iBRoad

Individual Building
Renovation Roadmaps

Quantifying home renovation

Report and database for techno-economic default assessment of renovation measures

TU Wien – Technische Universität Wien

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www.ibroad-project.eu

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EXECUTIVE SUMMARY

The objective and scope of this work under the iBRoad project, is to provide a default database supporting a generic techno-economic assessment of renovation measures. The default database consists of a list of possible renovation measures (building envelope and HVAC system) and their costs. This data is intended to support the auditor in the cost assessment of renovation measures while developing the renovation roadmap.

This report starts with a short introduction regarding the role of this database of techno-economic data of renovation measures in the iBRoad project. Subsequently, the different measures listed in the database are described. Finally, we explain the cost-data included and how it has been derived. The cost data as such is included in the corresponding spreadsheet supplementing this report. The spreadsheet currently includes data for Bulgaria. In the further process of the iBRoad project, this will be extended by the data for the other pilot countries (Germany, Poland, Portugal) of the project.

I. INTRODUCTION

The core iBRoad concept consists of two main customised products: the Logbook and the Renovation Roadmap. The Logbook (iBRoad-Log) consists of the repository of building information and the internal functionalities (e.g. building diagnosis, alerts and reminders). The Renovation Roadmap (iBRoad-Plan) is the renovation plan, which can be presented in a summarised or a detailed form. Both Logbook and Renovation Roadmap are explained in more detail in the following reports:

- The iBRoad tools structure – How to integrate techno-economic assessment, individual building renovation roadmap and logbook components in iBRoad
- Database structure and programming core of the roadmap and logbook
- The iBRoad Concept in practice – Report on suggested elements, content and layout of the iBRoad tools
- The Concept of the Individual Building Renovation Roadmap – An in-depth case study of four frontrunner projects

With the Roadmap Assistant tool, the energy auditors have the possibility to develop the iBRoad-Plan, and display energy performance, costs and co-benefits indicators of the measures in a standardised and user-friendly layout. From the Roadmap Assistant, the user (i.e. auditor) can have access to the renovation measures cost calculator, which will be supported by the default database of renovation measures presented in the present work.

The default database consists of a list of possible renovation measures (building envelope and HVAC system) and their default costs (for total and final costs, based on the material, labour, professional fees, value added tax and disposal). Figure 1 shows the integration of the default database in the overall iBRoad Concept (as part of the Energy Demand calculation), which is detailed in the project report "The iBRoad tools structure – How to integrate techno-economic assessment, individual building renovation roadmap and logbook components in iBRoad ". The authors are aware that cost data in particular is subject to considerable uncertainties and can vary across regions and in time. Thus, the auditor, being supported by the cost calculator, should also be able to provide own cost data during the development of the renovation roadmap and thus overwrite the data provided in this default database.

