3e-HOUSES Project – EC Contract 250491

METHODOLOGY FOR EFFICIENCY MEASUREMENT

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AGENDA

1. INTRODUCTION PROJECT
2. METHODOLOGY
   - 2.1. INTRODUCTION
   - 2.2. RATIOS / INDICATORS
   - 2.3. BACKGROUND
   - 2.4. PROPOSED METHODOLOGY
   - 2.4.1. METHODOLOGY ENERGY SAVINGS
   - 2.4.2. METHODOLOGY DEMAND RESPONSE
   - 2.4.3. METHODOLOGY CO2 avoided emissions

AGENDA

1. INTRODUCTION PROJECT
2. METHODOLOGY
   - 2.1. INTRODUCTION
   - 2.2. RATIOS / INDICATORS
   - 2.3. BACKGROUND
   - 2.4. PROPOSED METHODOLOGY
   - 2.4.1. METHODOLOGY ENERGY SAVINGS
   - 2.4.2. METHODOLOGY DEMAND RESPONSE
   - 2.4.3. METHODOLOGY CO2 avoided emissions

Introduction Project. Overview

PROJECT

- 3e-Houses: To build the customers into the energy system through ICTs, allowing them to develop or enhance their relationship with the environment by piloting in several social housing buildings the interaction between smart devices and the users.
- Under CIP-ICT-PSP-2009.4.1: ICT for energy efficiency in social housing.
- Project length: 3 years. Started on 1st February 2010
- Overall Budget: 3.998.785 €
- of which, a maximum of 1.999.391 € shall be granted by EC

- 3e-HOUSES deals with the integration of the most established ICT technologies in social housing in order to provide an innovative service for energy efficiency:
  - real time monitoring and management of the energy consumption;
  - integration of renewable energies;
  - creating the resources to lower energy consumption.
- The described new services will allow the integration of renewable energy and other sources of distributed energies. As well it is expected to achieve a reduction around 20% in energy consumption in social buildings, by means of the real time monitoring, and management and control systems.

Introduction Project. Objectives

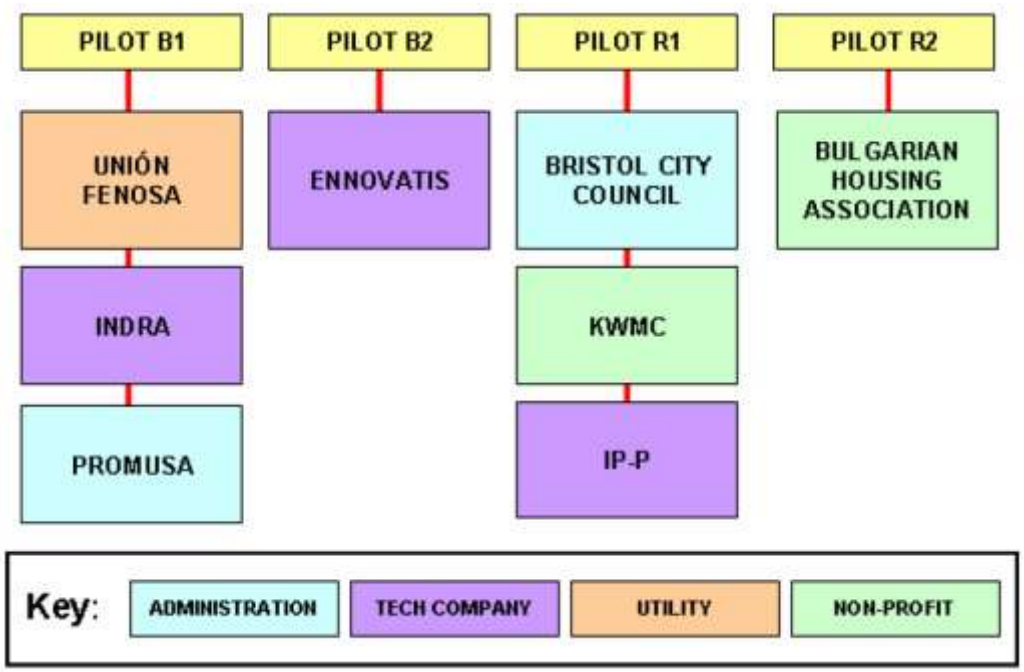
OBJECTIVES

4 pilot project to demonstrate ICT for Energy Efficiency in Social Housing

The **main objective** of this project is to improve the sustainability in European social housing, by the ICT-based centralized monitoring and management of the energy consumption and production, and to provide decision makers with the necessary tools to be able to plan energy saving and peak reduction measures.

The **specific objectives** of the 3e-HOUSES project are: definition of methodologies; pilots design; pilots monitoring; pilots implementation; pilots validation; replication of two pilots; results and impact analysis; dissemination and promotion

