,45
[10;22[		4625,99	0,68	980	0,45
[0,75;4[	Conveyors	3060,75	0,42	621	0,61
[4;10[		2787,90	0,41	916	0,53
[10;22[		3908,61	0,51	725	0,49
[0,75;4[	Cooling Compressors	5051,90	0,60		
[4;10[		1890,63	0,65		
[10;22[		5066,59	0,70		
[0,75;4[	Refrigeration			4200	0,70
[4;10[				4170	0,70
[10;22[				4050	0,75
[0,75;4[	Others	3086,64	0,34	500	0,30
[4;10[		2859,49	0,39	530	0,30
[10;22[		2299,44	0,45	570	0,30

## 4.1 Variable Speed Drives

- **Indicative default value** for the *Av. Default Savings* to calculate unitary savings (3) with option A (< 22 kW), level 1

End-Use	Average VSD Savings (%)
Pumps	28
Fans	28
Air Compressors	12
Cooling compressors	12
Conveyors	12
Other Motors	12

## 4.1 Variable Speed Drives

### ■ Main data needed for Option A

	Level 1	Level 2 and 3
<b>A)</b>	<ul style="list-style-type: none"> <li>- Mechanical power of motor for each VSD applied</li> <li>- Type of application (pump, fan, compressor, conveyor, other) for each VSD</li> <li>-Number of VSD sold</li> </ul>	<ul style="list-style-type: none"> <li>- Mechanical power of motor for each VSD applied</li> <li>- Average percentage of energy savings from VSDs (per end-use and possibly power range)</li> <li>-(Average) Number of working hours (per end-use and power range)</li> <li>-(Average) Load Factor (per end-use and power range)</li> <li>-Mechanical power</li> <li>-Type of application (pump, fan, compressor, conveyor, other)</li> <li>-Number of VSD sold</li> </ul>

## 4.1 Variable Speed Drives

- Main data needed for option B ( $\geq 22$  kW)

	Level 1 and 2	Level 3
<b>B)</b>	- not applicable	<ul style="list-style-type: none"> <li>- Motor electricity consumption at different typical loads</li> <li>- Flow Data Requirements at the same loads</li> <li>- annual hours of use at these loads</li> </ul>

## 4.1 Variable Speed Drives

- **Step 2.1: calculation formula for the total gross annual energy savings**

- unit = each installed VSD, both for option A and B.

$$Total\_gross\_annual\_energy\_savings = \sum_i^n [energy\_savings\_of\_VSD\_i]$$

## 4.1 Variable Speed Drives

### ■ Step 2.2: Requirements and methods for accounting for the number of unitary actions

→ Methods proposed for monitoring the number of actions (always LEVEL 3):

<p><b>Direct accounting methods are particularly appropriate with the use of:</b></p> <ul style="list-style-type: none"> <li>- Financial Tools (rebates, low interest rates, targeted taxation, e.g., tax rebates or faster depreciation rates)</li> <li>- Energy Audits</li> <li>- Energy Performance Contracting</li> <li>- White Certificates Schemes</li> </ul>	<p><b>Examples of methods</b></p> <ul style="list-style-type: none"> <li>- Collection of accounting documents (e.g. invoices, vouchers)</li> <li>- registry/database to collect details about participants and end-use actions proposed/taken</li> </ul>
<p><b>Indirect accounting methods are particularly appropriate with</b></p> <ul style="list-style-type: none"> <li>- Minimum Energy Performance Standards</li> <li>- Lifecycle costing campaigns</li> </ul>	<p><b>Examples of methods</b></p> <ul style="list-style-type: none"> <li>- surveys among the target groups to assess the portion/number of implemented end-use actions</li> <li>- surveys among the whole population targeted to assess compliance</li> </ul>

→ Finally, ex-post verification for a sample of participants should be done: monitoring of implementation and of energy consumption to ensure that end-use (EEI) actions are actually in place and operational, as specified initially.

