Cost of energy efficiency measures in buildings refurbishment:

a summary report on target countries

D3.1 of WP3 from Entranze Project

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August 2013

Updated: October 2013

Co-funded by the Intelligent Energy Europe
Programme of the European Union

ENTRANZE Project

Year of implementation: April 2012 – September 2014

Client: EACI

Web: http://www.entranze.eu

Project consortium:

	EEG	Energy Economics Group Institute of Power Systems and Energy Economics Vienna University of Technology
	NCRC	National Consumer Research Centre
	Fraunhofer	Fraunhofer Society for the advancement of applied research
	CENER	National Renewable Energy Centre
	eERG	end use Efficiency Research Group, Politecnico di Milano
	Oeko	Öko-Institut
	SOFENA	Sofia Energy Agency
	BPIE	Buildings Performance Institute Europe
	Enerdata	Enerdata
	SEVEn	SEVEn, The Energy Efficiency Center

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The ENTRANZE project

The objective of the ENTRANZE project is to actively support policy making by providing the required data, analysis and guidelines to achieve a fast and strong penetration of nZEB and RES-H/C within the existing national building stocks. The project intends to connect building experts from European research and academia to national decision makers and key stakeholders with a view to build ambitious, but reality proof, policies and roadmaps.

The core part of the project is the dialogue with policy makers and experts and will focus on nine countries, covering >60% of the EU-27 building stock. Data, scenarios and recommendations will also be provided for EU-27 (+ Croatia and Serbia).

This report provides a selection of the main energy efficiency measures to improve the building energy performance, as well as the cost data associated to these measures. It is based on the data collection which was carried out during WP3 (Tasks 3.3 and 3.4). It focuses on the 9 target countries (Austria, Bulgaria, Czech Republic, Finland, France, Germany, Italy, Romania and Spain).

Acknowledgement:

The authors and the whole project consortium gratefully acknowledge the financial and intellectual support of this work provided by the Intelligent Energy for Europe – Programme.

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1. Introduction

The aim of this report is to set the costs of different energy efficiency measures to be considered in the scope of this project.

This report is an essential input for the main calculations and forecasts carried out in WP3 and WP4.

1.1 Applicability

The group of energy efficiency measures considered in this report is set to be applied to four different kinds of buildings: single family houses, apartment blocks, offices and schools. However, the data gathered are also valid to evaluate the global cost for a large typology of buildings.

In line with EPBD Directive 2010/31/EU, Member States are required to establish cost-optimal levels of minimum energy performance requirements. The collection of cost data is an important component of the cost-energy curves developed in this project, which are needed for the cost optimality calculation of the different measures or packages of measures.

1.2 Gathering cost data

The regulation states that cost data must be obtained by market analysis and should be coherent as regards location and time for investment costs, running costs, energy costs and if applicable disposal costs. Therefore, cost data have been gathered from one of the following sources with the assistance of experts:

- (1) Evaluation of recent constructions projects;
- (2) Analysis of standard offers of construction companies;
- (3) Use of existing cost databases which have been derived from market-based data gathering.

It has been important that the cost data sources reflect the disaggregation level which is required to compare different measures/packages/variants for a given reference building.

The cost calculation approach has started from a base refurbishment level, to which additional measures (e.g. better insulation, high performance windows, shading device, a ventilation system with heat recovery, etc.) have been added.

The detailed sources of each country is shown in the table below:

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Tab. 1: Data sources

Target country	General sources (1), (2)	Specific sources / National database (3)
AT	Evaluation of recent construction projects, market prices and professional evaluation	-
BU	Data from implemented projects	Commercial database, which is updated every 6 months - http://smr.sek-bg.com/ (available only in Bulgarian).
CZ	Costs investigated from real market prices, costs provided by contractor companies and costs calculated and collected by experts and contractors during the SEVEn´s cost-optimality calculations for Czech Ministry of Industry and Trade.	-
DE	Professional evaluation	Product of SIRADOS - https://baupreise.de/
FI	Renovation costs 2010, book/catalogue published by the Building Information Foundation KlaraNet (https://www.rakennustieto.fi/index/tuotteet/klaranet.html) (Online programme for calculating construction costs, published by Building Information Foundation.) Statistics from the Finnish Concrete Industry. http://www.betoniyhdistys.fi/ JUKO 4.0 Calculation program for facade renovations ARA, The Housing Finance and Development Centre: unpublished data on renovation costs of single-family homes Finnish Real Estate Federation http://www.kiinteistoliitto.fi/en/ ATOPpts Calculation program for renovation works: http://www.atopnet.fi/36) Tampere energy company Haahtela Group: Cost database for construction. https://www.haahtela.fi/en/ FinnWind Oy (data from wind turbine manufacturer) Havulehto, J. (2010). Renovation of heating system for a single-family home. Thesis.	
FR	Professional evaluation	Le Moniteur http://www.lemoniteur.fr/

IT	Evaluation of recent construction projects, market prices and profes-sional evaluation	Official prices of Milan for public works 2011
RO	Professional evaluation	The project developed and implemented by SC IPCT SA Bucharest Romania
SP	Recent construction projects and real market prices	Commercial database Preoc – http://www.preoc.es/

Source: Partners (target countries)

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2. Description of the cost data

Under the Regulation, Member States are required to use the following basic cost categories:

- Initial Investment
- Running costs (including energy costs and periodic replacement costs)
- Disposal costs (if appropriate),
- The cost of greenhouse gas emissions (at macroeconomic level)

The cost categorization for the calculation of cost is shown below:

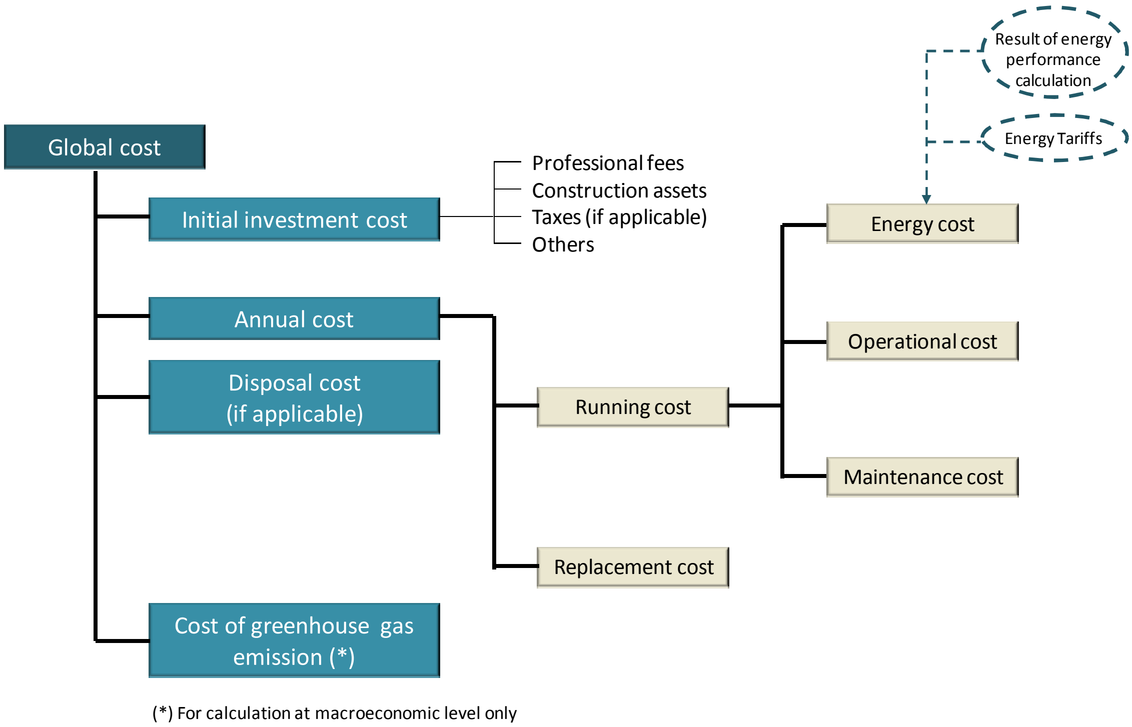

Fig. 1: Cost categorization according to the framework methodology

The investment cost includes all costs incurred up to the point when the building or the building element is delivered to the customer, i.e. ready to use. These costs include design, purchase of building elements, connection to suppliers, installation and commissioning processes.