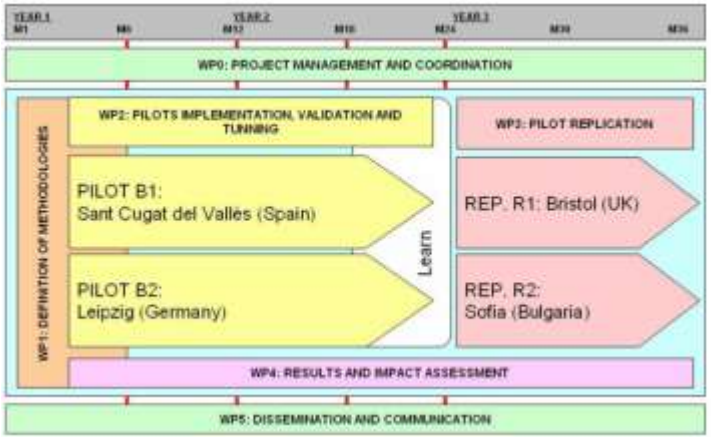
Introduction. Consortium Roles



CONSORTIUM

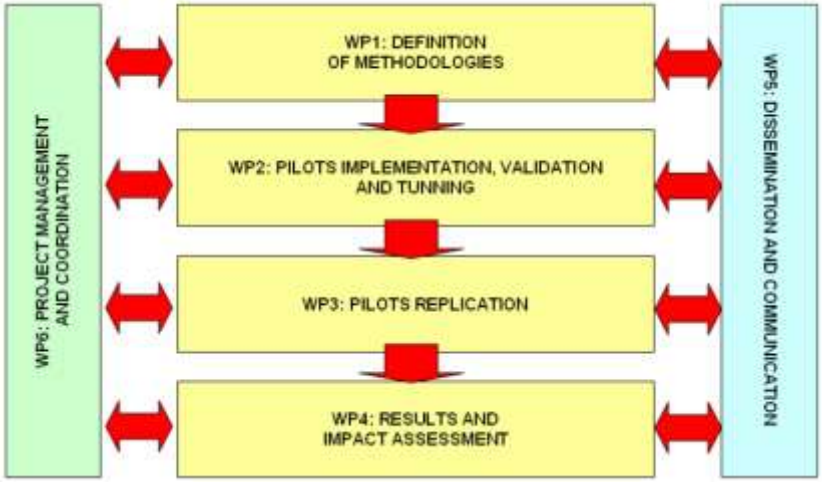
- **8 partners from 4 different countries.**
- **Including 4 different roles to cover all the actors represented in the project: Public administration, utilities, housing associations and ICT focused companies.**

Introduction. Methodology and Workplan



METHODOLOGY

WORKPLAN



AGENDA

1. INTRODUCTION PROJECT
2. METHODOLOGY
   - 2.1. INTRODUCTION
   - 2.2. RATIOS / INDICATORS
   - 2.3. BACKGROUND
   - 2.4. PROPOSED METHODOLOGY
   - 2.4.1. METHODOLOGY ENERGY SAVINGS
   - 2.4.2. METHODOLOGY DEMAND RESPONSE
   - 2.4.3. METHODOLOGY CO2 avoided emissions

2.1. INTRODUCTION. DEFINITION

What is the methodology for efficiency measurement?

It's a methodology to calculate energy and economic savings and evaluate the demand response and the avoided CO_2 emissions. They are determined by comparing measured energy use or demand before and after implementation of the energy efficiency measures (EEMs)

2.1. INTRODUCTION. REQUIREMENTS

Method used should meet the criteria:

- Is the method easy to implement?
- Are the results accurate?
- Are the results useful and transparent?
- Is the method adaptable on this type of projects?

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AGENDA

1. INTRODUCTION PROJECT
2. METHODOLOGY
   - 2.1. INTRODUCTION
   - 2.2. RATIOS / INDICATORS
   - 2.3. BACKGROUND
   - 2.4. PROPOSED METHODOLOGY
   - 2.4.1. METHODOLOGY ENERGY SAVINGS
   - 2.4.2. METHODOLOGY DEMAND RESPONSE
   - 2.4.3. METHODOLOGY CO2 avoided emissions

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2.2. RATIOS / INDICATORS

Technical ratios /indicators:

Heating:

Heating consumptions per person (kWh/person)
Consumptions per square meter (kWh/m2)
kWh/HDD
Primary Energy consumptions per square meter (kWh_{PE}/m2)

Cooling:

Cooling consumptions per person (kWh/person)
Consumptions per square meter (kWh/m2)
kWh/CDD
Primary Energy consumptions per square meter (kWh_{PE}/m2)

Lighting:

Lighting consumption per person (kWh/person)
Lighting consumption per square meter (kWh/m2)
Primary Energy consumptions per square meter (kWh_{PE}/m2)

Cooking:

Cooking consumption per person (kWh/person)
Primary Energy consumptions per person (kWh_{PE}/person)

Water ratios:

Consumptions per person (litre /person)

Pumping:

Solar pumping consumption per person (kWh/person): the solar contribution is for DHW, therefore the ratio should be by person that uses the DHW in the facililty.
Primary Energy consumptions per person (kWh_{PE}/person)

Other appliances:

Other consumption per person (kWh/person)
Other consumption per square meter (kWh/m2)

Renewable energy share in energy and electricity

[%] : The share of renewable energy in e. g. total primary energy consumption, total end energy consumption or electricity generation

2.2. RATIOS / INDICATORS

Environmental ratios/indicators:

HVAC, lighting:
CO_2 emissions per m2
CO_2 emissions per m2

Cooking, pumping:
CO_2 emissions per person
CO_2 emissions per person

Social ratios/indicators:

Comfort

Economical ratios/indicators:

Total consumption (€/person) , (€/m2)
Consumption per person (€ /person/per capita income).