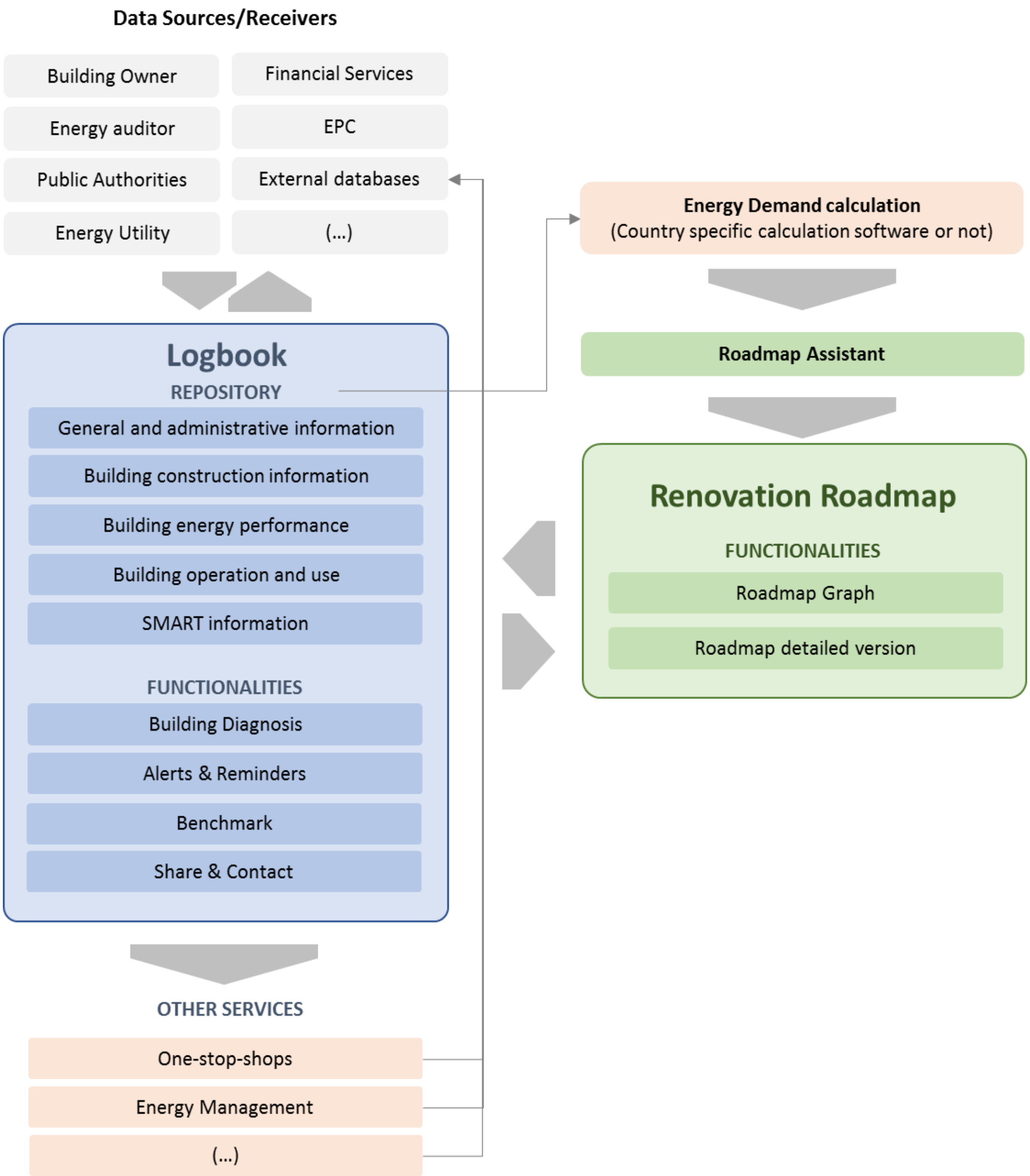

Figure 1: Integration of the default database, as part of the Energy Demand calculation, in the iBRoad concept

The present outcome consists of this report and the accompanying Excel spreadsheet with the default cost database. The intention of this report is to provide a short explanation about the chosen renovation measures and how their costs are structured in the database. Chapter II describes the renovation measures and chapter 0 describes how the cost data has been set.

II. DESCRIPTION OF RENOVATION MEASURES

For this report and the corresponding techno-economic database, the renovation measures are described based on the approach developed under the project ENTRANZE (Boneta et al., 2013) and have been divided in two main groups: building envelope and HVAC systems (and their variants). All renovation measures are described below:

1. Measures related to the Building Envelope

The building envelope measures include not only energy related but also aesthetic, functional or security measures. The energy efficiency measures, chosen to improve the thermal quality of the building envelope, aim at reducing the heating and cooling loads. Below, different construction solutions of each measure (and their variants) are described:

1.1 Measures to reduce heating loads and for aesthetic/functional/security reasons

1.1.1 Roof Insulation

a. Base refurbishment on the roof: Renovation of the exterior layer of the roof (plaster or tile etc.) for aesthetic/functional/security reasons. For this constructive solution, no variants are possible) (Boneta et al., 2013)

b. 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 will be installed over the insulation (Boneta et al., 2013). For this constructive solution, costs are specified for two variants, with 15 or 30 cm thermal insulation, for a roof area smaller than 500 m² (common for single-family houses).

Figure 2 illustrate the insulation layer location for sloping and flat roof:

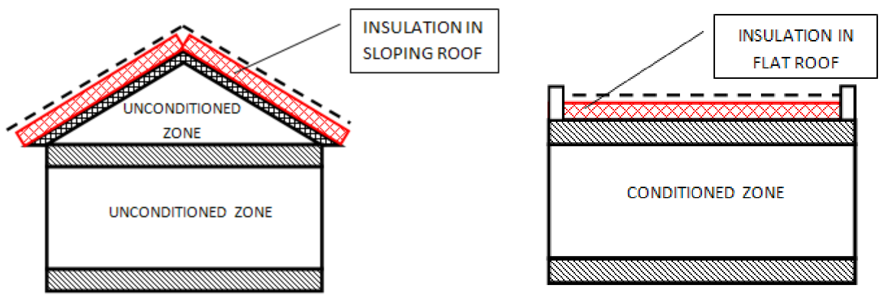

Figure 2: Insulation layer location for sloping and flat roof (Source: Boneta et al., 2013)

c. 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 (Boneta et al., 2013). For this constructive solution, costs are specified for two variants, with 15 or 30 cm thermal insulation, for a roof area smaller than 500m².

