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D3.3 – Abacus of "renovation mesures" at building and district scale

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TABLE OF CHANGES

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PUBLISHABLE EXECUTIVE SUMMARY

The project is aimed at stimulating the market uptake of deep retrofitting of buildings, with special regard to the Mediterranean area and to the residential built stock, by tackling major bottlenecks such as the fragmentation of the supply chain, the lack of transparency and of the perceived reliability of the interventions, of adequate financial support mechanisms, of integration among the relevant aspects connected to retrofitting, the low return on investments, or the lack of a retrofit approach clearly tailored for the Med environments. To this extent, the project will be acting on the following complementary themes: engagement and empowerment of target groups such as owners, inhabitants, building professionals; technological insight for the development of optimized one-stop shop packages of solutions for deep and beyond retrofitting; financial solutions for supporting the market uptake of deep retrofitting, and proposal of suitable changes in the regulatory frameworks.

In the above described Project framework, the definition of different suitable retrofitting options for each reference building into a specific climate and "integrated sets of renovation measures" plays a pivotal role. This deliverable is related to the Work Package 3 entitled "Optimal Solutions", in particular to the Task T3.2, whose title is "Optimal Solutions".

The aim of this Deliverable is to provide integrated alternative/complementary Renovation Measures synthesized into a "Renovation Measures" Abacus/Matrix. These "integrated Renovation Measures" will be assembled with an holistic approach, considering country-specific peculiarities, combined actions on the building envelope, technological systems and facilities, Renewable Energy Sources integration, behavioral measures and also measures that can be applied at urban or district scale and are not specifically designed for buildings in order to maximize the impact of the overall intervention. Starting from the introduction in which the main aim and objective of the document are described, a brief literature survey is provided. On the basis of the available literature results, the HAPPEN Approach employed to

conceive the Abacus of Renovation Measures is described and the identification of the best available technologies to be applied for renovation measures is carried out. Then, the optimization of the Abacus, in different steps, by taking into account all the Partners' Contributions is shown. Finally, the methodology to be applied for the construction of the Abacus of the renovation measures is completed by providing the description of the approach used to gather the renovation measures in solutions and then in packages of solutions. In the final remarks, the main outcomes of the analysis are reported and the next steps for the future work are described.

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ACRONYMS AND ABBREVIATIONS

All acronyms and abbreviations (AAs) used in the report should be listed in alphabetical order in the table below (other than symbols for units of measurement) in the following way:

AE	Aerogel
B	Basement
BAT(s)	Best available technology
CHP	Combined Heat and Power
ETICS	External Thermal Insulating Composite System
EPS	Expanded Polystirene
GW	Glass Wool
IACI	Internal Air Chamber Insulation
II	Internal Insulation
PU	Polyurethan
RW	Rock Wool
SRI	Solar reflectance Index
TR	Tilted Roof
VF	Ventilated Façade
XPS	Extruded Polystirene
WF	Wood Fiber
WW	Wood Wool

AAs must be defined the first time they are used in the text of the report, and AAs should not be introduced if they are not used again in the document.

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1 INTRODUCTION

1.1 Aims and objectives

At present, about 35% of the EU buildings are over 50 years old, almost 75% of the building stock is energy inefficient. 75%-85% of those buildings will be still in use in 2050 [1,2]. At the same time, only 0.4-1.2% (depending on the country) of the building stock is renovated each year. Therefore, currently the European Union is facing a double challenge: increasing building renovation rates while aiming at achieving "deep renovations". The increase in the current EU renovation rate from 1.2% per annum to 2-3% plays a crucial role to meet both the EU 2020 targets and the commitment undertaken in Paris in December 2015.