The initial investment cost has been disaggregated in order to ensure the consistency of data into the following categories: material cost, labour cost, business profit, general expenditure and professional fees.

INVESTMENT COST = MATERIAL COST + LABOR COST + BUSINESS PROFIT +GENERAL EXPENDITURE + PROFESSIONAL FEES

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3. Description of measures

Around 25 of the measures considered for the project are related to the building envelope and 40 to the HVAC[1] systems (and their variants[2]). The project partners have selected for each target country (Austria, Bulgaria, Czech Republic, Finland, France, Germany, Italy, Romania and Spain) the measures according to the context of their country (climate, infrastructures and market trends).

The description of measures according to their categorisation is shown in the next paragraphs.

3.1 Energy Efficiency Measures related to the Envelope

This section will focus on the definition of energy efficiency measures concerning the thermal envelope of the buildings. For each of them it indicates what is the base level or reference measure.

3.1.1 Measures to reduce energy need for heating

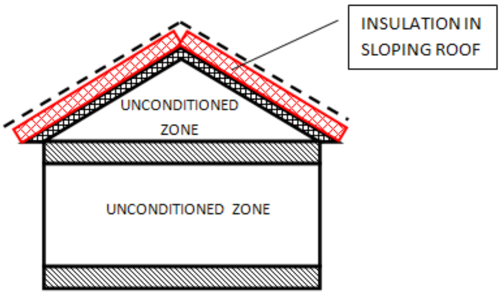
3.1.1.1 Roof Insulation

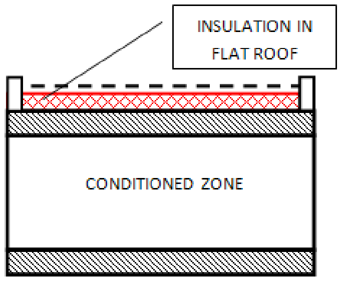
- **Base level refurbishment of roof:** Renovation of the exterior layer of the roof (tile or tar) for aesthetic/functional/security reasons.

- **Removal of the roof and refit by adding a new layer of insulation (**when repairing or renovation works of flat or sloping roofs). In flat roofs, all material layers up to the position of thermal insulation (over the waterproofing layer) will be removed. In addition, over the new thermal insulation layer, a protecting and a finishing layer (gravel, paving…) will be installed. In sloping roofs, the tiles, battens and waterproofing layer will be removed. Then, new insulation will be added over the slab/framework and new waterproofing layer, vapor barrier, battens and tiles over the insulation will be installed.
  The sketches which illustrate the insulation layer location for sloping and flat roof are shown bellow.

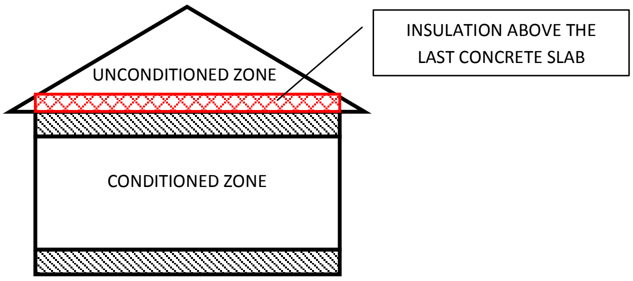
[1] HVAC - Heating, ventilation and air conditioning

[2] Different energy performance values inside the same measure description (insulation thickness, window class, equipment efficiency…)

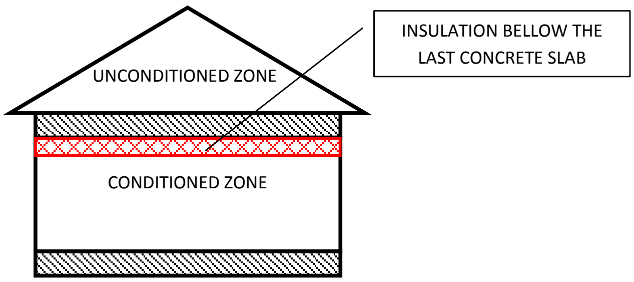




- **Addition of a thermal insulation layer over the last slab in contact with unconditioned space (attic):** This measure is only possible in buildings with unconditioned space (attic) above the concrete slab/framework of the highest floor. As this space is supposed to have not transit, the thermal insulation layer does not need to be protected by another material layer.



- **Insulation below the last concrete slab[3]:** Installation of a thermal insulation layer inside the false ceiling of the last conditioned storey of the building. In those cases when a false ceiling exists, it will be necessary to replace it so as to be able to install the insulation. If there was not false ceiling, it would be necessary to create one.



[3] This solution would require a minimum height for the original ceiling since it would be reduced.

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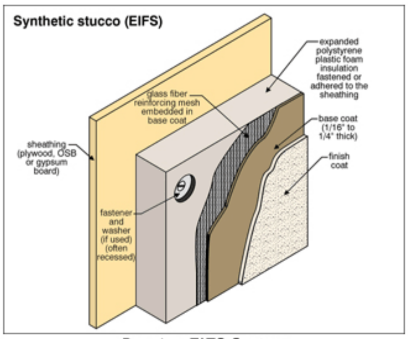
3.1.1.2 External Wall Insulation

- **Base refurbishment level of walls:** Renovation of the exterior layer of the walls (plaster or tile, etc) for aesthetic/functional/security reasons.

- **External insulation (ventilated façade):** The external insulation is made by adding thermal insulation to the external surface of the façade. Thermal insulation will be protected by a new external layer attached, through a substructure, to the existing structure or building façade. Between the insulation and the external layer there will be a highly ventilated air chamber which will protect the building from solar radiation.

- **External insulation (EIFS System):** EIFS is a lightweight synthetic wall cladding that includes foam plastic insulation and thin synthetic coatings.



Barrier EIFS System

- **Filling air chamber with thermal insulation:** Thermal insulation will be installed into the existing air chamber. The thickness of the thermal insulation will depend on the air chamber thickness.

- **Internal insulation (adding thermal insulation on the internal face of the wall):** Addition of thermal insulation, vapor barrier and a new inner plaster layer on the internal surface of the wall. The larger the insulation thickness, the greater the reduction in the useful floor area in the building.

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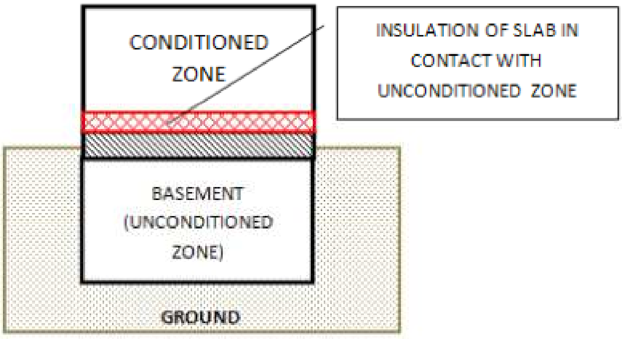
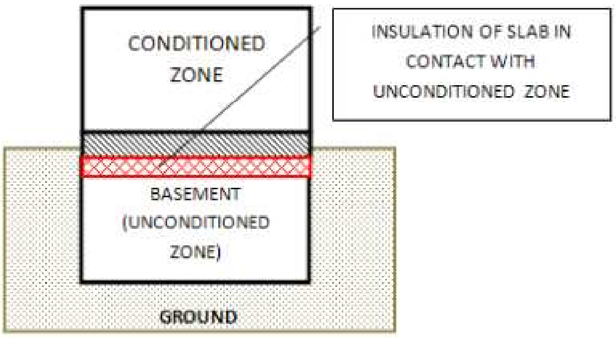
- **Internal insulation :** Remove the inner skin of the cavity wall and then create a new skin, separated by an air chamber from the external skin, and composed by thermal insulation, brick masonry and plaster inside.