## 4.1 Variable Speed Drives

### ■ Step 3.1: formula for the total ESD savings

*total net annual energy savings*

*= total gross annual energy savings of all VSDs (from step 2.1)*

*\* (1 - free-rider coefficient + multiplier coefficient)*

*\* double-counting factor*

→ Simplified formula, if total annual energy savings are below 40 million kWh/year, or if there is evidence that both the multiplier and the free-rider effects will be small:

*total net annual energy savings*

*= total gross annual energy savings of all VSDs (from step 2.1)*

*\* double-counting factor*

Possible range of coefficients:

Free-rider: share [0, 1]

Multiplier coefficient:  $\geq 0$

Double Counting: factor [0, 1]

## 4.1 Variable Speed Drives

### ■ Step 3.2: double counting

	Energy Audits	Energy Performance Contracting	White Certificates Schemes	Energy Taxation	Subsidy schemes	Risk of Overlap
Installation of Variable Speed Drives	X	X	X	X	X	X
Energy Efficient Motors	X	X	X	X	X	X
Improved Maintenance	X				X	
....						

### ■ Step 3.3: technical interactions

	VSDs	EEMs
VSDs		+
EEMs	+	

## 4.1 Variable Speed Drives

### ■ Step 3.4: multiplier effect

- Ex-ante calculations previewing the multiplier effect should be performed by the evaluator, as soon as the MS reveals its National Energy Efficiency Action Plan (NEEAP).

### ■ Step 3.5: free-rider effect

1 <sup>st</sup> approach	Stock/Market modelling: Level 2 - Baseline based on National Statistics Level 3 – Measure specific Data
2 <sup>nd</sup> approach	Definition of Net-to-Gross Ratios (NTGR) (implies surveys to participants or discrete choice modelling) Level 2 - National NTGR Level 3 – Measure Specific NTGR
3 <sup>rd</sup> approach	Progressive Approach

## 4.1 Variable Speed Drives

Years after start of facilitating measure implementation	Accounting Method/Progressive approach for the evaluation of the free-rider effect
[0,3[	General Default NTGR ratios <b>or</b> Stock/Market Modelling. MS can propose methods to define MS values of NTGR, taking into account that these methods should be applicable for all MS (it is up to the Commission – in a mid-term evaluation - to decide whether the methods are relevant or not).
>3	According to experience gained for all MS, new proposal not requiring the estimation of free-riders but the use of a default NTGR

### ■ Step 4: savings lifetime

<b>VSDs</b>	Default values: <b>8 years</b> (value from CWA-27).
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## 4.1 Variable Speed Drives

### ■ Quality assurance / uncertainties

for option A (<22 kW) we estimate:

**For efficiency : +/- 1 to 2%**

**For load factor and operating hours: +/- 10 to 15%**

**For default savings of VSD: +/- 10%**

for option B ( $\geq 22$  kW) we propose to require:

Measurement Equipment	Measurement Tolerances
4-Channel power data loggers , True RMS power analyzer, Flow meter	Data loggers: +/- 1% Power analyzer: +/- 1% Flow meter: +/- 2%

# Energy Audits

evaluate  
energy savings<sup>EU</sup>

## 5.0 Recalling Elements of Calculation:

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 (per end-use action)  
 (+)          no. of participants or units
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 (of a facilitating measure)
  - **step 3:**      **total ESD annual energy savings**  
 (of packages of EEI measures)
  - **step 4:**      **total ESD energy savings for year “i”** (i=2010 or 2016)
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## 5.2 Recalling Elements of Calculation: Three levels of evaluation efforts

	Data scale	Main data sources	Data processing and documenting
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Level 3	<b>Program- or Participant-specific</b>	<b>specific</b> monitoring systems, registries, surveys, measurements	requirements to report on the specific data and justifications <b>in detail</b> (standard report at least available)

→ an evaluation method may combine different levels of efforts, as several parameters are needed in the calculations

## 5.1 Energy audits in industry and tertiary sector

- a method dealing with a type of facilitating measures
- the unit is a participant (one energy audit)

(method developed by **Motiva**, Finland)