Costs per saved kWh of end energy: [Cent/kWh] Costs per saved kWh of end energy on the level of a building or dwelling

Profitability (additional cost approach) [€] Net present value of the investment on the level of a building or dwelling (additional cost approach)

Profitability (full cost approach) [€]

Public funding [%] Share of public funding on the energy saving investment

ROI

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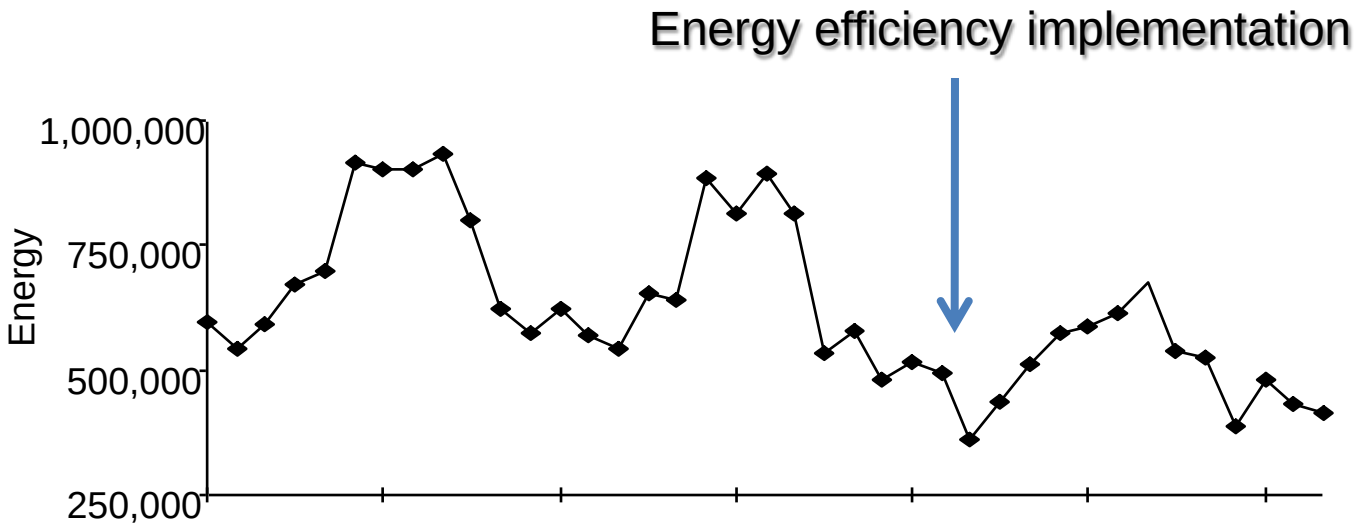
AGENDA

1. INTRODUCTION PROJECT
2. METHODOLOGY
   - 2.1. INTRODUCTION
   - 2.2. RATIOS / INDICATORS
   - 2.3. BACKGROUND
   - 2.4. PROPOSED METHODOLOGY
   - 2.4.1. METHODOLOGY ENERGY SAVINGS
   - 2.4.2. METHODOLOGY DEMAND RESPONSE
   - 2.4.3. METHODOLOGY CO2 avoided emissions

2.3. BACKGROUND

How to measure energy efficiencies savings?



Where are the savings?
How much are our savings?

2.3. BACKGROUND

How to measure energy efficiency savings?

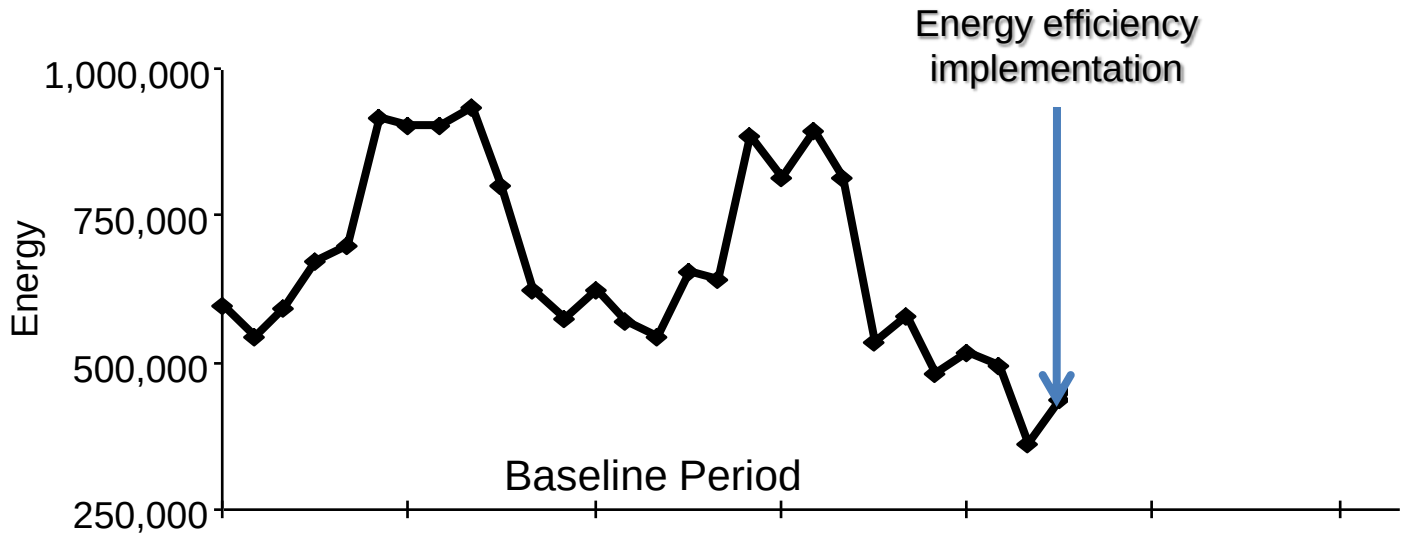
The saving is the difference between consumption after energy efficiency measures (EEMs) and the consumption that there would have been prior to their implantation

Impossible to measure directly energy savings.

It's necessary to have consumption data prior implantation of EEM (baseline period) in similar conditions than after implementation (reporting period). Then is necessary to make suitable adjustments for changes in conditions.