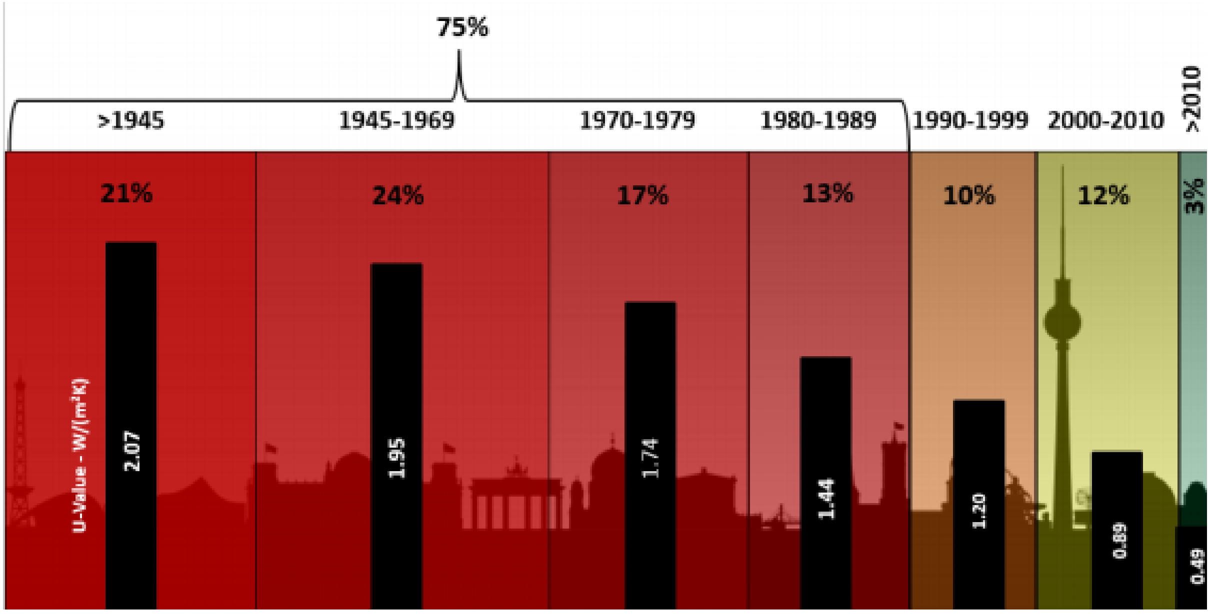

Figure 1. -Age of the EU building stock and corresponding average Unavalue (illustrated by the black bars) for building envelopes. The 2010 data for UnaValue is based on an average of just 7 countries, while the others are based on average of all 28 Member States (Source: EU Building Stock Observatory) [1]

Renovation of existing buildings can lead to significant energy savings and is of a paramount importance when considering the clean energy transition, as it could reduce the EU's total energy consumption by 5-6% and lower CO_2 emissions by about 5%.
In addition to energy efficiency gains, a renovated building stock can also:
-create economic, social and environmental benefits;
-contribute to the improved health, comfort and wellbeing of their residents by reducing respiratory and other illnesses caused by a poor indoor climate;
-make homes more affordable and help households escape energy poverty.

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Investments in energy efficiency also stimulates the economy, especially the construction industry, which generates about 9% of Europe's GDP and directly accounts for 18 million jobs. SMEs in particular benefit from a boosted renovation market, as they contribute more than 70% of the value added in the EU building sector.

In order to boost energy performance of buildings, the EU has established a legislative framework that includes the Energy performance of buildings directive (EPBD) (2010/31/EU) and the Energy Efficiency Directive (2012/27/EU). Both directives were recently amended as part of the"Clean energy for all Europeans Package". Together, the directives promote policies that will help achieve a highly energy efficient and decarbonised building stock by 2050, create a stable environment for investment decisions to be taken and that will enable consumers and businesses to make more informed choices for saving energy and money.

In particular, the 2010 EPBD recast now requests that Member States ensure that minimum energy performance requirements for buildings are set "with a view to achieving cost-optimal levels". The cost-optimal level shall be calculated in accordance with a comparative methodology established by the EU Commission. According to this methodology, each Member State has to:

- Define the reference buildings;
- Define energy efficiency measures to be assessed for the reference buildings: these can be measures for buildings as a whole, for building elements or for a combination of building elements;
- Assess the final primary energy need of these reference buildings;
- Calculate the costs of energy efficiency measures during the expected economic lifecycle of the reference buildings.

The term "cost optimal level "is defined as "the energy performance level, which leads to the lowest global cost during the economic lifecycle" as written in the EPBD recast 2010.

As it can be read in [3], the Energy Efficiency Measures should be assessed as a single measure or as a package of measures, for selected reference buildings as a whole and /or for building elements. The measures defined should cover building envelope design alternativesas well as options for HVAC systems renovation, which may also take into account the employment of renewable energy sources. The number of measures for each reference building has to be equal or higher than ten packages or variants.

However, when considering the building renovation process, the reality for many building owners is that it is not easy from a financial and logistic point of view to carry out a complete deep energy retrofit in one step. More common are step-by step retrofit which are partial retrofit steps completed over time.

Given the above described context, one of the main objectives of the Happen Project is to define integrated and holistic cost optimal packages of solutions, in order to adapt to the

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EPBD Recast.In particular, beyond the definition of reference climate conditions, the reference building typologies evaluated through a deep analysis of the existing building stock in each country involved, the Work Package 3 activities are aimed at the identification of integrated renovation measures synthesized into an "Abacus/Matrix" of Renovation Measures. These renovation measures are assembled with a holistic approach by employing a multilevel, pyramidal structure.