3.1.1.3 *Floor slab insulation (when it is in direct contact with outdoors or unconditioned spaces)*

- **Installation of insulation in the inner of the floor slabs or frameworks[4]:** Removal of the existing layers over the concrete slab. Installation over the insulation of a concrete screed, a vapour barrier and finally the finishing layer/s (ceramic tiles, wood, etc).



- **Installation of insulation in the outer of the floor slabs:** Installation of a layer of thermal insulation below the first conditioned plant of the building and a plaster or gypsum panel.



[4] For this solution it is necessary to have enough ceiling height, and it could be necessary to adapt the height of all doors and to raise the parapets and electric sockets.

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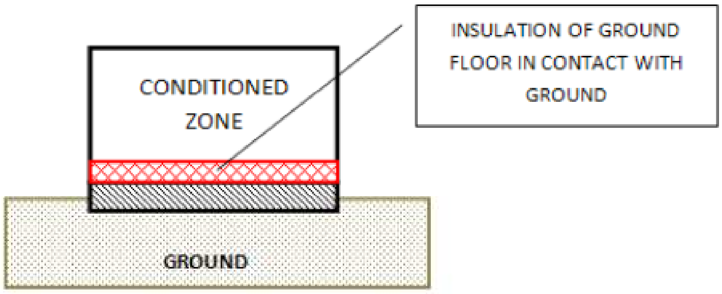
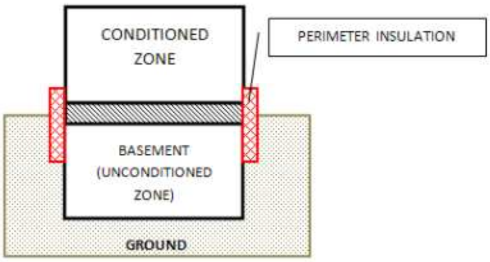
3.1.1.4 Insulation of the ground floor in contact with the ground

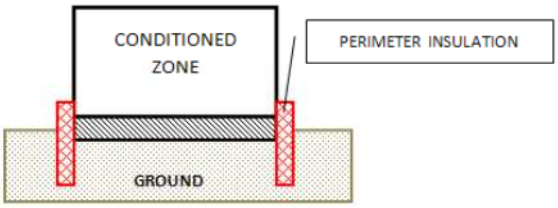
- **Installation of a thermal insulating layer on top of concrete ground floor in contact with the ground[5]:** Removal of the existing layers over the concrete slab. Installation of the thermal insulation and, over the insulation a concrete screed, a vapour barrier and finally the finishing layer/s (ceramic tiles, wood, etc).



3.1.1.5 Perimeter insulation

- Vertical perimeter insulation to a depth of approximately 1m (according to the drawings). For this solution it will be necessary to make a trench to a depth enough in order to insert insulation panes.





3.1.1.6 Improvement of the air permeability of the envelope

- **Improvement for traditional masonry (brick/concrete constructions):** Installation of a new internal plaster layer (min 1 cm) over the existing one, plus an air stop band in correspondence of the connection element ("wall-ceiling", "wall-floor", "wall-wall (angular)"), plus an air stop element where the building plant crosses the building element (pipe, ventilation, etc...), plus a sealing electric box and tube. After works, verification costs are applicable (e.g. blower door test, Air Leakage Testing Audits, etc.).

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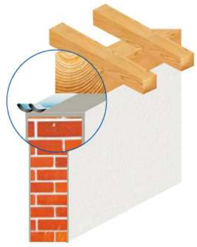
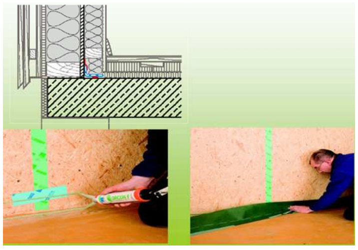
[5] For this solution it is necessary to have enough ceiling height, and it could be necessary to adapt the height of all doors and to raise the parapets and electric sockets.





- **Improvement for wood/prefabricated wall:** Removal and replacement of the internal layer, plus air stop band in correspondence of the connection element ("wall-ceiling", "wall-floor", "wall-wall (angular)"), plus air stop element where the building plant crosses the building element (pipe, ventilation, etc...), plus sealing electric box and tube. After works, verification costs are applicable (e.g. blower door test, Air Leakage Testing Audits, etc.).




3.1.1.7 Improvement of the thermal quality of the window

- **Base refurbishment level of windows:** Repair/restoration of the old window components (glasses and frames) for aesthetic/functional/security reasons.

- **Window glazing substitution:** Windows glazing substitution, keeping the actual frames.

Tab. 2: New properties of glazing

Variants	U_g (W/m^{2}K)	g	T_{vis}
Double glass with air cavity (16mm)	2.7	0,78	0.82
Double glass with air cavity (16mm) and a low-e glass	1.7	0.72	0.81
Triple glass with argon cavity (2x16mm) and low-e glass	1.0	0.64	0.74

Source: WINDOW 6 database

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- **Window replacement:** Replacement of the old single-glazed or double-glazed windows by highly efficient, airtight double-glazing windows. This solution will therefore improve the tightness.

Tab. 3: New properties of windows

Variants	U_g (W/m²K)	g	T_{vis}	U_f (W/m²K)	Air permeability (m^3/hm^2)
Double glass with air cavity (16mm)	2.7	0.78	0.82	2.2	27
Double glass with air cavity (16mm) and a low-e glass	1.7	0.72	0.82	1.4	9
Triple glass with argon cavity (16mm) and a low-e glass	1.0	0.64	0.74	1	3
Triple glass with argon cavity (18mm) and low-e glass es	0.65	0.6	0.73	0.95	3

Source: WINDOW 6 database and market offers

- **Double window (adding a new window to the existing one):** Addition of a new window in the wall thickness maintaining the existing one. The new window will be installed in the opposite alignment of the wall to the existing one.

Tab. 4: New properties of exterior window glazing

Variants	U_g (W/m²K)	g	T_{vis}
Single glazing	5.8	0.85	0.89
Double glazing	2.7	0.75	0.81

Source: WINDOW 6 database

- **Sealing of joints:** The weather-stripping around the perimeter of the frame seals the window, eliminating drafts and creating a thermal barrier. Reduce air permeability of the window at least to 3rd class (9 m³/hm²) of the standard "EN 12207 Windows and doors - Air permeability - Classification".


3.1.2 Measures to reduce energy need for cooling

3.1.2.1 Solar Shading

- **Base refurbishment level of existing solar shading:** Repair/restoration of the old solar shading devices for aesthetic/functional/security reasons.

- **Drop-arm awnings installation:** Drop-arm awnings offer the ideal solution for providing shade for windows and balconies only in summer periods. Opacity coefficient of the awning material 0,7.

- **External window blinds**

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- **Automation of solar shading devices:** Installation of electrical motors, electrical control for shading devices, solar radiation sensors, etc.