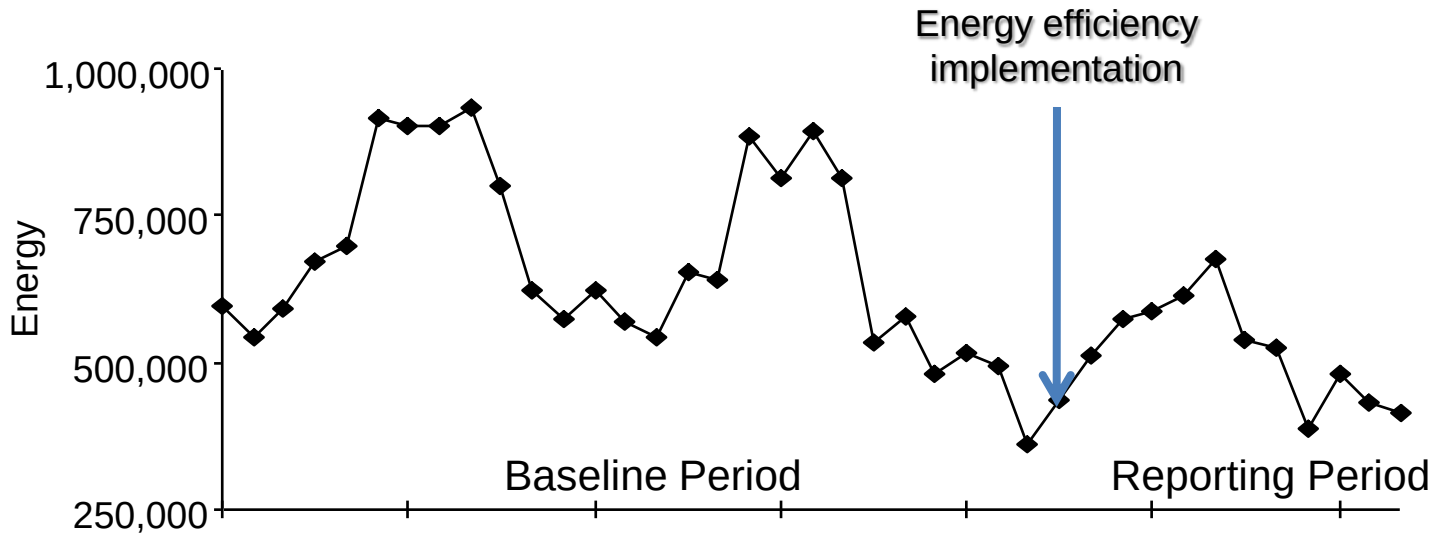
2.3. BACKGROUND

Baseline Period: Time necessary to be representative of the operation of the dwelling before implementation of the energy efficiency measures.



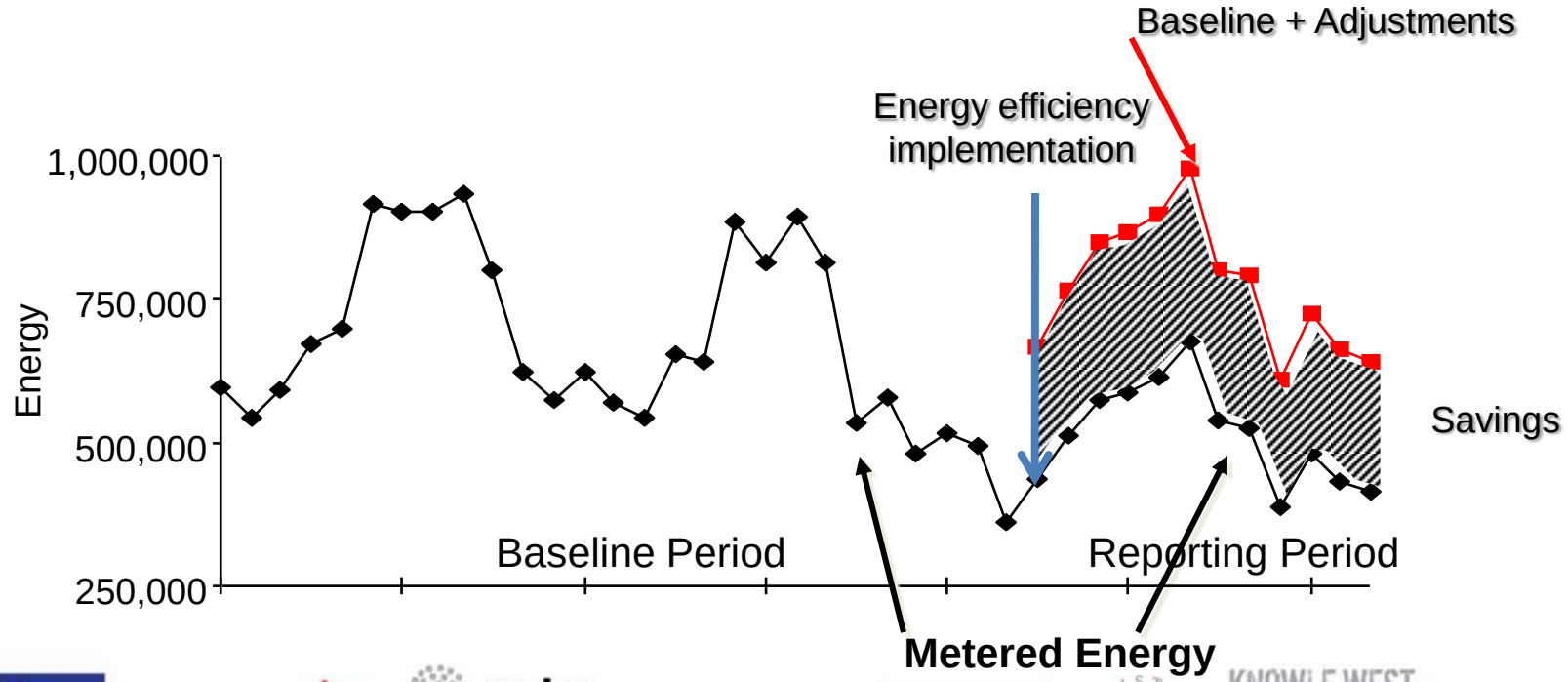
2.2. BACKGROUND

Reporting Period: Time after the implementation of the EEM



2.2. BACKGROUND

How to measure energy efficiencies savings? - SOLUTION



2.2. BACKGROUND

IPMVP (International Performance Measurement & Verification Protocol)