Figure 3 illustrates the insulation layer above the last concrete slab:

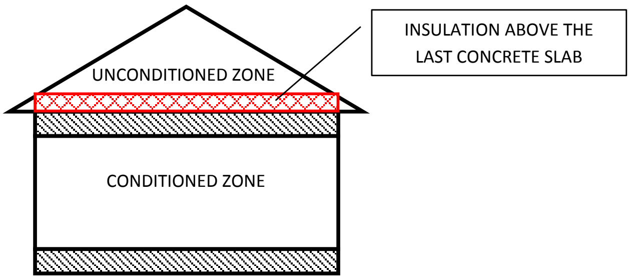

Figure 3: Insulation layer above the last concrete slab (Source: Boneta et al., 2013)

d. **Insulation below the last concrete slab:** 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, to enable the installation of the new insulation. If a false ceiling does not exist, it is necessary to create one (Boneta et al., 2013). For this constructive solution, costs are specified for two variants, with 10 or 20 cm thermal insulation, for a roof area smaller than 500m².

Figure 4 illustrates the insulation layer below the last concrete slab:

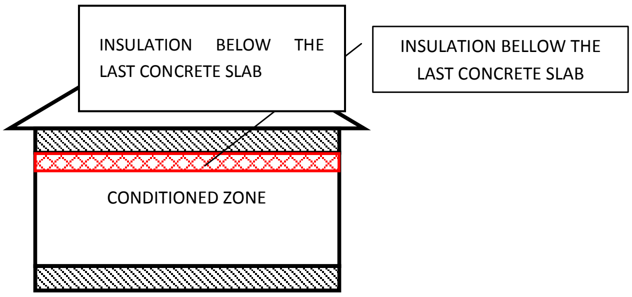

Figure 4: Insulation layer below the last concrete slab (Source: Boneta et al., 2013)

1.1.2 External Wall Insulation

a. **Base refurbishment on exterior walls:** Renovation of the exterior layer of the walls (plaster or tile, etc.) for aesthetic/functional/security reasons (no variant is possible) (Boneta et al., 2013).

b. **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 allows that the heat transferred to the outside not before achieving the inside of the building (Boneta et al., 2013). For this constructive solution, costs are specified for two variants, with 10 or 20 cm thermal insulation, for an external wall area smaller than 500m².

Figure 5 illustrates the different external wall layers, including an air chamber between the insulation and the external layer:

Figure 5: Measure External wall insulation (Source: Boneta et al., 2013)

c. External insulation (EIFS System): EIFS is a lightweight synthetic wall cladding that includes foam plastic insulation and thin synthetic coatings (Boneta et al., 2013). For this constructive solution, costs are specified for two variants, with 10 or 20 cm thermal insulation, for an external wall area smaller or bigger than 500m².

d. 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 (Boneta et al., 2013). For this constructive solution, costs are specified for two variants, with 10 or 20 cm thermal insulation, for an external wall area smaller or bigger than 500m².

e. 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 (Boneta et al., 2013). For this constructive solution, costs are specified for two variants, with 10 or 15 cm thermal insulation, for an external wall area smaller or bigger than 500m².

f. Internal insulation (removing inner skin): 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 (Boneta et al., 2013). For this constructive solution, costs are specified for two variants, with 10 or 15 cm thermal insulation, for an external wall area smaller or bigger than 500m².

g. Replacement of door by another with a high thermal performance in external walls: Replacement of door by another with a high thermal performance in external walls (Boneta et al., 2013).

1.1.3 Floor slab insulation

The measures described below should be considered, for cases where there is in direct contact with outdoors or unconditioned spaces.

a. Installation of insulation in the inner of the floor slabs or frameworks: 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 (ce-ramic tiles, wood, etc) (Boneta et al., 2013). For this constructive solution, costs are specified for two variants, with 10 or 15 cm thermal insulation, for a floor area smaller than 500m².