At the top of the pyramid there is level zero, in which the building, the behavioural issues and urban environment at a district scale are set. The building is then divided in subparts: the envelope and the technical systems, which are both set on level one.

The components at level one are furtherly split up in another level, that is the final level two, in which the BATs for the renovation measures are extensively described.

When considering the level two of the building, renovation measures for the external walls, roof, heating and cooling systems are presented. In order to take into account the country specific peculiarities, each partner country has provided its own contribution to the abacus construction. In order to provide a holistic approach to the renovation process, the improvement in wellbeing of occupants in the living spaces as well as measures to enhance the quality of life at neighbourhood/ district level are evaluated.

The definition of the Abacus of the Renovation Measures represents the main aim of this document and of the Task T3.2 of the Project. Starting from a literature survey, the HAPPEN multilevel approach for the Renovation Measures Abacus is presented and extensively described in the following paragraphs. Different suitable retrofitting options will be examined and optimized, considering the country specific peculiarities.

Each "integrated set of Renovation measures" is identified as a solution for the building retrofitting. A comprehensive set of solutions provides a package of solutions. However, the renovation measures identified in the Abacus provide about 142500 combinations, Therefore, the methodology for the construction of the Abacus concerning the Packages of solutions is described, but it was not possible to define a matrix with only 12 packages of solutions. A further reduction will be performed in Task T3.3, when the cost-optimality evaluation of the sets of the renovation measures will be performed according to the main European standards (EN 15459 and EN 15603). Cost-optimal one-stop-shop packages of solutions tailored for the Mediterranean space, based on state-of-the-art Best Available Technology (BAT), and related to the main target buildings addressed by the project will be individuated in Task T3.3 and delivelabe D3.4, respectively.

1.2 Relations to other documents

1.2.1 Legal Framework

The Consortium and Project activities are regulated under the following legal framework:

- The Grant Agreement (GA) - contract between the Commission and the Consortium, especially relevant Annex 1 (also known as Description of Action - DoA);
- The Consortium Agreement (CA) - agreement among the Consortium members.

The above documents constitute the legal framework which defines the relations, obligations and rights during the project duration.

1.2.2 Other Project Documents

This deliverable is related to the following documents:

WP(3) Title:Optimal Solutions

- D(3).1 Report on representative climates and zoning;
- D(3).2 Catalogue of reference building classes in Mediterranean countries7
- D(3).4 Report on optimal packages of solutions

1.3 Report structure

This report is divided into seven main paragraphs. Starting from the introduction in which the main aim and objective of the document are described, a brief literature survey is provided. The benchmark European projects and the outcomes of selected papers referring to the cost optimal building renovation targeted for the Mediterranean Area are presented in the second paragraph. On the basis of the available results, the HAPPEN Approach employed to conceive the Abacus of Renovation Measures is depicted in the third paragraph. The identification of the best available technologies to be applied for renovation measures is carried out in the fourth paragraph. Then, the optimization of the Abacus, in different steps, by taking into account all the Partners' Contribution is shown in paragraph 5. Finally, in the sixth paragraph, the Abacus of the renovation measures is completed by providing the description of the approach used to gather the renovation measures in solutions and then in packages of solutions. The conclusions and reccomendations are shown in paragraph 7.

2 ABACUS OF RENOVATION MEASURES: BACKGROUND ANALYSIS

In this section a brief description of selected European Projects carried out in the framework of deep renovation is presented. A short survey of the literature papers available focused on the identification of the renovation measures in the Mediterranean area is provided. The analysis of the benchmark projects and literature is performed in order to define the baseline,

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on whose basis the HAPPEN approach to the renovation process and in particular the construction of the building renovation measures abacus is conceived.