## 5.1 Energy audit

- **What end-use actions are considered?**
- all kind of end-use (EEI) actions (improvement actions) proposed as a result of an energy audit including e.g.
  - investments in energy efficient technologies or
  - better operation and maintenance due to improved information

## 5.1 Energy audit

- **Step 1.1: Basic calculation formula for the unitary savings**

*Annual energy savings of one participant = the participant's electricity energy savings + the participant's (heat + fuel) energy savings through the implemented improvement actions identified in the audit*

*→ + distinction between energy carriers: electricity on one hand, (heat + fuels) on the other hand*

## 5.1 Energy audit

### ■ Step 1.2: General baseline

- Average baseline values cannot be formulated for energy audits
- In practice energy consumption before and after each improvement action is usually calculated by the auditors - this difference represents the savings achieved in each improvement action
- Due to the character of energy audits, a different approach is followed
  - The approach 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."

## 5.1 Energy audit

- **Step 1.3: Normalisation factors e.g., weather conditions, occupancy levels, plant throughput, opening or operating hours, plant throughput)**
- Normalisation factors are not used when total savings by energy audit programmes are calculated.
- Some of normalisation factors can be taken into account by the auditor 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.
  - Several factors can be taken into account when calculating the savings by individual improvement actions e.g. equipment operating times are an important source of potential savings when improvement actions are proposed. Also temperature corrections are usually made for the total heat consumption (excluding the use of hot water) of the audited facility but not used for the calculation of the savings in this method.

## 5.1 Energy audit

- **Step 1.4: Four possible options to calculate unitary annual energy savings (abbrev. as *[savings]* see also step 1.1)**
  - A) [savings] are estimated **from the annual consumption** of a participant audited, using a **EU default % for savings (Level 1)**  

$$[savings] = [\% \text{ of savings (EU)} * \text{Annual Consumption (GWh/a)}]$$
  - B) [savings] are estimated **from the total energy savings potential** reported **in the audits**, using a **EU default % for realised savings (Level 3&1)**  

$$[savings] = [\% \text{ for realised savings (EU)} * \text{Total Savings Potential (GWh/a)}]$$
  - C) [savings] are collected **directly through surveys**, ex post, for past but recent energy audit schemes, if option B or D not possible **(Level 2)**
  - D) [savings] are calculated **from the total savings potential** reported in the audit and the average **degree of implementation** in energy audits **(Level 3)**  

$$[savings] = [\% \text{ Degree of Implementation} * \text{Total Savings Potential (GWh/a)}]$$

## 5.1 Energy audit

### ■ Step 1.4: Option A) = Level 1 (not recommended)

$[savings] = [\% \text{ of savings (EU)} * \text{Annual Consumption (AC)} \text{ (GWh/a)}]$

- *distinction between energy carriers to be used: electricity on one hand, (heat + fuels) on the other hand*

#### Data needed:

- **EU default values for savings (% of AC in energy audits in industrial, municipal or private service sector)**
- **AC (annual energy consumption) of the audited facilities**  
 tertiary sector: AC possible to calculate via average specific consumption (per m<sup>2</sup> or m<sup>3</sup>) by building type and by energy type (electricity and heat) AND audited building volumes (m<sup>2</sup> or m<sup>3</sup>) by building type

## 5.1 Energy audit

- **Proposed EU default value for option A, Level 1:**  
*[% of savings (EU)] (average energy savings achieved by energy audits)*

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

## 5.1 Energy audit

- **Step 1.4: Option B) = Level 1 and 3 combined**

*[savings] = [% of realised savings \* Total Savings Potential (TSP) (GWh/a)]*

- *distinction between energy carriers to be used: electricity on one hand, (heat + fuels) on the other hand*

### Data needed:

- **EU default value % for realised savings of the TSP reported in energy audits by sector (Level 1)**
- **TSP (total savings potential) for the audited facilities by sector from audit database (Level 3)**

## 5.1 Energy audit

- **Proposed default value for option B, level 1:**  
*[% for realised savings] (% for realised savings out of potential savings)*