Protocol of the Office of Energy Efficiency an Renewable Energy of U.S. Department of Energy

The IPMVP is being widely adopted by national and regional government agencies and by industry and trade organizations to help increase investment in energy efficiency and achieve environmental and health benefits.

The IPMVP is the basis of energy savings determination in energy performance contracting.

It can't be used at 100%

Use this methodology as basis

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2.2. BACKGROUND. IPMVP

Savings = Baseline Consumption – Reporting Period Consumption Adjustments

Option A - Retrofit Isolation: Measurement of the key parameter

- **Field measurement of the key performance parameter(s)**
- **Parameters not selected for field measurement are estimated** (*historical* data, manufacturer's specifications, etc)
- **sub-metering in EEM affected system**

Option B - Retrofit Isolation: Measurement of all parameters of system affected by EEM

- **Field measurement of all parameters**
- **Sub-metering in EEM affected system**

Option C - Whole Facility

- **Field measurement of all parameters**
- **No sub-metering in EEM affected system: measuring energy use at the whole facility or sub-facility level**
- **Possibility of control groups**

AGENDA

1. INTRODUCTION PROJECT
2. METHODOLOGY
   - 2.1. INTRODUCTION
   - 2.2. RATIOS / INDICATORS
   - 2.3. BACKGROUND
   - 2.4. PROPOSED METHODOLOGY
   - 2.4.1. METHODOLOGY ENERGY SAVINGS
   - 2.4.2. METHODOLOGY DEMAND RESPONSE
   - 2.4.3. METHODOLOGY CO2 avoided emissions

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2.4.1. PROPOSED METHODOLOGY. ENERGY SAVINGS.

Energy Savings = Baseline Energy Consumption – Energy Consumption after ICT's Adjustments

1. **Establish baseline: through**
   - **Energy audits**
   - **Measurement campaign**
2. **MEASUREMENT & VERIFICATION Savings**

   Establish adjustments

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2.4.1. PROPOSED METHODOLOGY. ENERGY SAVINGS.

Baseline's definition

Electricity or fuel/gas:

If ELECTRICITY CONSUMPTIONS + DHW:
Baseline period: a week
Information to register:
- **Week consumption (daily average)**
- **Independent variables (routine adjustments):**
  - **HDD or CDD**
  - **Occupancy level**
- **Static factors (non-routine adjustments): environmental, operational and maintenance characteristics**

If THERMAL CONSUMPTION:
Baseline period: a year
Information to register:
- **Monthly consumption**
- **Independent variables (routine adjustments):**
  - **HDD or CDD**
  - **Occupancy level**
- **Static factors (non-routine adjustments): environmental, operational and maintenance characteristics**

Water :

Baseline period: a week
Information to register:
- **Week consumption (daily average)**
- **Independent variables:**
  - **Occupancy level**
- **Static factors (non-routine adjustments): environmental, operational and maintenance characteristics.**

IP performance

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2.4.1. PROPOSED METHODOLOGY. ENERGY SAVINGS.

Energy Savings Calculation. Option A

Option A: submetering + estimation

Option A *Savings = Estimated Value x (Baseline Period – Reporting Period) Adjustments*

Example: lighting update

- *Before: Power = 60 W operation hours: 10 h/week (**estimated** value)*
- *After EEM: Power = 15 W operation hours: 10 h/week (**estimated** value)*
- *Savings: (60 – 15) * 10 = 450 Wh*
- *Saving year: 450 Wh * 52 weeks/year = 23,4 kWh/year*

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2.4.1. PROPOSED METHODOLOGY. ENERGY SAVINGS.

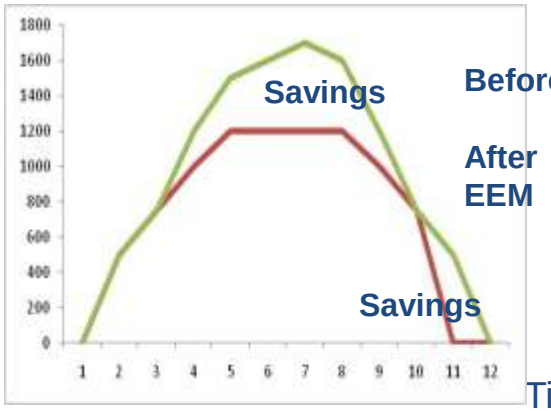
Energy Savings Calculation. Option B

Option B: measurement of all parameters + submetering

Option B *Savings = Baseline Energy – Reporting Period Energy Adjustments*

Example

Power



Hour	Power before (W)	Power after (W)	Savings (W)
1	0	0	0
2	500	500	0
3	750	750	0
4	1150	950	200
5	1500	1200	300
6	1600	1200	400
7	1700	1200	500
8	1600	1200	400
9	1250	1000	250
10	800	800	0
11	500	0	500
12	0	0	0
	Power Savings	**2.550**	**W**
	Energy Savings	**30.600**	**Wh**

Energy Savings =

∑ (kW before - kW after) * running hours

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2.4.1. PROPOSED METHODOLOGY. ENERGY SAVINGS.