2.1 – Benchmark Projects

2.1.1 ENTRANZE- EU Project

As it can be read in [4], the aim of this 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 national building stocks. The project intended 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 roadmap.
The core part of the project was the dialogue with policy makers and experts and focused on nine countries, covering >60% of the EU27 building stock. Data, scenarios and recommendations were also provided for EU27 (+ Croatia and Serbia).
When focusing on the renovation measures, energy efficiency measures to improve the building energy performance, as well as the cost data associated to these measures were described in a dedicated deliverable [5]. It is focused on the 9 target countries (Austria, Bulgaria, Czech Republic, Finland, France, Germany, Italy, Romania and Spain) and both residential and non-residential buildings were examined. In particular, going into the depth of the procedure, 25 of the measures considered for the project were related to the building envelope and 40 to the HVAC systems (and their variants) and different levels of renovation were planned. When considering the measures for the building envelope, options to reduce energy need for heating as roof insulation, external wall insulation, floor and slabs insulation and the windows improvement were presented. Among the measures to reduce the energy need for cooling, the solar shading, the solar glass control and the ventilation may be found. The analysis of the HVAC systems was performed by considering the generation systems, the emission, distribution and control systems, the mechanical ventilation, the auxiliary system, the lighting and the measures based on RES.
The final matrix of the renovation measures, although technically exhaustive, do not take into account neither the behavioral aspects nor the measures at urban and district scale.

2.1.2 EPISCOPE TABULA EU Project

As stated in [6], in the IEE project TABULA, residential building typologies have been developed for 13 European countries. Each national typology consists of a classification scheme grouping buildings according to their size, age and further parameters and a set of exemplary buildings representing the building types. They have been published by the project partners in national "Building Typology Brochures", written in their respective languages. As a common element all brochures contain double page "Building Display Sheets" for all

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example buildings on which energy related features and the effects of refurbishment measures are illustrated graphically.

In order to better describe the renovation measures, a comprehensive review of the Building Typology brochure was carried out, in particular for the Italian case [7]. The brochure presents a work concerning the identification of reference buildings in different historical periods and diverse climate zones. Several renovation measures involving the envelope and the generation systems are listed for two levels of building refurbishment, standard and advanced, respectively. However, when analysing the HVAC, the cooling aspect is not taken into account. Only the improvement of the heating system, the DHW and the use of solar thermal systems were considered. Moreover, the behavioural issue and measures at urban and district scale were not evaluated.

To exchange information on the European level the "TABULA WebTool" provides an online calculation of the exemplary buildings from all countries, displaying their energy related features and the possible energy savings by implementing refurbishment measures. Basis of the TABULA WebTool is a simple and transparent reference procedure for calculating the energy need, the energy use by energyware and the energyware assessment (primary energy, carbon dioxide, costs).

Apart from the reference calculation used for cross-country comparison, a calibration of the calculated energy use to the typical levels of actual consumption is foreseen – with the intention to enable a realistic assessment of energyware and heating costs savings. Based on the residential building typologies, building stock models have been created for seven countries, which enable a projection of the actual national building stock consumption and the energy saving potentials.

2.1.3 RePublic ZEB EU Project

As it may be found in [8], this Project is firstly devoted to the analysis of the stock of existing public buildings and definition of reference buildings. This activity precedes the collection of data and the analysis of the energy consumption of the current stock of public buildings in each partner country of the project, taking into consideration the consumption for heating, hot water for sanitary use, cooling and lighting. The analysis of the national data allows for a cross comparison to define benchmarks of energy performance for each type of public building, based on use, size and function (operation).

The reference buildings thus identified serve as prototypes for developing a range of standard economic efficiency measures (packages of measures). This allows the project partners to identify a group of public buildings to be used as case studies in order to verify the impact of the adoption of a set of measures during the renovation and/or refurbishment activity.

By means of the assessment of the status quo and analysis of opportunities for the renovation of public buildings in nZEB, the identification of the most efficient construction technologies

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available on the market to reach the nZEB target for the current stock of public buildings is carried out.
In particular, in this framework, the outcomes of the report in [9] are crucial and they are reported in this document. After the analysis of the best practices in in each target country, energy efficiency measures applicable through deep refurbishment of public buildings are presented. The interventions are related to the building envelope, HVAC and DHW systems, Building Management Systems, lighting and power generation system, including several technologies based on RES. The energy efficiency measures take into account the country specific peculiarities and the diverse level of performance of the technology for each country is taken into account.
"Several packages of energy efficiency measures are proposed taking into account the technologies that had been gathered as regards the refurbishment towards nZEB level of the reference building categories in each target country. Among the packages, the typical combinations of the energy efficiency measures can be found, which represent the currently applied refurbishment practice in the given country, as well as those combinations of innovative measures that represent a high level of energy efficiency." Although the extremely comprehensive analysis, the behavioural aspect is not deeply examined and the measures at district scale are not evaluated.