Sector	Proportion of realised savings (% , compared to the Total Potential Savings assessed by the audit)			
	Percentages to be used as default value in option B calculations			
	Electricity	Heat and fuels		
<b>Buildings</b> in the <b>municipal</b> services sector (residential buildings not included)	25%	25%		
<b>Buildings</b> in the <b>private</b> services sector (residential buildings not included)	25%	25%		
<b>Industry</b> (energy-intensive process industry not included)	20%	15%		

## 5.1 Energy audit

- **Step 1.4: Option C) = Level 2**
- **Proposal:** Only to be allowed for past but recent energy audit schemes, if option B or D not possible, i.e., no database of energy savings potentials identified in audits exists;
- Both expensive and rather unreliable

### **Data needed:**

- **Each participants' ex-post achieved annual energy savings due to actions implemented as a consequence of the audit, from a national survey**

## 5.1 Energy audit

- Step 1.4: Option D) = Level 3 (recommended)
- Step 1.4: Option D) = Level 3 (recommended)
- $[savings] = [% \text{ degree of implementation } (DI) * \text{Total Annual Savings Potential } (TSP) (GWh/a)]$

$[degree \text{ of implementation } DI [\%] ] = [Implemented \text{ actions } (\%) + \text{actions } \mathbf{D}ecided \text{ to be implemented } (\%) + \mathbf{a} * \text{actions under } \mathbf{C}onsideration (\%)]$   
 (default value for  $\mathbf{a}=0,05$  for actions in industry and  $\mathbf{a}=0,3$  for actions in tertiary sector)

### Data needed:

- Ex-post follow up data (for remarkable share of audited facilities) for **I**, **D** and **C** to calculate the **DI [%]** in different sectors
- **TSP (total savings potential) defined in the audit**
- default values or national average for **a** in different sectors

## 5.1 Energy audit

- **Step 2.1: calculation formula for the total gross savings**

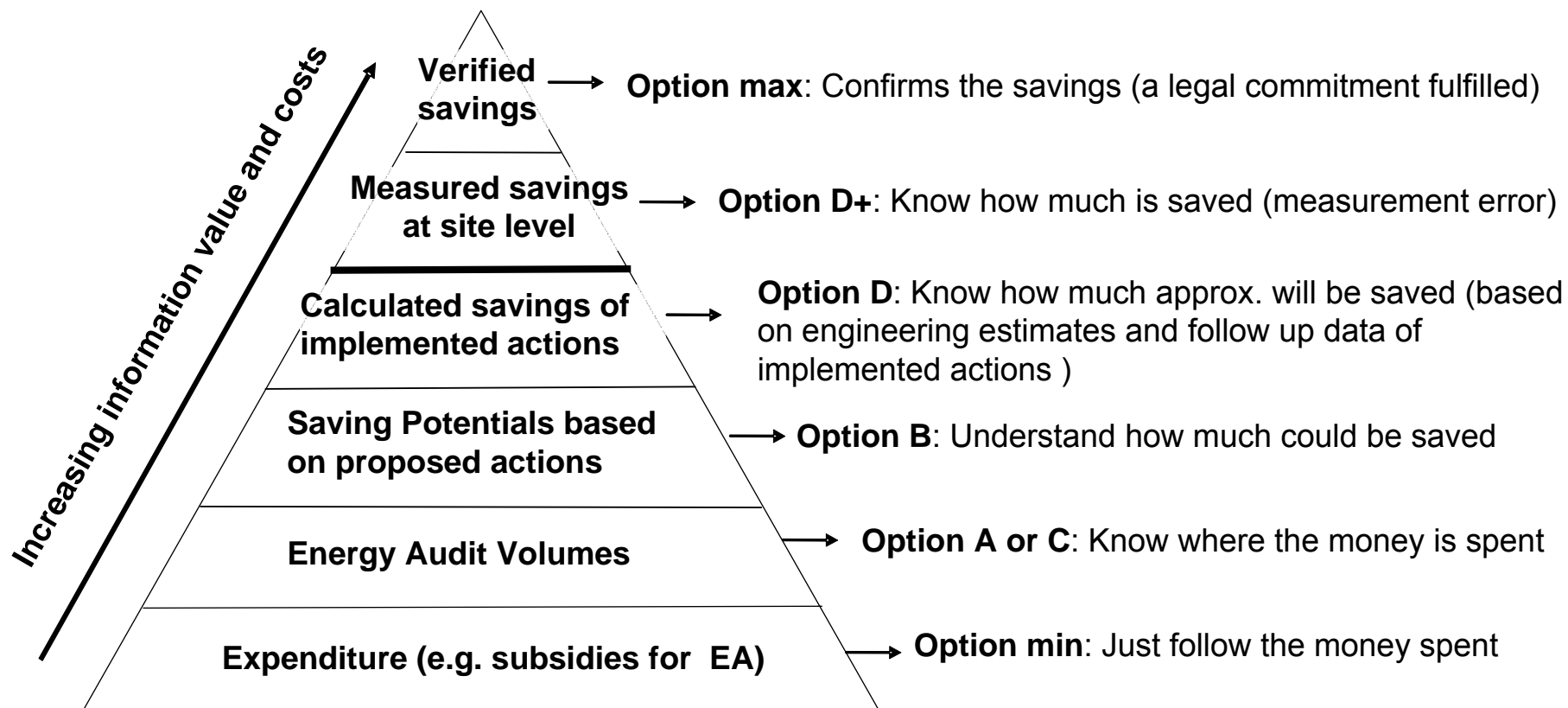
→ summing up the savings per participants, making a distinction between industry and tertiary