Energy Savings Calculation. Option C

Option C: measure whole facility (utility meter)

Option C *Savings = Baseline Energy – Reporting Period Energy Adjustments*

It is possible to explain the residential consumption with the following formula:

*Electricity consumption = constant + X * number people + Y * HDD + Z * CDD*

*Fuel consumption = constant + X * number people + Y * HDD + Z * CDD*

*Water consumption = constant + X * number people*

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2.4.1. PROPOSED METHODOLOGY. ENERGY SAVINGS.

Energy Savings Calculation. Option C

It is possible to reduce the previous formula:

- *No heating:* constant + X * number people + ~~Y * HDD~~ + Z * CDD
- *No cooling:* constant + X * number people + Y * HDD + ~~Z * CDD~~
- *Occupancy constant:* constant + ~~X * number people~~ + Y * HDD + Z * CDD
- *No cooling & heating:* constant + X * number people + ~~Y * HDD + Z * CDD~~
- *No cooling & heating & occupancy constant:*

constant + ~~X * number people + Y * HDD + Z * CDD~~

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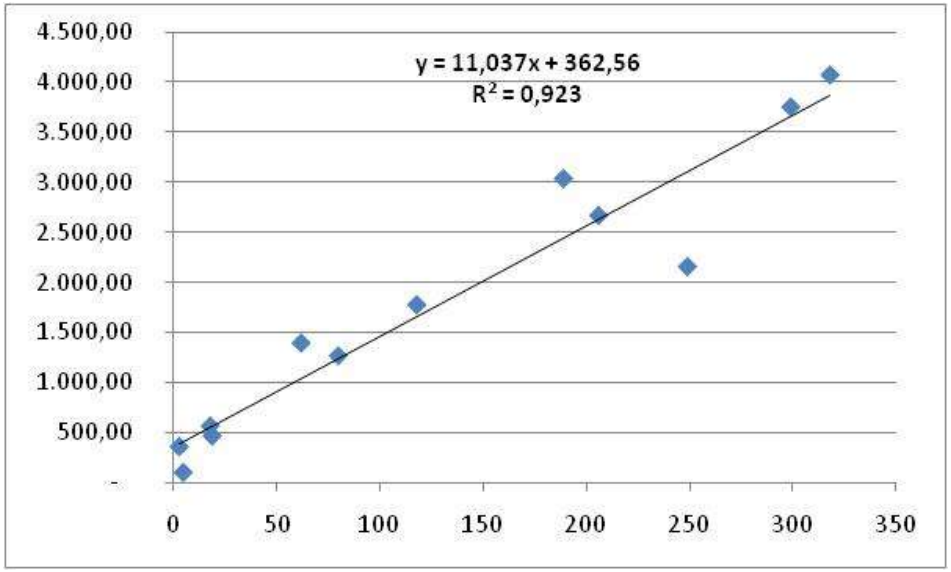
2.4.1. PROPOSED METHODOLOGY. ENERGY SAVINGS.

Energy Savings Calculation. Option C.. Examples – Individual Apartment

Example – Baseline calculation (Before EEM implementation) without changes in occupancy level and no cooling

Baseline year (2008) **Consumption (kWh): 11,037 * HDD + 362,56**

	Baseline (kWh)	HDD
January	3.746,80	299
February	3.033,87	189
March	2.666,27	206
April	1.778,29	118
May	1.396,91	62
June	471,53	19
July	366,56	3
August	109,28	5
September	571,41	18
October	1.269,90	80
November	2.158,28	249
December	4.066,22	318
	21.635	**1.566**



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2.4.1. PROPOSED METHODOLOGY. ENERGY SAVINGS.

Option C – Examples – Individual Apartment

Example – Baseline (before EEM implementation)

It's necessary adapt the previous consumptions to the actual consumptions conditions

This year (2009) is coldest than the baseline year and will increase the reference consumption

Baseline year (2008)

	Baseline (kWh)	HDD
January	3.746,80	299
February	3.033,87	189
March	2.666,27	206
April	1.778,29	118
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June	471,53	19
July	366,56	3
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October	1.269,90	80
November	2.158,28	249
December	4.066,22	318
	21.635	**1.566**

Consumption (kWh)=

11,037 * HDD + 362,56

Baseline year adjusted (to 2009)

	Baseline (kWh)	HDD
January	3.894,40	320
February	2.581,00	201
March	2.294,04	175
April	2.018,11	150
May	1.234,48	79
June	583,30	20
July	417,75	5
August	406,71	4
September	583,30	20
October	1.355,89	90
November	3.232,18	260
December	4.059,90	335
	22.661	**1.659**

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2.4.1. PROPOSED METHODOLOGY. ENERGY SAVINGS.

Option C – Examples – Individual Apartment

Example – After EEM implementation

Baseline year adjusted (to 2009)

	Baseline (kWh)	HDD
January	3.894,40	320
February	2.581,00	201
March	2.294,04	175
April	2.018,11	150
May	1.234,48	79
June	583,30	20
July	417,75	5
August	406,71	4
September	583,30	20
October	1.355,89	90
November	3.232,18	260
December	4.059,96	335
	22.661	**1.659**

–

Real consumption (2009) after ICTs implementation

	Real consumption (kWh)
January	3.055,50
February	2.003,00
March	1.895,00
April	1.609,00
May	934,00
June	550,00
July	400,00
August	395,00
September	450,00
October	1.100,00
November	2.978,00
December	3.345,00
	18.715

Savings

= **17,4%**

2.4.1. PROPOSED METHODOLOGY. ENERGY SAVINGS.

Feasible alternative method for Option C in new building: CONTROL GROUPS[1]

Baseline "CONTROL GROUPS".

methodology:

1 - Select a group of facilities.
2 - Divide it into 2 groups: TREATMET group and CONTROL group
3- Establish couples of analogues cases from both groups.
4- Assess energy consumption in each group before the EEM is implemented in the treatment group
5 - Implement EEM in the treatment group.
6 - Measure defined variables during the reporting period,
7 – Calculate energy savings.