Figure 6 illustrates the insulation of slab in contact with unconditioned zone (inner):

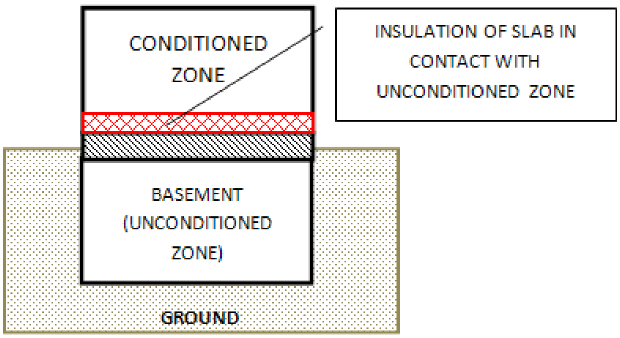

Figure 6: Insulation of slab in contact with unconditioned zone (inner) (Source: Boneta et al., 2013)

b. 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 (Boneta et al., 2013). For this constructive solution, costs are specified for two variants, with 10 or 15 cm thermal insulation, for a floor area smaller than 500m².

Figure 7 illustrates the insulation of slab in contact with unconditioned zone (outer):

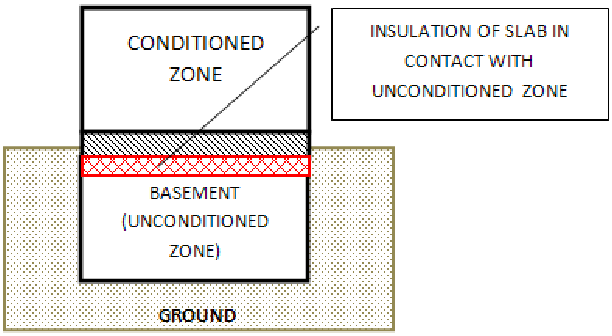

Figure 7: Insulation of slab in contact with unconditioned zone (outer) (Source: Boneta et al., 2013)

1.1.4 Insulation of the ground floor in contact with the ground

a. Installation of a thermal insulating layer above the concrete ground floor in contact with the ground: 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.) (Boneta et al., 2013). For this constructive solution, costs are specified for two variants, with 10 or 15 cm thermal insulation, for a floor area smaller than 500m².

Figure 8 illustrates the insulation of ground floor in contact with ground (above the concrete ground):

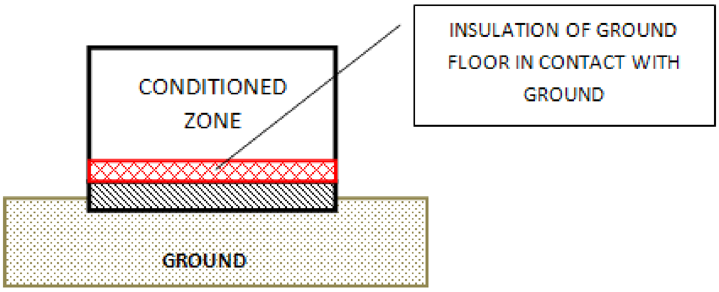

Figure 8: Insulation of ground floor in contact with ground (above the concrete ground) (Source: Boneta et al., 2013)

1.1.5 Perimeter insulation

a. Installation of a 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 (Boneta et al., 2013). For this constructive solution, no variants are possible.

Figure 9 illustrates two examples of perimeter insulation:

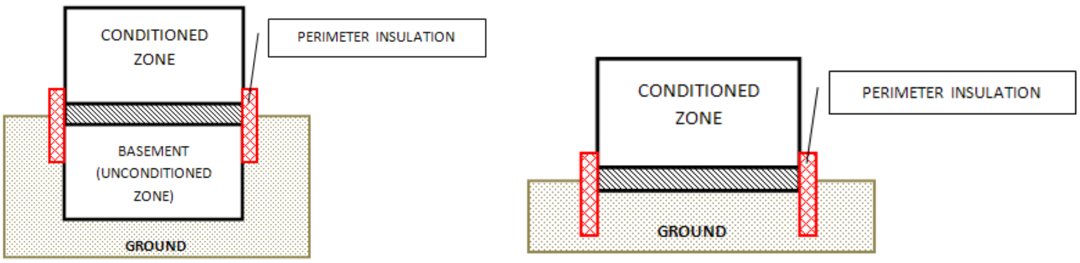

Figure 9: Perimeter insulation (Source: Boneta et al., 2013)

1.1.6 Improvement of the air permeability of the envelope

a. 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.) (Boneta et al., 2013). For this constructive solution, no variants are possible.

Figure 10 illustrates the installation of a new internal plaster layer:

Figure 10: Measure improvement for traditional masonry (Source: Boneta et al., 2013)

b. 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.) (Boneta et al., 2013). For this constructive solution, no variants are possible.