*total gross annual energy savings =*

$$\begin{aligned}
 & \sum_{i=1}^n [\text{annual energy savings of } \underline{\text{industrial}} \text{ participant } i] \\
 & + \sum_{j=1}^m [\text{annual energy savings of } \underline{\text{tertiary}} \text{ participant } j]
 \end{aligned}$$

## 5.1 Energy audit (7a)

### ■ Step 2.2 Possible monitoring systems



## 5.1 Energy audit (7b)

### ■ Corresponding monitoring technique and costs (1)

Options	Coverage	Complexity	Rough cost estimates		Information gained from
			< 100 audits/year	> 100 audits/year	
<b>MIN</b> Expenditure	All audits	Easily achieved	No extra costs	No extra costs	Application
<b>A or C</b> Energy audit volumes	All audits	Easily achieved	Negligible extra costs	Minor extra costs – 0.25 man-months/year	Application
<b>B</b> 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
<b>D</b> Calculated savings of implemented end-use actions	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

## 5.1 Energy audit (7b)

- Corresponding monitoring technique and costs (2)

Options	Coverage	Complexity	Rough cost estimates		Information gained from
			< 100 audits/year	> 100 audits/year	
<b>D+</b> 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)
<b>MAX</b> 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

## 5.1 Energy audit

- **Choice of the evaluation efforts and the calculation option**
  - depends on the share of the audit programmes for the national ESD target; a **threshold of 10%** is proposed, above which **at least level 2** values are **required (i.e., option A excluded, C?)**
  - depends also on the **data availability** (and hence on the monitoring system used)

## 5.1 Energy audit

- **Step 3.1: formula for the total ESD savings**

*total ESD annual energy savings =*

*total gross annual energy savings - **double counting** estimate  
- **technical interactions** (?) + **multiplier energy savings** - **free-rider** savings (?)*

## 5.1 Energy audit

### ■ Step 3.2: double counting

- possible crossing with other facilitating measures (e.g. subsidies, voluntary agreements, etc.)
- can't be estimated as a coefficient factor, should be estimated in absolute terms
- recommendation: exchanging information between the monitoring systems for the different facilitating measures or even an integrated monitoring and evaluation process
- the decision how to allocate the possible double counting is always up to the Members State

### ■ Step 3.3: technical interactions

- best addressed during audit when estimating the savings potential by ranking the proposed actions by priority order, and then using as baseline consumption for the next lower ranked action the consumption taking account of the higher ranked actions