2.1.4 REFURB EU Project

As it may be found in [10] The REFURB project was set up in responce to the important Europe wide challenge of improving energy efficiency in residential buildings, and especially in uptake of major renovation of houses. The main barriers thet REFURB related to are the fragmentation of the renovation process itself. On the supply side each supplier (technology providers, contractors and architects) only delivers a fraction of the renovation work and – in general – does not take responsibility for the overall success of the renovation (i.e. the desired energy reduction level). On the demand side, the main barrier lies not only in financial restrictions to renovation or even general awareness of the potential benefits of renovation, but in the fact that private homeowners do not have a structured way to obtain all the necessary information for decisions on renovation solutions.
As response to the above challenge and main barriers, the REFURB project focused on bridging the gap between the supply side (building construction sector) and demand side (homeowners) by developing dedicated renovation packages for different market segments. The overall approach was to bring together all relevant stakeholders of the supply and demand sides to a) develope a holistic methodology for the renovation process in which technology combinations trigger step-by-step deep energy renovation of existing, private residential buildings towards NZEB-standards, and b) introduce a "Compelling Offer" (i.e. an

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offer you can't refuse) to residential homeowners based on a match between available technologies and their concerns.
In particular, when focusing on the renovation measures to NZEB, a selection of relevant existing renovation solutions or initiatives are presented in tables per
REFURB partner country. In general, two categories of solutions can be distinguished in technological solutions and non-technological solutions.
The technological solutions are less country-specific and aredividedinto three categorie(building envelope, technical installations and renewable energy sources) and linked to the buildingtypologies in each country.
Looking at the non-technological solutions, the following categories can be distinguished:
-innovative financial models (new ways of financing)
-Online tools for management or decision making (which are partially applied by one-stop-shops
either as a lead-producing tool or as a first information tool)
-Demonstration projects or showcases visible to other homeowners
-New approaches to organising the supply side through building teams of smaller craftsmen
- Quality assurance
- Renovation packages = One-stop-shop-solutions
-Other solutions (such as innovative communication and marketing)

2.1.5 EuroPhit EU Project

This Project plays a crucial role in the literature review not only because it deals with deep retrofitting, but also because of the step by step approach proposed to carry out the building renovation and the certification scheme conceived in the framework of the renovation process. The project is based on the deep renovation applying the Passive House technologies. As it can be read in [11], the reality for many building owners is that it is not easy from a financial and logistic point of view to carry out a complete deep energy retrofit in one step. More common are stepnaby step retrofit which are partial retrofit steps completed over time. In order to reach an optimal energy standard for the whole building after the completion of all the individual retrofit steps, a common masterplan is prepared. This plan is tailored for each individual building and ensures that the lock-in effects are avoided. In the Project Europhit EU, an approach for such a masterplan has been developed and it is known as EnerPhit Retrofit Plan. A schematic view of the EnerPhit Retrofit plan in presented in Figure 2. The renovation measures involve the building envelope and its connections and the building services. When considering the behavioral aspects, the occupant satisfaction is evaluated taking into account the ventilation systems, the frequency of overheating, the presence of excessive humidity. Some advices are provided like [13]

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-"*All living areas must have at least one operable window;*
-It must be possible for the user to operate the lighting and temporary shading elements. Priority must be given to usernaoperated control over any automatic regulation"
-In case of active heating and/or cooling, it must be possible for users to regulate the interior temperature for each utilisation unit.
-The heating or air conditioning technology must be suitably dimensioned in order to ensure the specified temperatures for heating or cooling under all expected conditions".

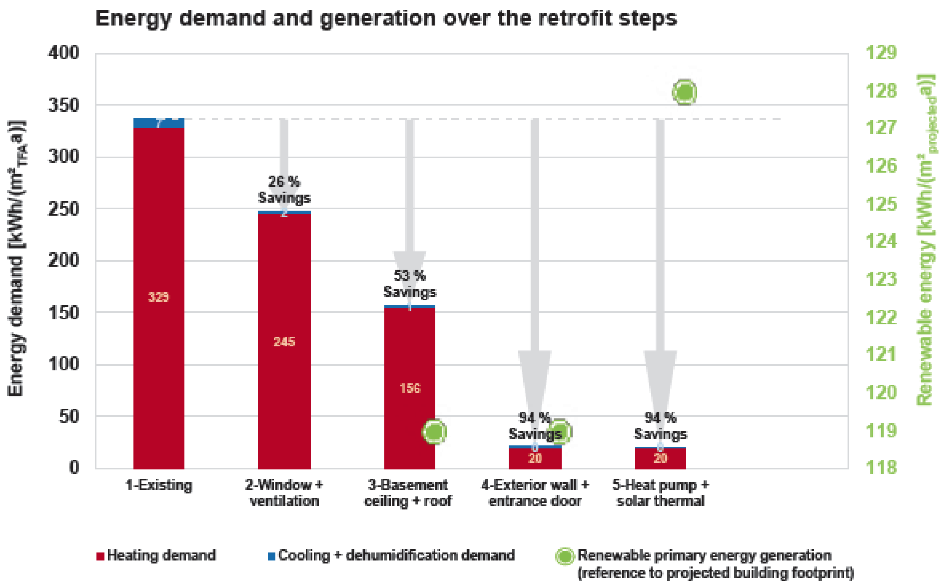

Figure 2. illustration of an EnerPHit Retrofit Plan for an endnaofnaterrace house showing the heating demand and generation of renewable energy (right and axis) in the existing building and after the four steps [12].