	Before EEM	After EEM
Treatment Group	T_{pre}	T_{post}
Control Group	C_{pre}	C_{post}

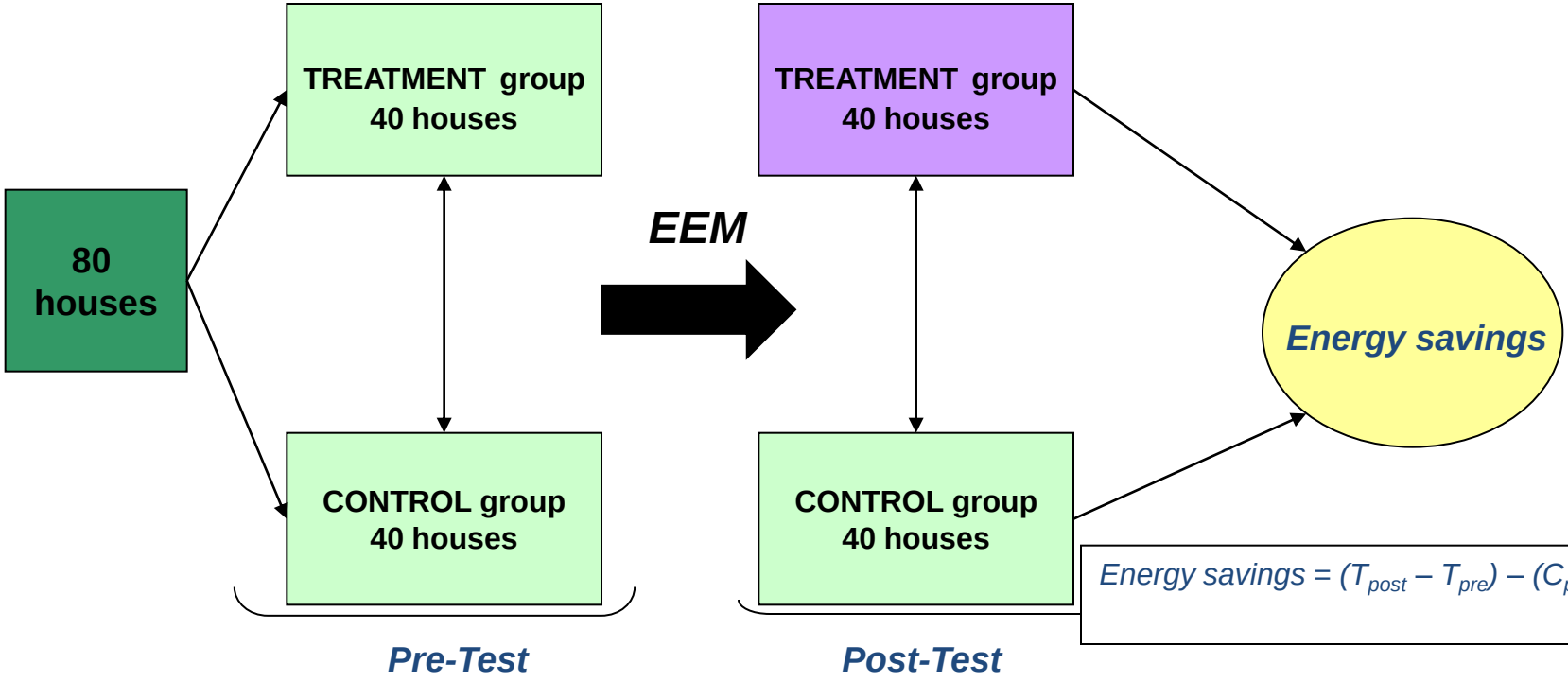
$$Effect = (T_{post} - T_{pre}) - (C_{post} - C_{pre})$$

Advisable for new construction

[1]International Performance Measurement&Verification Protocol.. Concepts and Options for Determining Energy Savings in New Construction. Volume III

2.4.1. PROPOSED METHODOLOGY. ENERGY SAVINGS.

Control groups - Example



AGENDA

1. INTRODUCTION PROJECT
2. METHODOLOGY
   - 2.1. INTRODUCTION
   - 2.2. RATIOS / INDICATORS
   - 2.3. BACKGROUND
   - 2.4. PROPOSED METHODOLOGY
     - 2.4.1. METHODOLOGY ENERGY SAVINGS
     - 2.4.2. METHODOLOGY DEMAND RESPONSE
     - 2.4.3. METHODOLOGY CO2 avoided emissions

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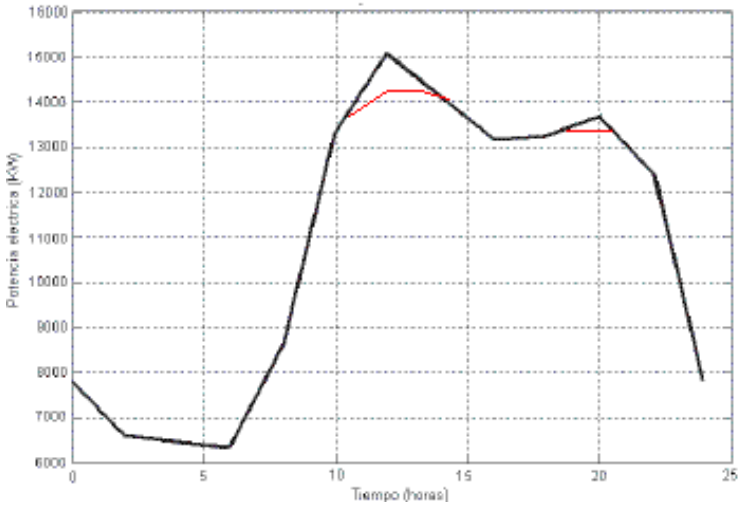
2.4.2. PROPOSED METHODOLOGY. DEMAND RESPONSE.