## 5.1 Energy audit

- **Step 3.4: multiplier effect**
  - no significant evidence from existing studies
  - studies to quantify this effect are costly → recommended to consider this only when multiplier effect is strongly expected (e.g. for identical small facilities like a chain of small supermarkets)
  
- **Step 3.5: free-rider effect**
  - a Finnish study assessed it to be 10-15% of the realised actions
  - compensation with multiplier effect in some extent
  - may be assumed to be rather limited for energy audits (especially if conservative values are used for savings lifetime)
  - free riders (not mentioned in ESD) need not to be taken into account

## 5.1 Energy audit

### ■ Step 4: savings lifetime

<b>Level 1</b>	Default values: <b>6 years</b> for tertiary and <b>8 years</b> for industry (6 years for all, if no sector distinction can be made from monitored data)
<b>Level 2</b>	Proven <b>national average</b> per type of participant
<b>Level 3</b>	Lifetime value <b>per type of improvement actions</b> (or group of actions) if: <ul style="list-style-type: none"> <li>- the Member State can present justifying information</li> <li>- values per type of actions are proven (national values) or agreed among Member-States (default EU values)</li> </ul>

### ■ Early actions

- in principal all energy savings raised from energy audits (improvement actions) since 1995 can be taken into account if Member State is able to show the savings still exist in 2010 or 2016.

## 5.1 Energy audit

### ■ Quality assurance/uncertainties

- uncertainties can be reduced significantly by **quality assurance** of the audits → if no quality assurance is done, calculations particularly at level 1 are void
- 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:

- 1) the **competence of the auditors**;
- 2) the **quality of the audit reports**.

## 5.1 Energy audit

- **Possibilities to report uncertainties**

<b>Level 1</b>	Identify and report <b>sources of uncertainties</b> .
<b>Level 2</b>	Identify and report sources of uncertainties + estimate <b>range of magnitude</b> for each parameter used (min-max)
<b>Level 3</b>	Identify and report sources of uncertainties + conduct a <b>sensitivity analysis</b> with pessimistic/optimistic scenarios or quantify uncertainties (confidence intervals)

# Improved Lighting Systems (Tertiary Sector)

evaluate  
energy savings<sup>EU</sup>

## 5.0 Recalling Elements of Calculation:

### Four steps for calculation

- **step 1:**     **unitary gross annual energy savings**  
(per end-use action)  
(+)         no. of participants or units
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(of a facilitating measure)  
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(of packages of EEI measures)  
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## 5.0 Recalling Elements of Calculation: Three levels of evaluation efforts

	Data scale	Main data sources	Data processing and documenting
Level 1	<b>European default values</b>	<b>existing/available</b> European regulation, studies and statistics	<b>security factor</b> according to the level of <b>reliability</b> of the default value
Level 2	<b>National representative values</b>	<b>up-to-date</b> national statistics, surveys, samples, registries	requirements = <b>minimum set of information and justifications</b> to be reported
Level 3	<b>Program- or Participant-specific</b>	<b>specific</b> monitoring systems, registries, surveys, measurements	requirements to report on the specific data and justifications <b>in detail</b> (standard report at least available)

→ an evaluation method may combine different levels of efforts, as several parameters are needed in the calculations

## 5.1 Harmonised bottom-up evaluation methods

### Method 9: Improvement of Lighting Systems

- a method dealing with several types of **end-use actions** and their **combination**
- the **unit** is a Lighting System installed at a **Participant**
- In combination of end-use actions to improve lighting systems in the tertiary sector, large energy savings can be made (up to 80 %)

(method developed by eERG – Politecnico di Milano, Italy)

## 5.1 Improvement of Lighting Systems - end-use actions

- Exchange of **lamps**: Incandescent => Compact Fluorescent Lamps (CFLs); T12 => T8 => T5 Fluorescent Lamps
- Use of **electronic ballasts** instead of electromagnetic ballasts
- Use of energy-efficient **luminaires**
- Improved **lighting controls**