The Passive House Institute makes a thorough check of the EnerPhit retrofit plan assessed by means of a prenacertification of the stepnabynastep retrofit. Once the first step is completed, a preliminary certification can be issued. A schematic representation of the Enerphit certification Process is provided in Figure 3.
The criteria, which a refurbished building has to achieve in order to be awarded of the certificate are based on energetic aspects.

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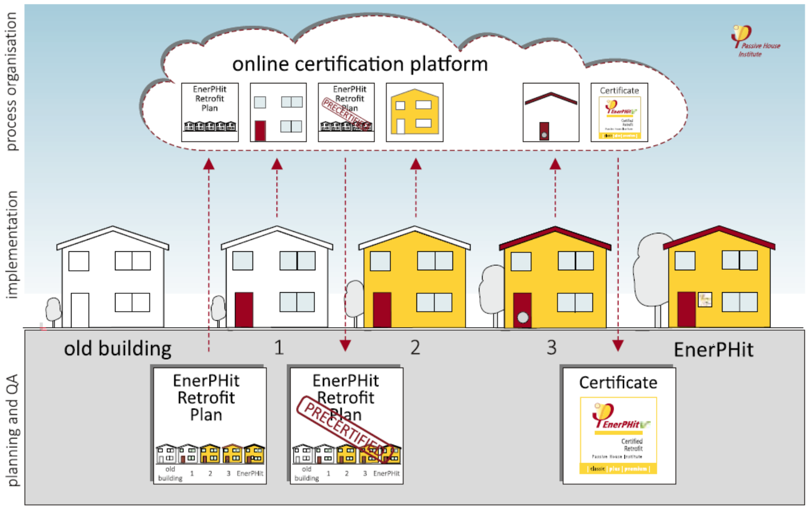

Figure 3- Schematic representation of the certification process

2.2 – Literature overview at a glance

In this section the main outcomes of the papers available in the literature are added. In particular, the papers targeted to the building renovation in the Mediterranean Area are reviewed. For this pupose, the analysis of the above mentioned papers is reported below

In [14], after defining the reference buildings, high energy efficiency measures both for the building envelope and the technical systems are considered to reduce the primary energy consumption of the reference buildings; with regard to the external walls and windows a multi-objective analysis has been carried out to obtain several types of high efficiency external walls in relation with the Mediterranean climate. When considering the supply systems, three main HVAC systems are taken into account to satisfy heating, ventilation and air conditioning demand. Moreover, two types of generation systems are considered, a heat pump with air ground heat source and a variation of the number of PV panels. The renovation measures regarding the envelope (e.g. wall configurations, windows type), the technical systems and the RES are listed and grouped with the aim of defining a series of combinations, more specifically 144 combinations of measures were individuated. Then, 12 combinations of renovation measures form a package of solutions. The cost optimality of each package of solutions is calculated. The results show that the cost-optimal configuration selected allows the building to reach a high energy performance with a primary energy reduction between 56% and 90%. However, in this document, behavioural aspects or measures at urban and district level are not taken into account.

Baglivo et al. [15] evaluated cost-optimal levels of minimum energy performance requirements in mononaresidential reference building located in South of Italy. After defining the characteristics of the envelope and the technical systems, a proper selection of energy efficiency technological measures was carried out. They are able to reduce significantly the enengy needs of a building and involve the external walls, the windows and the supply

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systems. These measures were then grouped in packages and 168 cases were defined, resulting by the combination of walls, windows and technical systems variants. The combinations obtained were then compared in terms of primary energy consumption and global costs. The cost-optimal solution is identified assessing technical features and energy performance. Standard and high efficient buildings were examined, in order to show how the selected configuration enables a reduction of primary energy consumption and CO_2 emissions at the lowest cost. The results shown in this work refer to Mediterranean residential reference buildings in relation to Italian requirements, technologies and energy costs. However, the methodology used is general and it can be applied to other cases.