Figure 11 illustrates the installation of an internal layer on the walls and windows:

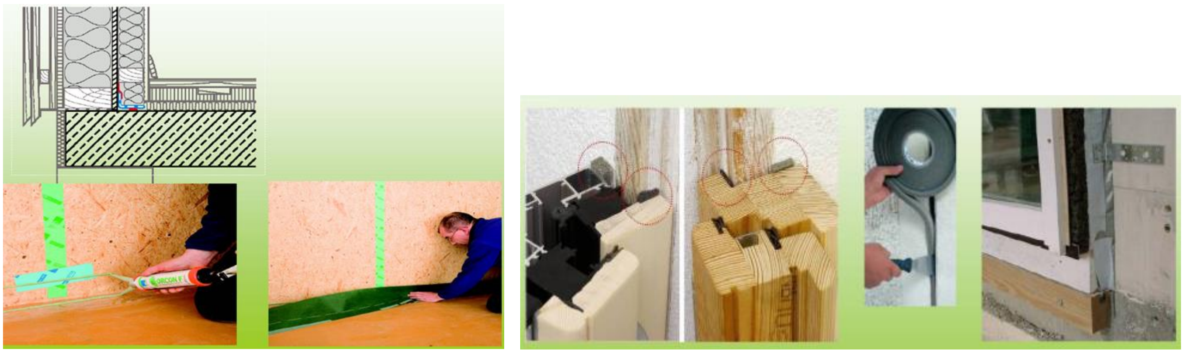

Figure 11: Measure improvement for wood/prefabricated wall (Source: Boneta et al., 2013)

1.1.7 Improvement of the thermal quality of the window

a. Base refurbishment level of windows: Repair/restoration of the old window components (glasses and frames) for aesthetic/functional/security reasons (Boneta et al., 2013). For this constructive solution, no variants are possible.

b. Window glazing substitution: Windows glazing substitution, keeping the actual frames (Boneta et al., 2013)..

For this constructive solution, costs are specified for following glazing properties[1] variants, with window area smaller or bigger than 100 m²:

- Double glass with air cavity (16mm): Ug =2.7; g=0,78; Tvis = 0.82
- Double glass with air cavity (16mm) and a low-e glass: Ug =1.7; g=0.72; Tvis=0.81
- Triple glass with argon cavity (2x16mm) and low-e glass : Ug =1.0; g=0.64; Tvis=0.74

c. Window replacement: Replacement of the old single-glazed or double-glazed windows by highly efficient, airtight double-glazing windows. This solution will therefore also improve the air tightness (Boneta et al., 2013). For this constructive solution, costs are specified for following glazing properties[2] variants, with window area smaller or bigger than 100m²:

- Double glass with air cavity (16mm): Ug = 2.7; g=0.78; Tvis= 0.82; Uf= 2.2; ka = 27
- Double glass with air cavity (16mm) and low-e glass: Ug =1.7; g = 0.72; Tvis=0.82; Uf= 1.4; ka = 9
- Triple glass with argon cavity (16mm) and low-e glass: Ug = 1.0; g = 0.64; Tvis = 0.74; Uf= 1; ka=3
- Triple glass with argon cavity (18mm) and low-e glass: Ug = 0.65; g=0.6; Tvis = 0.73; Uf= 0.95; ka = 3

d. 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 (Boneta et al., 2013). For this constructive solution, costs are specified for following glazing properties[3] variants, with window area smaller or bigger than 100m²:

- Single glazing: Ug= 5.8; g=0.85; Tvis=0.89
- Double glazing: Ug= 2.7; g=0.75; Tvis=0.81

e. 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 EN 12207 standard (Boneta et al., 2013). For this constructive solution, costs are specified for window area smaller or bigger than 100m²:

Figure 12 illustrates the window frame sealing:

[1] Ug = window glazing U-value (W/m²K)
g = glazing g-Value (-)
T-vis = visible transmittance of the glazing (-)

[2] Ug = window glazing U-value (W/m²K)
g = glazing g-Value (-)
T-vis = visible transmittance of the glazing (-)
Uf = window frame U-value (W/m²K)
ka = air permeability (m³/hm²)

[3]
Ug = window glazing U-value (W/m²K)
g = glazing g-Value (-)
T-vis = visible transmittance of the glazing (-)

Figure 12: Measure sealing of joints (Source: Boneta et al., 2013)

1.2 Measures to reduce cooling loads

1.2.1 Roof and external walls

a. Light color roof and external walls painting to increase reflection of solar radiation. For this constructive solution, no variants are possible.