## 5.1 Improvement of Lighting System

- **Step 1.1: Basic calculation formula for the unitary savings**

*quite complex formula to calculate the following:*

*Annual energy savings of one participant = the participant's energy consumption with an inefficient lighting system – the participant's energy consumption with an energy-efficient lighting system*

## 5.1 Improvement of Lighting System

- **Step 1.2: Baseline (reference system)**

→ The baseline against which to calculate the energy savings depends on end-use action and situation

End-use action	Advanced reinvestment or upgrade of existing system	Normal reinvestment or new build
Use of energy-efficient lamps, ballasts, luminaires	Energy efficiency of existing system / stock average	Energy efficiency of new, inefficient system / market inefficient average
Improved lighting controls	Energy efficiency of existing system / stock average	Energy efficiency of new, inefficient system / market inefficient average

## 5.1 Improvement of Lighting System

### ■ Step 1.3: Normalisation factors

- Annual Operating hours are both an input parameter for the calculation of energy savings, and a potential normalization factor for energy use of lighting systems.
- Proposed Level 1 Normalisation Factors:
  - 1.2 for Northern Europe (DK, FI, SE, EST, LV, LT; NO)
  - 1.1 for Western Europe (UK, IRL)
  - 1.0 for Central Europe (AT, BE, CZ, DE, FR, HU, LU, NL, PL, SK)
  - 0.9 for Southern Europe (BG, CY, ES, GR, IT, MA, PO, RO, SL)

## 5.1 Improvement of Lighting System

- **Step 1.4: Specifying the calculation method and its three related levels: two options depending on complexity of end-use actions**
- A) [savings] are estimated **for CFLs, electronic ballasts, occupancy and daylight sensors** using a default value (in kWh/year/unit) or a default % of savings in **level 1** (EU default values for parameters) and **level 2** (national average values for parameters from sample surveys), or a **measure-specific level 3** (average values for parameters from surveys of a sample of participants to the facilitating measure being evaluated).

## 5.1 Improvement of Lighting System

- **Step 1.4: Specifying the calculation method and its three related levels**
- B) [savings] are estimated **for more complex combinations of end-use actions**, particularly if **energy-efficient luminaires** with T8 or T5 lamps and electronic ballasts are used, **with a case-specific level 3 method of evaluation, using the complex formula but possibly some level 1 values.**

## 5.1 Improvement of Lighting System

- **Indicative default value** for the unitary savings (1)
- default values for **option A, Level 1**:

End-use action	Savings against stock average baseline	Savings against market inefficient average baseline
Use of CFLs instead of Incandescents	102 kWh/year/CFL	102 kWh/year/CFL
Use of electronic ballasts with T8 systems	18 kWh/year/ballast	12 kWh/year/ballast
Use of occupancy sensors on T8 systems	80 kWh/year/sensor or 20 %	80 kWh/year/sensor or 20 %

## 5.1 Improvement of Lighting System

- **Indicative default value** for the unitary savings (2)
- default values for **option B, Level 1**:

End-use action	energy consumption of baseline system	energy consumption of energy-efficient system
Use of efficient luminaires with T8 systems	90 kWh/year/ballast	80 kWh/year/ballast
Use of efficient luminaires with T5 systems	90 kWh/year/ballast	83 kWh/year/ballast
Annual hours of use	2,500 h/year	2,500 h/year
Number of luminaires	<b>Case-specific! (Level 3)</b>	<b>Case-specific! (Level 3)</b>

## 5.1 Improvement of Lighting System

- **Step 2.1: calculation formula for the total gross annual energy savings**

- unit = one lighting system (Participant).

$$Total\_gross\_annual\_energy\_savings = \sum_i^n [energy\_savings\_of\_Participant\_i]$$

## 5.1 Improvement of Lighting System

### ■ Step 2.2: Requirements and methods for accounting for the number of unitary actions

→ Methods proposed for monitoring the number of actions (always LEVEL 3):