In [16], an identification of the cost-optimal levels related to the energy performance requirements for the Italian building stock is discussed. An innovative energy cost optimization procedure based on a sequential search-optimization technique is developed and applied to each reference building to calculate the cost-optimal energy performance. It can be read that "the method considers, for each energy efficiency measures, a discrete number of options (e.g. different levels of thermal insulation) described by relevant parameters (e.g. thermal transmittance). Different packages of energy efficiency measures are applied and compared: each package is a set of energy efficiency options one for each measure".

The reference buildings considered are taken from the TABULA project. The energy efficiency measures are applied to the building envelope, for the technologies using renewable energy sources and for the technical systems. Five energy efficiency options have been identified for each measure, starting from the inefficient to the envelope is reported in Figure 4.

EEM		EEO 1	2	3	4	5
Wall insulation (on external surface)	U_{wl} [$Wm^{-2}K^{-1}$]	0.45	0.34	0.29	0.25	0.20
	cost [€]	41 719	49 484	55 001	61 003	71 883
or Wall insulation (on cavity)	U_{wl} [$Wm^{-2}K^{-1}$]	0.45	0.34	-	-	-
	cost [€]	34 338	41 326	-	-	-
Upper floor insulation	$U_{fl,up}$ [$Wm^{-2}K^{-1}$]	0.40	0.30	0.27	0.23	0.20
	cost [€]	8 489	11 427	12 732	15 003	17 303
Lower floor insulation	$U_{fl,lw}$ [$Wm^{-2}K^{-1}$]	0.45	0.33	0.29	0.24	0.20
	cost [€]	15 386	18 585	20 240	23 084	26 383
Windows	U_w [$Wm^{-2}K^{-1}$]	5.00	2.20	1.90	1.60	1.30
	cost [€]	51 320	68 984	72 803	86 887	90 945
Associated technology		single glass	double glass	double low-e glass	triple low-e glass	triple low-e glass
Solar shading devices	τ_{sh} [-]	0.20	0.20	-	-	-
	cost [€]	9 548	25 063	-	-	-
Associated technology		fixed louvres	mobile louvres	-	-	-

Figure 4 Energy efficiency measures and related options referred to the building envelope of the case study [16]

The energy performance and the global costs are evaluated according to the UNI/TS 11300 national Standard and the European UNI EN 15459 Standard. The results obtained with the procedure based on sequencial search technique, considering a number of discrete options,

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have demonstrated the validity of the procedure itself, that has been then adopted for the EPBD recast implementation at Italian national level.
In [17], an elaboration of information required to carry out the renovation measures cost optimal analysis of two case study buildings, representative of the most common ones of the Italian residential stock is presented. With regard to the definition of the case studies, a single family house and a multi family house in two different Italian climate zones (E, Milan and B, Palermo) are taken into account. Both buildings are characterized by unheated basement, reinforced concrete structure with hollow clay bricks, uninsulated envelope, wooden frame windows with double panes glazing in zone E and single glass in zone B. When considering the HVAC, centralized heating system and individual DHW are assumed for MFH, whereas in SFH, DHW systems are considered as separate from the space heating. Moreover, existing splits or multisplits for space cooling are forseen in SFH located in the climatic zone B. The cost assessment in this work is based on the detailed Milan municipality building price-list for public works.it can be read that "with this regards, it should be noted that its prices are mainly taken as a reference for public tenders (involving large size works) allowing decreases during the offer phase of the competition (in some case also up to 20-25% […]. The reduction of the prices was limited to the following specifications. In zone E (northern Italy) only for the MFH, measures of 10% of reduction has been considered, while for the SFH ones the prices are maintained as they are, in order to consider the economies of scale (small size)".
The renovation measures adopted for the envelope forsee common maintenance envelope measures (e.g. substitution of deteriorate external plaster of walls) and energy improving measures based on two different increasing levels of insulation. Moreover, several options of the HVAC systems substitutions are summarized in Figure 5.

	MULTI-FAMILY HOUSE			SINGLE-FAMILY HOUSE	
HEATING	**100-150 kW (zone B)**		**200-250 kW (zone E)**	**15 kW (only heating)**	**25 kW (combined DHW)**
Wall-mounted condensing boiler	-		-	2.2	2.4
Floor-standing condensing boiler	13.2		17.7	4.4	4.5
Multisplits	-		-	14.1	-
Air-to-water heat pump	30.6		47.0	6.2	7.0
Ground water heat pump	35.1		42.2	-	-
COOLING	**23 kW (5 ext. units)**	**14 kW (10 ext. units)**	**5 kW (20 ext. units)**	**14 kW**	
Multisplits	108.5	126.0	130.0	14.1	
DHW	**wall mounted**			**floor standing (except electric one)**	
Electric water heater	5.8			0.6	
Gas-based water heater	21.0			2.1	
Heat pump water heater	28.0			3.3	

Figure 5-Costs of buildings HVAC systems, k€, [17]

When considering the RES; solar systems for providing 50% of DHW production are taken into account only for SFH; photovoltaic systems, grid connected are taken into account for both SFH and MFH and their costs are also listed. Additionally, an analysis of several

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references has been carried out in order to collect national energy consumptions and GHG emissions values.