1.2.2 Solar Shading

a. Base refurbishment level of existing solar shading: Repair/restoration of the old solar shading devices for aesthetic/functional/security reasons. For this constructive solution, no variants are possible (Boneta et al., 2013).

b. 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. For this constructive solution, no variants are possible (Boneta et al., 2013).

c. External window blinds: Installation of window blinds. For this constructive solution, no variants are possible.

Figure 13 illustrates an example solar shading:

Figure 13: Measure solar shading (Source: Boneta et al., 2013)

d. Automation of solar shading devices: Installation of electrical motors, electrical control for shading devices, solar radiation sensors, etc. For this constructive solution, no variants are possible (Boneta et al., 2013).

1.2.3 Solar Control Glass

a. 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 (Boneta et al., 2013).

b. Solar control tint film: Installation of tint film in the glazing, which protect the indoor from solar radiation, reducing solar heat gains (Boneta et al., 2013). For this constructive solution, no variants are possible. Cost varies according to window area smaller or bigger than 100m² (Boneta et al., 2013).

Figure 14 illustrates an installation of solar control tint film:

Figure 14: Measure solar control glass (Source: Boneta et al., 2013)

c. Window replacement: replacement of the old single-glazed or double-glazed windows by highly efficient ones, airtight double-glazing windows with solar con-trol 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 (Boneta et al., 2013). For this constructive solution, cost varies according to window area smaller or bigger than 100m².

1.2.4 Natural Ventilation

a. Automatic Natural Ventilation: This solution includes electrical motors, electrical control for opening (based on for example CO_2 concentration, or indoor/outdoor temperatures), internal partitions grids, outdoor temperature sensor, etc. (Boneta et al., 2013). For this constructive solution, cost varies according to window area smaller or bigger than 100m².

b. Natural Ventilation: Installation of self-regulating opening grills on the façade. For this constructive solution, cost varies according to window area smaller or bigger than 100m².

2. Energy Efficiency Measures on Building HVAC and lighting systems

The chosen energy efficiency measures aim at improving the heating and cooling (generation, emission, distribution, control and others), mechanical ventilation system (heat recovery, air distribution and control), auxiliary systems (pumps and fans), lighting (equipment efficiency) and renewable energy system for electricity generation (RES). Below, different measures and their cost criteria are described:

2.1 Heating and cooling systems

2.1.1 Generation Measures

a. Substitution of the heating system by a condensing gas boiler. The expected heating performances range from 98% to 110% (Boneta et al., 2013). For this measure, costs are specified for heating systems with a heating power less than 35 kW.

b. Substitution of the heating/cooling system by a heat pump (Air to Air technology) with medium nominal COP[4] (around 3.23) and EER[5] (around 2.91) for cooling (Boneta et al., 2013). For this measure, costs are specified for heating systems with a heating power less than 35 kW.

c. Substitution of the heating/cooling system by a heat pump (Air to water technology) with high nominal COP (between 3.48 and 4.66 for heating) and EER (between 2.78 and 3.39 for cooling) (Boneta et al., 2013).For this measure, costs are specified for heating systems with a heating power less than 35 kW.

d. Installation of a cogeneration system (gas turbine or I.C. engine) to meet DHW 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% (Boneta et al., 2013). For this measure, costs are specified for heating systems with a heating power less than 35 kW.

e. Installation of a ground source heat pump system (water to water, with high COP) to meet base thermal load. COP is expected to range between 3.66 and 4.88 whereas EER is expected to range between 4.2 and 5 (Boneta et al., 2013). For this measure, costs are specified for heating systems with a heating power less than 35 kW.

f. Connection to a district heating network (Boneta et al., 2013). For this measure, costs are specified for heating area smaller than 170 m².

g. Removal of the old heating/cooling system and installation of a chiller with medium nominal EER (around 3.0) (Boneta et al., 2013). For this measure, costs are specified for heating systems with a heating power less than 35 kW.

h. Remove the old heating/cooling system and installation of a chiller with high nominal EER (including cooling tower (Boneta et al., 2013). For this measure, costs are specified for heating systems with a heating power less than 35 kW.

i. Removal of the old heating/cooling generation system and installation of a new system of the same type. Applicable for defining as base refurbishment level (Boneta et al., 2013), if the old generator type is not included in the previous alternatives (e.g. standard oil boiler). Heating performance must be greater than 80%. For this measure, costs are specified for heating systems with a heating power less than 35 kW.