3.1.2.2 Solar Control Glass

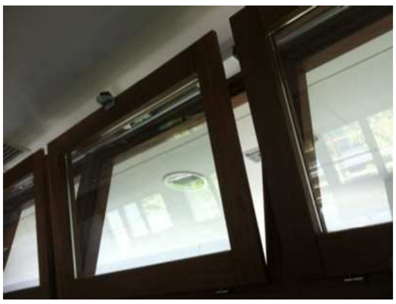
- **Window glazing substitution:** Replacement of old single-glazed or double-glazed windows by highly efficient ones, airtight double-glazing with solar control. New thermal transmittance value of glazing Ug= 1,7 W/m²K; g= 0,39 (solar control glass); Tvis = 0,70

- **Solar control vinyl**

- **Window replacement:** replacement of the old single-glazed or double-glazed windows by highly efficient ones, airtight double-glazing windows with solar control glasses. New thermal transmittance value of glazing Ug= 1,7 W/m²K; g= 0,39 (solar control glass); Tvis = 0,70 . This solution will therefore improve the tightness.

3.1.2.3 Natural Ventilation

- **Automatic Natural Ventilation:** This solution includes electrical motors, electrical control for opening, internal partitions grids, outdoor temperature sensor, etc.

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3.2 Energy Efficiency Measures on Building HVAC and lighting systems

This section aims to explain the different energy efficiency measures regarding heating and cooling, lightning, auxiliary and other systems to be considered in the scope of Entranze project.

3.2.1 Heating and cooling systems

3.2.1.1 Generation Measures

- Substitution of the heating system by a standard gas boiler. The expected performances for heating range between 90% and 93%.

- Substitution of the heating system by a condensing gas boiler. The expected heating performances range from 98% to 110%.
- Substitution of the heating/cooling system by a heat pump (Air to Air technology) with medium nominal COP[6] (around 3.23) and EER[7] (around 2.91) for cooling).
- Substitution of the heating/cooling system by a heat pump (Air to water technology) with high nominal COP[6] (between 3.48 and 4.66 for heating) and EER[7] (between 2.78 and 3.39 for cooling).

- Installation of a cogeneration system (gas turbine or I.C.[8] engine) to meet DHW[9] loads and/or a fraction of heating loads. The thermal performance (heating) is expected to be around 61% whereas the electrical performance is expected to be around 27%.

- Installation of a ground source heat pump system (water to water, with high COP) to meet base thermal load. COP[6] is expected to range between 3.66 and 4.88 whereas EER[7] is expected to range between 4.2 and 5.

- Connection to a district heating network.

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[6] COP - Coefficient of performance: Ratio between useful energy (heat) and energy consumed (work needed for the compressor working)

[7] EER - Energy efficiency ratio: Coefficient of performance when the heat pump is working for cooling.

[8] I.C. - Internal combustion

[9] DHW - Domestic hot water

- Removal of the old heating/cooling system and installation of a chiller with medium nominal EER[7] (around 3.0)

- Remove the old heating/cooling system and install a chiller with high nominal EER[7] (including cooling tower).

- Removal of the old heating/cooling generation system and installation of a new system of the same type. Applicable for defining the BASE REFURBISHMENT LEVEL, if the old generator type is not included in the previous alternatives (e.g. standard oil boiler). Heating performance must be greater than 80%.

3.2.1.2 Emission systems

- Installation of an insulated radiant floor emission system. Heating performances are expected to be between 97 and 99% and the cooling around 97%.
- Installation of an insulated radiant ceiling system. Cooling performance is expected to be around 98%.
- Installation of a radiator emission system. Heating performance is expected to range between 92% and 95%.
- Installation of a fan coil emission system. Heating performance is expected to range between 94% and 96% whilst cooling performance is supposed to be around 98%.
- Installation of an air diffuser emission system. The expected heating performance ranges between 94% and 96% and the cooling one around 97%.

3.2.1.3 Distribution systems

- Low pipe insulation (Pipe, 2 cm of insulation material)
- Medium pipe insulation (4 cm of insulation material)

3.2.1.4 Control systems

- Installation of a climatic control system: 2 temperature sensors, a 3-way mixing valve with actuator, control system (supply temperature will vary according to outside temperature).
- Installation of an indoor thermostatic control system: Room thermostat, two 2-way valve with servo (system is on according to the thermostat setpoint temperature).
- Installation of a climatic-indoor thermostatic system: 2 temperature sensors, 3-way mixing valve with actuator, control system, room thermostat, 2-way valve with servo.

3.2.1.5 Other systems

- Installation of a local dehumidifier: local dehumidifier, fixing system, condensate tank and evacuation system.
- Installation of a local electric hot water boiler

3.2.2 Mechanical Ventilation systems

3.2.2.1 Heat recovery systems

- Installation of a heat recovery unit with medium efficiency (60%) or high efficiency (80%): Heat recovery unit, fixing system (Note that installing a heat recovery unit requires extraction and impulsion air flow ducts).

3.2.2.2 Air distribution systems

- Installation of ducts and grilles: Ducts and grilles to do the distribution of mechanical ventilation system (remember that a heat recovery installation requires extraction and impulsion air flow ducts).

3.2.2.3 Control systems

- Use of free-cooling: Specific control system, sensors and actuators are needed.
- Introducing exterior air according to the building occupancy: Specific control system, sensors and actuators are needed.

3.2.3 Auxiliary systems

3.2.3.1 Pumps

- Removal of the old pumps and installation of new equipments with high efficiency rates.

3.2.3.2 Fans

- Removal of the old fans and installation of new equipments with high efficiency rates.

3.2.4 Lighting (In tertiary sector)

3.2.4.1 Equipment efficiency

- Removal of magnetic ballasts from the luminaires and installation of electronic ballasts

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- Removal of the old luminaires and installation of new ones for fluorescent lamps with electronic ballasts.
- Removal of the old luminaires and installation of new ones for LED lamps.
- Paint of the walls and ceiling in white colour in order to improve the efficiency value of the lighting system.

3.2.4.2 Control systems

- Installation of a programmable dimming control using programmable time scheduling (Including the time scheduling elements and electrical wiring).
- Installation of occupancy sensors (Occupancy sensors, electrical wiring)
- Installation of automatic continuous daylight dimming systems in day lighted areas (luminaires with compatible ballasts, sensors, electrical wiring).
- Installation of both automatic continuous daylight dimming systems in day lighted areas and occupancy sensors (luminaires with compatible ballasts, sensors, electrical wiring).

3.2.5 Lighting (In residential sector)

3.2.5.1 Equipment efficiency

- Removal of the old lamps and install new LED lamps.

3.2.6 Measures based on RES

- Installation of a photovoltaic system to generate electricity: panels, support structure, inverter, electricity meter, electrical wiring.
- Installation of a thermal solar system to meet DHW loads and/or a fraction of heating loads: panels, storage, circulation pumps, expansion vessel.
- Installation of a small wind turbine to generate electricity: wind turbine, support structure, electricity meter, electrical wiring.
- Install a biomass boiler to meet a part or whole heating loads: generator (including burner), fittings, internal pumps, smoke evacuation system, basements, storage pellet silo.
- Installation of an absorption chiller connected to thermal solar collectors (solar cooling): absorption chiller, solar panels, tank, internal pumps, condensate tank and evacuation systems, basements.

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4. Main results of the cost data evaluation

Although the total cost data gathering is attached in the document *"ENTRANZE Cost database.xlsx"*, this section aims to show the total investment cost of the main energy efficiency measures, as well as, to establish a comparison between the different countries.

The comparison highlighted possible inconsistencies among countries .