It´s possible **shifting** energy demand from peak hours to other periods with less consumption avoiding problems



… to measure its benefits & impacts the methodology to apply is similar to energy efficiency savings determination (**Savings: baseline – consumption after demand response program**). What change in this case is the way to establish the baseline

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2.4.2. PROPOSED METHODOLOGY. DEMAND RESPONSE.

Demand Response Baseline Methodology [1]

1. Baseline Profile Model (BPL) 10 day time model

2. Baseline Profile Model (BPL) 10 day time model (High 3 of 10 data)

[1]Ernest Orlando Lawrence: Berkeley National Laboratory: Estimating Demand Response Load Impacts

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2.4.2. PROPOSED METHODOLOGY. DEMAND RESPONSE.

1. Baseline Profile Model (BPL) 10 day time model

- It is generally accepted that a period of approximately **10 business days** reasonably represents consumption for normal operations and therefore makes up a preferred **baseline** window for resource adequacy and demand programs.
- **Average calculation method**
- baseline: For each hour:
  (d1(t,h)+d2(t,h)+d3(t,h)+d4(t,h)+d5(t,h)+d6(t,h)+d7(t,h)+d8(t,h)+d9(t,h)+d10(t,h))/10

	Power Demand (kW)
day 1, hour 20:00	4,00
day 2, hour 20:00	4,15
day 3, hour 20:00	4,00
day 4, hour 20:00	3,90
day 5, hour 20:00	4,00
day 6, hour 20:00	4,30
day 7, hour 20:00	3,85
day 8, hour 20:00	4,05
day 9, hour 20:00	3,95
day 10, hour 20:00	4,10
Baseline	**4,03**

Example : EEM implemented the day 11 at 20:00h → Consumption : 3.70 kW

Demand Response savings =

Demand event day (day 11) – Baseline (average)

Demand Response savings = 3,70 kW – 4,03 kW = 0,33 kW

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2.4.2. PROPOSED METHODOLOGY. DEMAND RESPONSE.

2. Baseline Profile Model (BPL) 10 day time model (High 3 of 10 data)

- High 3 of 10 exclusion rules among the prevoius10 days, excluding event days and holidays
- b: max $_{(1,3)}$ (∑dn(t,h))/3

	Power Demand (kW)
day 1, hour 20:00	4,00
day 2, hour 20:00	4,15
day 3, hour 20:00	4,00
day 4, hour 20:00	3,90
day 5, hour 20:00	4,00
day 6, hour 20:00	4,30
day 7, hour 20:00	3,85
day 8, hour 20:00	4,05
day 9, hour 20:00	3,95
day 10, hour 20:00	4,10
Baseline	**4,18**

EEM implemented the day 11 at 20:00h →
Consumption : 3.70 kW

Demand Response savings =

Demand event day (day 11) – Baseline (high 3 of 10)=

3,7- 4,18 = 0,48

AGENDA

1. INTRODUCTION PROJECT
2. METHODOLOGY
   - 2.1. INTRODUCTION
   - 2.2. RATIOS / INDICATORS
   - 2.3. BACKGROUND
   - 2.4. PROPOSED METHODOLOGY
   - 2.4.1. METHODOLOGY ENERGY SAVINGS
   - 2.4.2. METHODOLOGY DEMAND RESPONSE
   - 2.4.3. METHODOLOGY CO2 avoided emissions

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2.4.2. PROPOSED METHODOLOGY. CO2 avoided emissions.

Avoided CO2 emissions = Avoided CO2 emissions related energy savings + Avoided CO2 emissions related demand response

1. Avoided emissions related to energy savings

When we know the energy savings obtained by ICT's implementation we can calculate the CO2 avoided emissions as:

CO2 avoided emissions (kgCO2/a) = energy savings (kWh/a) * emission factor (kgCO2/kWh)

The emission factor depends on the type of energy saving:

- electricity: depending the composition of the electricity generation mix of each country

Country	CO2 equivalent for electrical energy [kg CO^2/kWh]
Spain	0,39
Germany	0,55
UK	0,54
Bulgaria	

- natural gas: 0,201 (kg CO2/kWh)
- gasoil: 0,287 (kg CO2/kWh)

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2.4.3. PROPOSED METHODOLOGY. CO2 avoided emissions.

2. Avoided CO2 emissions related to demand response

When we achieve a shifting of the demand curve we are avoiding emissions because the electricity produced in off-peak hours has a bigger contribution of renewable, therefore the CO2 emissions associated to this consumption are lower.

CO2 avoided emissions (kgCO2/a) = consumption energy displaced (kWh/a) *(emission factor peak hours (kgCO2/kWh) - emission factor off- peak hours (kgCO2/kWh))

These peak and off-peak hours emission factors are different each day but we can calculate a medium value for each country.

Thank you
Questions?

www.3ehouses.eu