<p><b>Direct accounting methods are particularly appropriate with the use of:</b></p> <ul style="list-style-type: none"> <li>- Financial Tools (rebates, low interest rates, targeted taxation, e.g., tax rebates or faster depreciation rates)</li> <li>- Energy Audits</li> <li>- Energy Performance Contracting</li> <li>- White Certificates Schemes</li> </ul>	<p><b>Examples of methods</b></p> <ul style="list-style-type: none"> <li>- Collection of accounting documents (e.g. invoices, vouchers)</li> <li>- registry/database to collect details about participants and end-use actions proposed/taken</li> </ul>
<p><b>Indirect accounting methods are particularly appropriate with</b></p> <ul style="list-style-type: none"> <li>- Minimum Energy Performance Standards</li> <li>- Lifecycle costing campaigns</li> </ul>	<p><b>Examples of methods</b></p> <ul style="list-style-type: none"> <li>- surveys among the target groups to assess the portion/number of implemented end-use actions</li> <li>- surveys among the whole population targeted to assess compliance</li> </ul>

→ Finally, ex-post verification for a sample of participants should be done: monitoring of implementation and of energy consumption to ensure that end-use (EEI) actions are actually in place and operational, as specified initially.

## 5.1 Improvement of Lighting System

### ■ Step 3.1: formula for the total ESD savings

*total net annual energy savings*

*= total gross annual energy savings of all participants (from step 2.1)*

*\* (1 - free-rider coefficient + multiplier coefficient)*

*\* double-counting factor*

→ Simplified formula, if total annual energy savings are below 40 million kWh/year, or if there is evidence that both the multiplier and the free-rider effects will be small:

*total net annual energy savings*

*= total gross annual energy savings of all participants (from step 2.1)*

*\* double-counting factor*

Possible range of coefficients:

Free-rider: share [0, 1]

Multiplier coefficient:  $\geq 0$

Double Counting: factor [0, 1]

## 5.1 Improvement of Lighting System

### ■ Step 3.2: double counting

	Energy Audits	Energy Performance Contracting	White Certificates Schemes	Energy Taxation	Subsidy schemes	Risk of Overlap
Energy-efficient Luminaires	X	X	X	X	X	X
Energy-efficient Lamps & ballasts	X	X	X	X	X	X
Improved Control	X				X	X
....						

### ■ Step 3.3: technical interactions

- Interaction possible with HVAC systems: reduced cooling/increased heating demand

## 5.1 Improvement of Lighting System

### ■ Step 3.4: multiplier effect

Indicators and data that can be used:

- sales data analysis (numbers and efficiency levels)
- Surveys among representative samples of (non-)participants
- Surveys with trade allies and/or other relevant stakeholders

### ■ Step 3.5: free-rider effect

1 <sup>st</sup> approach	Stock/Market modelling: Level 2 - Baseline based on National Statistics Level 3 – Measure specific Data
2 <sup>nd</sup> approach	Definition of Net-to-Gross Ratios (NTGR) (implies surveys to participants or discrete choice modelling) Level 2 - National NTGR Level 3 – Measure Specific NTGR
3 <sup>rd</sup> approach	Progressive Approach

## 5.1 Improvement of Lighting System

- **Step 3.5: free-rider effect - proposed Level 1 default values for free-rider coefficient based on market data**

End-use action	Proposed free-rider coefficient for EEI measures in the years 2008 and 2009
Use of CFLs	0.5
Electronic ballasts	2008: 0.6 2009: 0.65
Efficient luminaires - T8	0.5
Efficient luminaires - T5	0.3
Occupancy sensors	0.05

## 5.1 Improvement of Lighting System

- **Step 4: savings lifetime - default values from CWA-27**

<b>New/renovated office lighting (<i>Commercial/ Public sector</i>)</b>	<b>12 years</b>
<b>Motion detection light controls (<i>Commercial /Public sector</i>)</b>	<b>10 years</b>

- **Early Action:**
- If decided to be eligible, early energy savings could be counted from 2004/2006 using these default values
- The same Level 1 default values presented above for unitary annual energy savings could be used

## 5.1 Improvement of Lighting System

- **Quality assurance / uncertainties**

Still to be developed!