4.1 Business profit and general expenditure

The following graph shows the different values provided by the partners in terms of the percentage of business profit & general expenditure.

Business profit + General expenditure = % (Material cost + Labour cost)

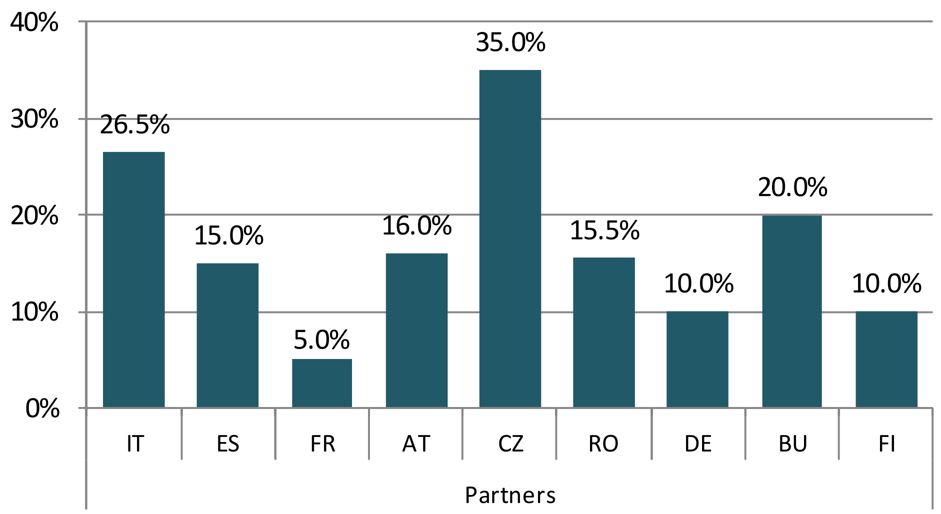

Fig. 2: Business profit & general expenditure

As can be seen in the previous graph, the sum of business profit and general expenditure varies significantly across countries: from 5% in the case of France to 26.5% for Italy. The average value is around 16%.

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4.2 Professional fees

The cost associated to professional fees includes the cost associated to professional consultation which involves project design or the technical definition of the specific measure regarding each building.

The following graph shows the different values provided by the partners for the professional fees.

Professional fees = % (Material cost + Labour cost)

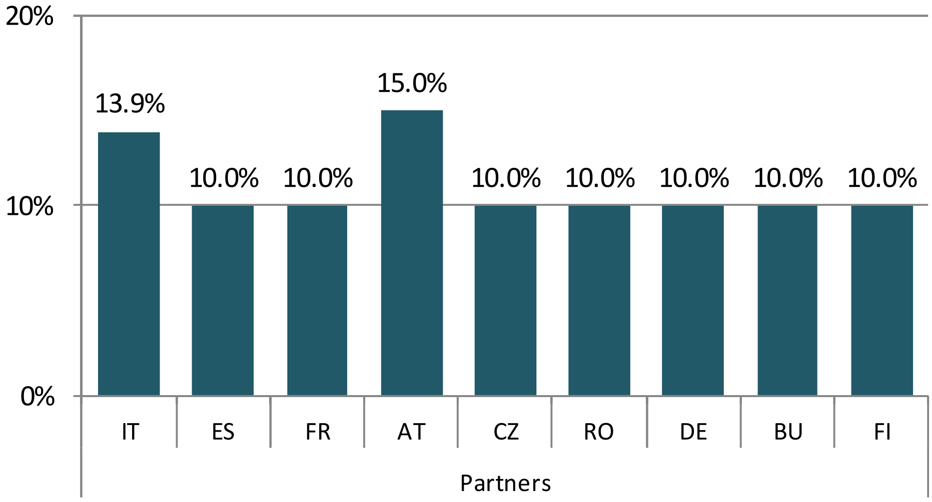

Fig. 3: Professional fees

Professional fees depends on the technology, cost and implementation difficulty of the refurbishment measure. It means that a different value (%) of professional fees can be associated to each measure. If the measure's material cost is high and the technical definition is easy, the percentage of professional fees will be lower. On the other hand, if material cost is lower but the technical definition is complex, the percentage of professional fees expected will be higher due to the difficulty of project design definition. Thus a mean value has been used in order to evaluate the cost associated to professional fees across the target countries.

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4.3 Energy efficiency measures by countries

The most significant energy efficiency measures have been selected in order to compare their final cost values.

The comparison in terms of total cost for these measures for the nine target countries is given below in a graphical way, although all the values can be founded in the document *"ENTRANZE Cost database.xlsx".*

The total cost is the sum of four components, as follows: MC+LC+BP&GE + PF, with:

- MC for the material cost.
- LC for the labour cost.
- BP&GE for the business profit and general expenditure (BP&GE cost is calculated from a percentage applied to the sum of MC and LC)
- PF for the Professional fees (PF cost is calculated from a percentage applied to the sum of MC and LC)

Cots of equipment and technology are different across countries because of:

a) Different economic situation;
b) Market trends or most common measures and maturity of technology;
c) Different qualities or brands selected according to countries habits;
d) Free interpretation of measures according to typical refurbishments of each country.

4.3.1 Building envelope energy efficiency measures[10]

The most typical actions related to envelope measures are shown in the next figures:

[10] Costs represented in the graphs are only given for countries that selected them as a feasible measures in the country.

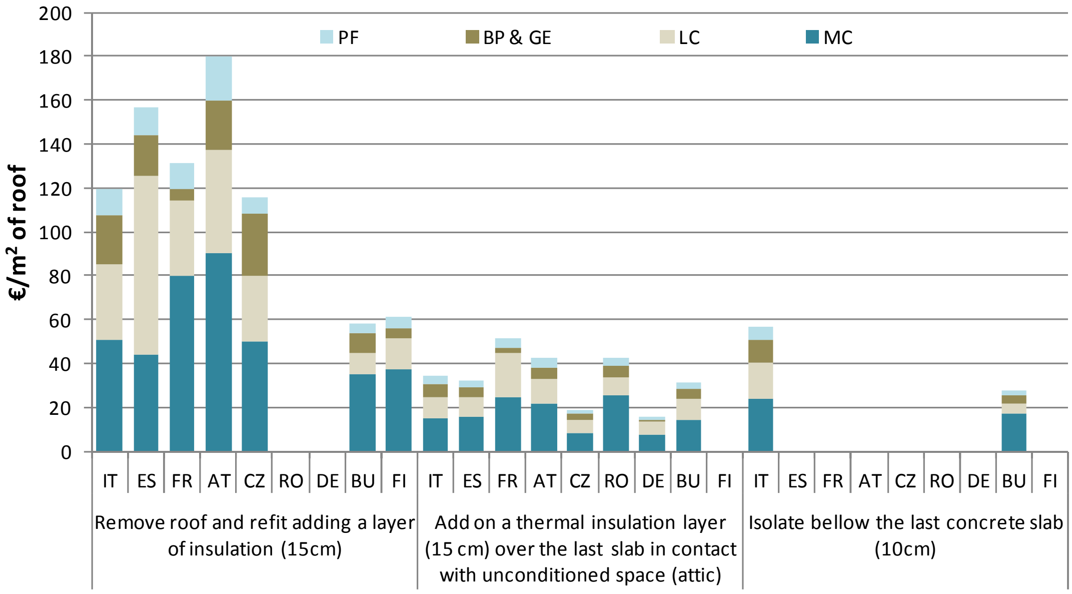

Fig. 4: Measures based on roof insulation

The previous graph shows the most typical insulation measures for roof. The unitary cost of refitting the roof is much higher than the insulation over the last slab. The specific cost of refitting the roof (including a thermal insulation layer of 15 cm) is on average 60-180€/m^2 of roof, depending on the country. However, the addition of an insulation layer (15cm) over the last slab is much cheaper because the material and labour involved are minimum. That unitary cost is around 20-40€/m^2 of slab.