4 COP - Coefficient of performance: Ratio between useful energy (heat) and energy consumed (work needed for the compressor working)
5 EER - Energy efficiency ratio: Coefficient of performance when the heat pump is working for cooling.

j. Installation of a solar thermal system to meet DHW loads and/or a fraction of heating loads: panels, storage, circulation pumps, expansion vessel (Boneta et al., 2013). For this measure, costs are specified for panel area less than 10 m² or between 10 and 40 m² (common for single-family houses).

k. 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 (Boneta et al., 2013). For this measure, costs are specified for installed power less than 35 kW.

l. 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 (Boneta et al., 2013). For this measure, costs are specified for installed power less than 35 kW.

2.1.2 Emission systems

a. Installation of an insulated radiant floor emission system. Heating performances are expected to be between 97 and 99% and the cooling around 97% (Boneta et al., 2013). For this measure, costs are specified for a floor area smaller than 600 m² (common for single-family houses).

b. Installation of an insulated radiant ceiling system. Cooling performance is expected to be around 98% (Boneta et al., 2013). For this measure, costs are specified for a ceiling area smaller than 600 m².

c. Installation of a radiator emission system. Heating performance is expected to range between 92% and 95% (Boneta et al., 2013). For this measure, costs are specified for a conditioned area smaller than 600 m².

d. 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% (Boneta et al., 2013). For this measure, costs are specified for a conditioned area smaller than 600 m².

e. Installation of an air diffuser emission system. The expected heating performance ranges between 94% and 96% and the cooling one around 97% (Boneta et al., 2013). For this measure, costs are specified for a conditioned area smaller than 600 m².

2.1.3 Distribution systems

a. Low pipe insulation (Pipe, 2 cm of insulation material) (Boneta et al., 2013). For this measure, costs are specified according to the pipe length.

b. Medium pipe insulation (4 cm of insulation material) (Boneta et al., 2013). For this measure, costs are specified according to the pipe length.

2.1.4 Control systems

The main purpose of the described controlling systems measures is to provide an automatically control of indoor conditions, especially based on temperature control, in other to reduce the energy demand. The control system can be installed according to building user's request (sleeping rooms, working rooms, living rooms and etc).

a. **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). (Boneta et al., 2013). For this measure, fix prices of control systems are considered.

b. **Installation of an indoor thermostatic control system:** Room thermostat, two 2-way valve with servo for controlling the water flow and energy supply to the radiators (system is on according to the thermostat set point temperature) (Boneta et al., 2013). For this measure, costs are specified according to the number of rooms or units.

c. **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 for controlling the water flow and energy supply to the radiators (Boneta et al., 2013). For this measure, costs are specified according to the number of rooms or units

2.1.5 Other systems

a. Installation of a local dehumidifier: local dehumidifier, fixing system, condensate tank and evacuation system (Boneta et al., 2013). For this measure, costs are specified according to the number of units

b. Installation of a local electric hot water boiler (Boneta et al., 2013). For this measure, costs are specified according to the number of units

2.2 Mechanical Ventilation systems

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) (Boneta et al., 2013). For this measure, costs are specified for ventilation systems of dimensioned for a maximum air flow rate of 250 m^3/h.

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) (Boneta et al., 2013). For this measure, costs are specified for air flow rate less than 250 m^3/h (common for single-family houses).

2.2.3 Control systems

a. **Use of nocturnal ventilative cooling**: For a nocturnal ventilative cooling, specific control system, sensors and actuators are needed (Boneta et al., 2013). For this measure, costs are specified according to the number of units

b. **Introducing exterior air according to the building occupancy:** Specific control system, sensors and actuators are needed (possible to be measure according to parameters as for example CO_2) (Boneta et al., 2013). For this measure, costs are specified according to the number of units

2.3 Auxiliary systems

2.3.1 Pumps

Removal of the old pumps and installation of new equipment with high efficiency rates (Boneta et al., 2013). For this measure, costs are specified according to the number of units.

2.3.2 Fans

Removal of the old fans and installation of new equipment with high efficiency rates (Boneta et al., 2013). For this measure, costs are specified according to the number of units.

2.4 Lighting

2.4.1 Equipment efficiency

Removal of the old lamps and install new LED lamps (Boneta et al., 2013). For this measure, costs are specified according to the illumined area.

2.5 Electricity from RES

2.5.1 Generation

a. Installation of a photovoltaic system to generate electricity: panels, support structure, inverter, electricity meter, electrical wiring (Boneta et al., 2013). For this measure, costs are specified according to installed power in kWp.

b. Installation of a small wind turbine to generate electricity: wind turbine, support structure, electricity meter, electrical wiring (Boneta et al., 2013). For this measure, costs are specified according to installed power in kWp.