The most feasible insulation measures for external walls are represented in the following graph. The unitary cost of ventilated facade system is much higher (double or more) than the typical external insulation facade system (EIFS). The unitary price of ventilated facade is on average around 138-230€/m^2 of facade, depending on the quality of external skin materials. On the other hand, the EIFS cost not exceed 80€/m^2 for any country and the unitary cost of internal insulation is around 50€/m^2 of facade.

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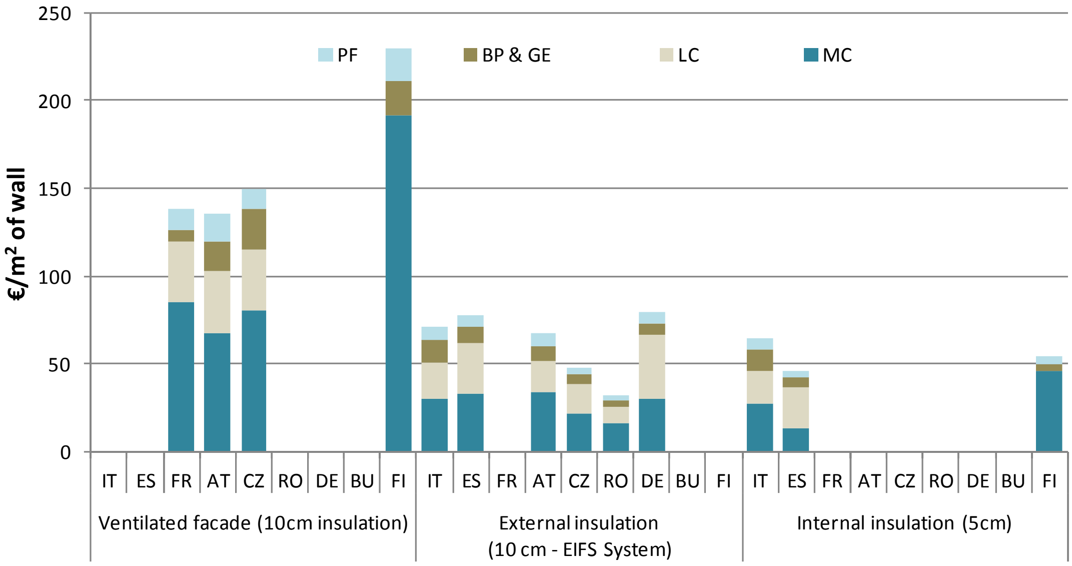

Fig. 5: Measures based on external wall insulation

The next figure shows three different class of window substitution (from lowest to highest performance). The cost is higher when a higher performance is chosen; however the difference is small for most of countries, as it is just due to the material cost because the labour cost is practically the same for the three solutions. The difference of material cost between countries is high in some cases because some types of windows are not so common in some European countries. As can be seen in the graph, Romania shows the lowest cost, on the other hand, Germany, France and Spain show the highest values.

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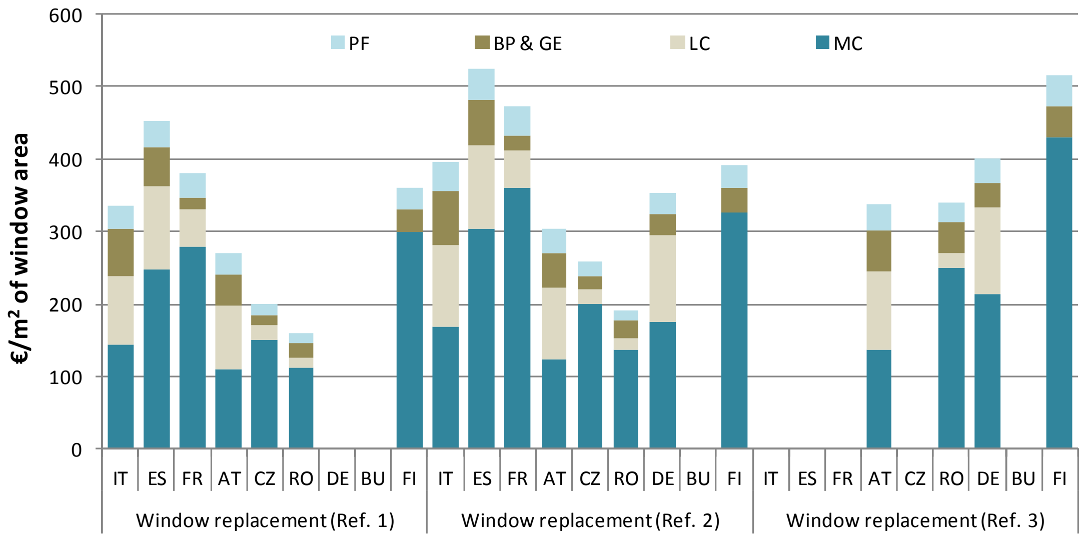

Ref. 1: Double glass with air cavity (16mm), Ug= 2.7 W/m²K; g= 0.78, Tvis= 0.82, Uf=2.2 W/m2K
Ref. 2: Triple glass with argon cavity (16mm), Ug= 1.7 W/m²K; g= 0.72, Tvis= 0.82, Uf=1.4 W/m2K
Ref. 3: Triple glass with argon cavity (18mm), Ug= 0.65 W/m²K; g= 0.61, Tvis= 0.74, Uf=0.95 W/m2K

Fig. 6: Measures based on improving windows performance

As can be seen, only some of the coldest climate countries (Austria, Germany and Finland) have selected as a suitable measure, the window with highest performance.

4.3.2 Building plants energy efficiency measures

Regarding the high performance heating and cooling equipment and RES technologies, the most suitable measures from all the measures considered, are shown in the next graphs.

The most representative measures have been grouped according to the kind of system affected, what means:

- Measures based on generation systems
- Measures based on distribution systems
- Measures based on control systems and others
- Measures based on lighting systems
- Measures based on RES systems

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In general, the disparity of cost across countries for measures related to HVAC[11] systems are higher than for measures related to building envelope. That is due to the fact that the influence of free interpretation of the measure is higher for measures related to HVAC systems. The practice of project designers and installers regarding equipment's quality and brand selected can establish a significant difference.

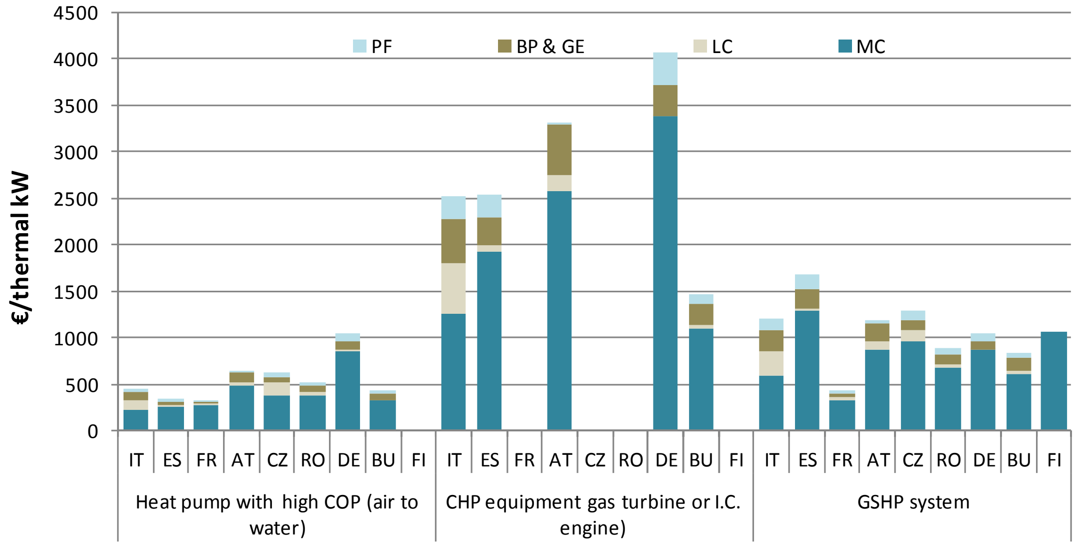

Fig. 7: Measures based on generation systems

The cost of the generation equipment has been evaluated according to thermal capacity installed in kW. As can be seen in the previous graph, a reasonable cost associated to a heat pump of high efficiency can be around 350-450€/kW. However, the cost associated to ground source heat pumps (GSHP) is higher in general because of the borehole perforations, and this cost can get around 1000-1500€/kW, depending on the country.