III. DESCRIPTION OF THE COST DATA

For developing the cost database, we built on the structure provided in the Project ENTRANZE (2012) results. The renovation measures' prices were corrected with the inflation index for 2017 (Database - Eurostat, 2018). This was taken as a starting point to cross-check with other data sources for the four pilot countries of the iBRoad project. According to these sources, the data from the ENTRANZE project was adapted and updated. In this report and the corresponding database we provide data for single family houses in Bulgaria. In the further steps of the project iBRoad (work package 4) we will provide a similar dataset also for the countries Germany, Poland and Portugal.

The default renovation measures and their costs database deliver initial investment cost, which 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, and 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 (MC), labour cost (LC), professional fees, business profit[6] and general expenditure(PF), value added tax (VAT) and disposal cost (D), also shown in

Table **1** below.

TOTAL INVESTMENT COST [€] = MATERIAL COST [€] + LABOR COST[€] + PROFESSIONAL FEES, BUSINESS PROFIT & GENERAL EXPENDITURE [€] + VALUE ADDED TAX [€]

FINAL INVESTMENT COST [€] = MATERIAL COST [€] + LABOR COST [€] + PROFESSIONAL FEES, BUSINESS PROFIT & GENERAL EXPENDITURE [€] + VALUE ADDED TAX [€] + DISPOSAL [€][7]

The "total investment costs" cover the expenses which have to be paid at the time of installation or construction work. The "final investment costs" also include the disposal costs, which often are not taken into account in the assessment of renovation measures.

Table 1 below exemplifies a renovation measure related to the Building Envelope, for Bulgaria:

- From column 1 to 6 details about the renovation measures are specified: specific renovation measure, possible constructive solution, possible variants, cost criteria and units;
- From column 7 to 13 the disaggregated costs are defined for each category: material costs, labor costs, professional fees, business profit & general expenditure, value added tax, and disposal costs.

In the table, total and final investments costs are calculated as described through the equations above. The material and labor costs are based on the Project ENTRANZE and actual research (https://smr.sek-bg.com/). It was assumed 20% added value tax (of sum from materials, labors and professional fees). And, after a discussion with the iBRoad project partners from Bulgaria, it was decided not to consider the professional fees.

6 „Business" includes installers and other craftsmen carrying out the installation or construction work.
7 For the project iBRoad disposal costs are not considered as crucial. However, the auditor may take them into account if considered as relevant for a certain case.

(*) Nominal thermal conductivity of the new insulation layer λ=0,034 W/mK

							BULGARIA				
							MATERIAL COSTS	LABOR COSTS	PROFESSIONAL FEES [if applicable]	VAT	TOTAL COSTS
	Measure	Constructive solution	Description of the measure	Variants	Cost Criteria	Unit base year 2017	COST OF MEASURE	COST OF MEASURE	[% of MC+LC]	[% of MC+LC+PF]	[MC+LC+PF+VAT]
MEASURES TO REDUCE HEATING LOADS	ROOF INSULATION	**Base refurbishment on roof**	Renovation of the exterior layer of the walls (plaster or tile or …) for aesthetic/functional/security reasons	-	m² roof	€/m²	14.6	25.0	0.0	20.0	47.6
		Removal of the roof and refit by adding a new layer of insulation (when repairing or renovation works of flat or sloping	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.	15 cm of thermal insulation	m² roof	€/m²	43.7	10.0	0.0	20.0	64.4
				30 cm of thermal insulation	m² roof	€/m²	50.4	11.0	0.0	20.0	73.6
		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.	15 cm of thermal insulation	m² roof	€/m²	10.7	5.0	0.0	20.0	18.9
				30 cm of thermal insulation	m² roof	€/m²	18.4	5.0	0.0	20.0	28.1
		Insulation below the last concrete slab	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.	10 cm of thermal insulation	m² roof	€/m²	17.9	10.0	0.0	20.0	33.5
				20 cm of thermal insulation	m² roof	€/m²	25.6	10.0	0.0	20.0	42.7

Table 1: Default cost database, as example: roof insulation measure (for Bulgaria)

IV. REFERENCE

Boneta, M.F., Lapillonne, B., Sebi, C., 2013. Cost of energy efficiency measures in buildings refurbishment: a summary report on target countries (D3.1 of WP3 from Entranze Project) [WWW Document]. URL http://www.entranze.eu/files/downloads/D3_1/D3.1_Summary_cost_data__T3.4__-_Def_v5.pdf (accessed 10.22.18).

Database - Eurostat [WWW Document], 2018. URL https://ec.europa.eu/eurostat/web/hicp/data/database (accessed 10.30.18).

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