The next figure shows other three interesting technologies to improve the energy performance of buildings.

[11] HVAC – Heating, ventilation and air conditioning

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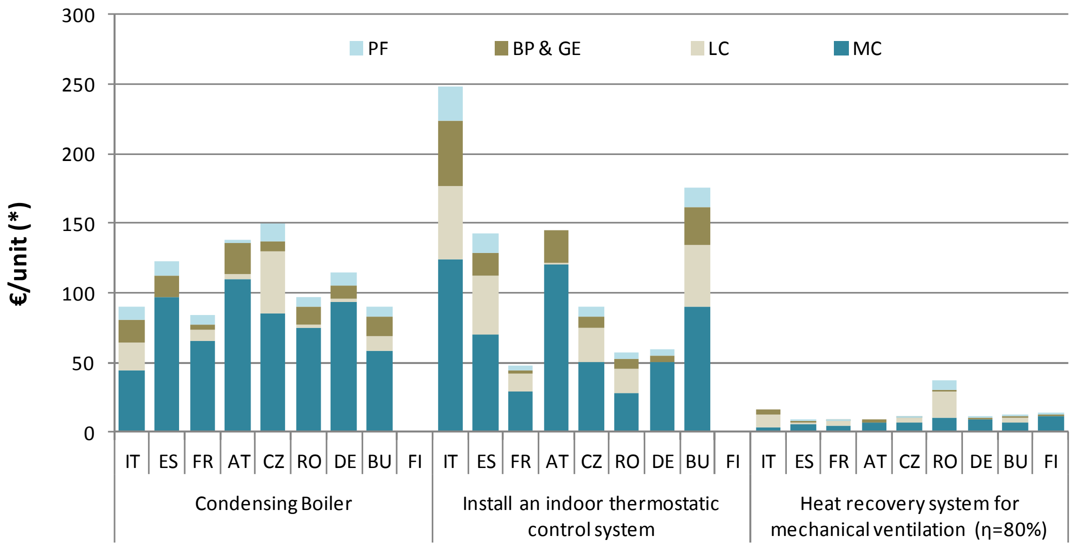
When the gas network exists near the building, an effective measure is the substitution of the heat generator by a gas condensing boiler, which the unitary cost round 90-150€/kW.

The installation of an indoor thermostatic control system can reduce significantly the energy consumption inside the building. The cost associated to the installation of a control thermostat can be estimated around 150-250€/unit.

Finally, one of the most important energy losses is related to ventilation of the buildings, to ensure the indoor air quality requirements. These losses can be reduced by the installation of a mechanical ventilation system with heat recovery. This cost is one of the most difficult to estimate without any knowledge of the building, but it can be around 9-40€ per m^3/h of air flow rate, depending the installation considered.



(*) kW for Condensing boiler, Room for thermostat and m3/h for heat recovery

Fig. 8 Measures based on other HVAC technologies

The evaluation of suitable distribution system regarding high efficiency generation systems is needed. High efficiency generation systems (e.g. condensing boiler or ground source heat pump) need a low temperature distribution system in order to operate with a high efficiency. These systems can be for example radiant floor emission system or fan coil emission system. The cost associated are shown below.

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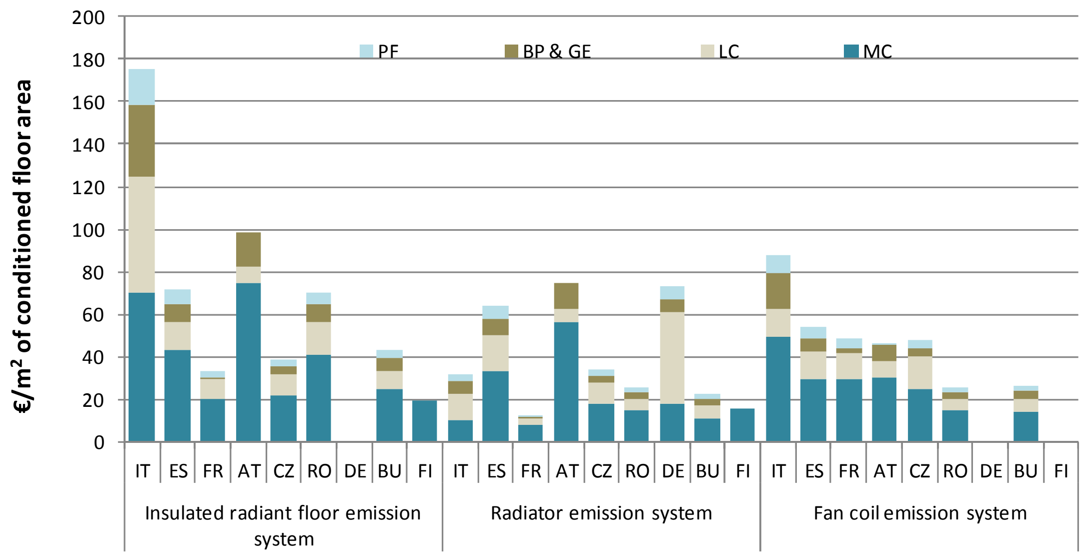

Fig. 9: Measures based on distribution systems

The lighting system represents one of the most important consumption of electricity in the tertiary sector. Hence, several measures have been proposed and evaluated in order to reduce this consumption. The next figure shows some of them:

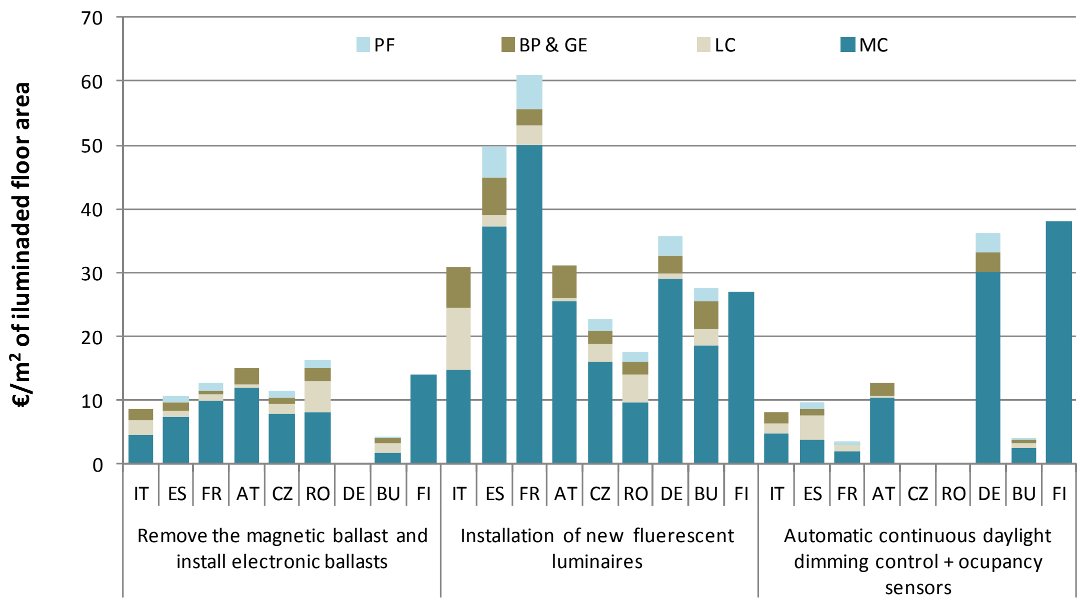

Fig. 10: Measures based on lighting system

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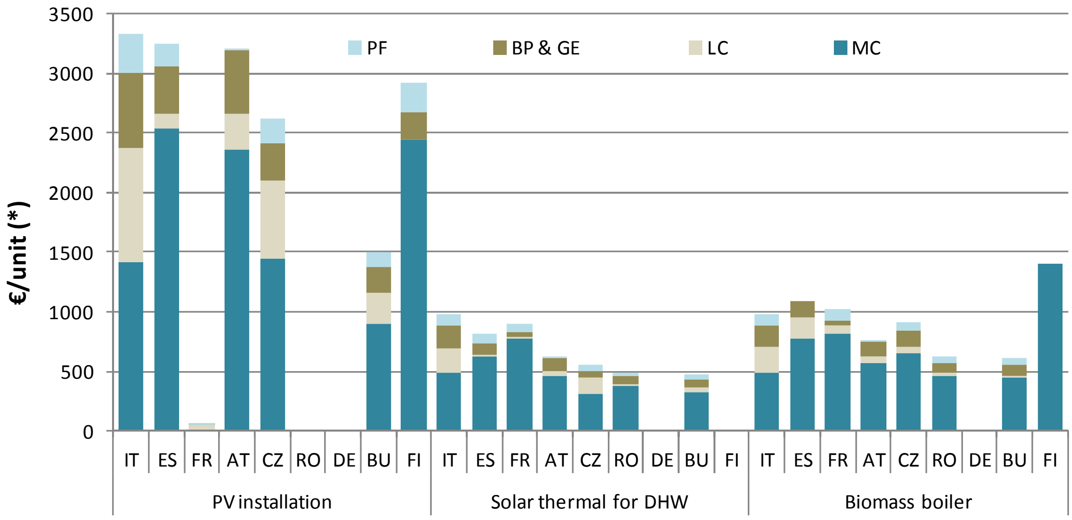
Automatic continuous daylight dimming control with occupancy sensors is an effective way of reducing lighting energy consumption in the tertiary sector (e.g. office or school buildings). This measure involves the installation of lighting sensors and luminaires with electronic ballasts which allow the dimming control. Therefore, it means a high investment cost, depending on the initial assumption (i.e. number of equipment per m^2 of floor area), the unitary cost for this measure can be estimated around 10-40€/m^2 of illuminated floor area (not including the luminaires substitution).

The next figure shows the most feasible RES technologies to be implemented on buildings. A PV installation represent a cost around 2600-3400€/kWp, although that value will decrease according to its learning curve. A solar thermal installation can be estimated around 500-1000€/m^2 of panel, depending on the piping and storage installation considered. And finally, the unitary cost of a biomass boiler is around 1000€/kW.



(*) kWp for PV, m2 of panel for Solar Thermal and kW for Biomass boiler

Fig. 11: Measures based on RES systems

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4.4 Assumptions for missing data

Due to the database breadth, as well as the new technologies[12] for some countries, it has not been possible completing all data, which are required for the cost-optimal calculation[13], from some partners.

Hence, it has been necessary to develop a procedure for estimating missing data, which has been based on using statistical parameters (e.g. median and average), supported by the cost data of other countries.

Moreover, other estimations based on similar characteristics across countries or using the same progression rate across size variants within the same technology, have been used.

The result of this work is a database more complete and consistent, although all data estimated during the process have been highlighted in the database with the aim of conserve the original data[14].

As an example, the schematic procedure is shown below:

escalation rate based on original data

Median + escalation rate

		IT	SP	AT	CZ	RO	DE	BU	FI
Measure n	Size 1	Value 1	Value 1	Value 1	Value 1	Value 1	Value 1	Value 1	Value 1
	Size 2	Value 2	Value 2	Value 2	Value 2	Value 2	Value 2	Value 2	Value 2
	Size 3	Value 3	Value 3	Value 3	Value 3	Value 3	Value 3	Value 3	Value 3

Black value: original data
Red value: estimated data

Fig. 12: Assumption procedure example

[12] Technologies whose implementation is not typical in a specific country.

[13] The cost-optimal calculation according to EPBD has been developed in the task 3.6 of the project and will be documented in the deliverable D3.3.

[14] Data from the sources that have been specified by the partners (Table 1).

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4.5 VAT

In order to promote investment in refurbishment activities in the residential sector, several countries have drastically reduced the VAT applied to refurbishment (e.g. Italy and Spain from 21% to 10%) . In France the reduction applies for part of the investment , on labour cost only, from 19.6 % to 7%).

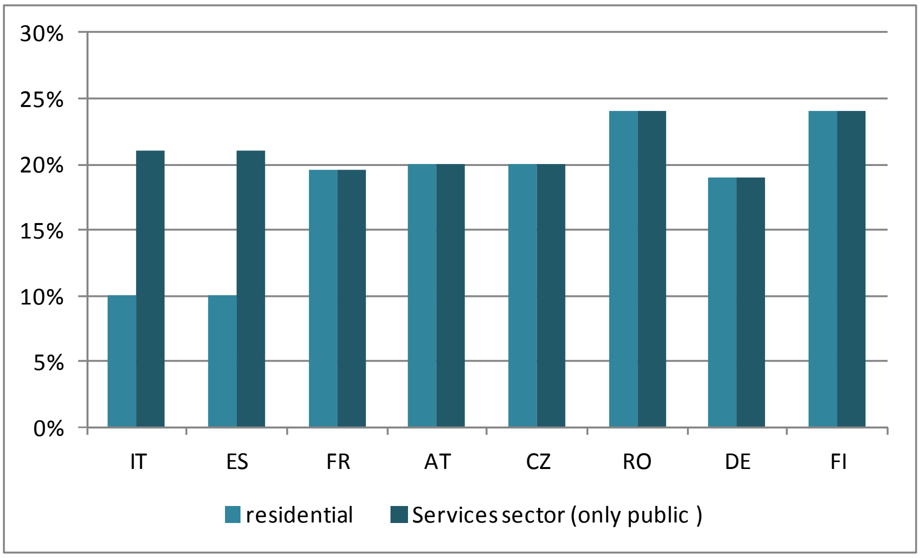

Fig. 13: Comparison of VAT

5. Conclusions

The work carried out during this task has enabled the generation of a techno-economic database, which contains the unitary cost associated with the most important energy efficiency measures for energy rehabilitation.

Although there are cultural differences regarding some of the energy efficiency measures and some of them are more suitable in some countries than in others, the main measures based on envelope, HVAC[15] systems, lighting and RES technologies are common for all target countries.

The different practices regarding qualities, market trends, maturity of technology as well as installer experience cause dispersion in the cost data for the same measure in different countries, mainly in the HVAC measures. Additionally, the manufacture location of the material or equipment associated with the measure is a significant issue, as the cost associated with transportation can be high in some cases.

[15] HVAC – Heating, ventilation and air conditioning

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