In [18] building refurbishment and renewable enrgy generation was taken into account for three building projets to be refurbished in the framework of the European HERB Project. It was shown that the refurbishment of the residential building envelopein Southern dry climate region has a slight influence on energy demand reduction along with the investment costs, even whin taking cooling energy into account. I the other two investigated locations (Mediterranean climate and oceanic climate regions), refurbishment has a higher potential for saving energy compared to solar energy production. However, in the Mediterranean climate region it comes with higher costs for the refurbishment than for solar technology integration. The results of the renewable energy supply simulation allow to determine the best combination of solar electric and solar thermal systems for the given building load situation.
In [19], different energy retrofit alternatives for a social housing subjected to the Mediterranean climate conditions, are analysed and discussed, also taking into account the cooling reqirements. The reference building was a social housing unit characterized by inefficient and obsolete solutions.
Consequently, the research is aimed at investigating how the limited energy performances of the reference building affect the achievement of the optimal levels, by identifying the most costnaeffective retrofit measures, with particular reference to those required to the attainment of the n-ZEB standard level. The energy efficiency measures involve the opaque and the glazed elements of the building envelope. Eight configuration for the HVAC plant were also taken into account and three photovoltaic alternatives were presented. Energy efficiency measures are then combined in *packages* since the aggregation of different intervention creates synergies that allows for better results in terms of costs as well as in energy performance, compared with those obtainable with single measures. For each package of costna effective retrofit actions, the annual primary energy savings were determined employing the procedure dictated by the EPBD 2010/31 UE, applying the EN 15459:2017 standard for the calculation of the global costs. Energy evaluation and economic optimization were carried out by using the same simulation tool, which includes modules both for the energy performance in transient regime and for the optimal solutions identification by means of the genetic algorithm.

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3 ABACUS OF RENOVATION MEASURES: THE HAPPEN APPROACH

3.1 – Multilevel Approach

After the review of the main targeted literature, the HAPPEN approach to the Abacus of renovation measures was conceived. In order to ensure a holistic renovation process, combined actions on the building, behavioural measures and also measures that can be applied at an urban and district scale and not specifically designed for buildings are considered, in order to maximize the interventions.
For this purpose, a multilevel approach designed on three levels is presented.

- On Level zero: the building, behavioural aspects and the urban environment at district scale are set;
- On Level one: the building components: the envelope and the technical systems;
- On Level two: the Best Available Technologies (BATs) for the building envelope and the building technical systems are investigated.

The starting level is level zero, in which the three main aspects, are set, as depicted in Figure 6.

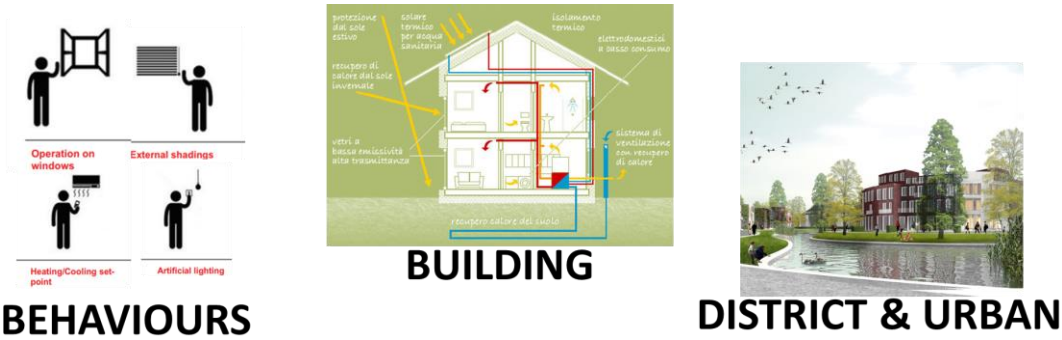

Figure 6. HAPPEN Multilevel Approach-Level zero

Beyond the building element, when focusing on its energy consumption, studies have demonstrated that the actual energy consumption of the building is sometimes three times greater than the extimated calculations [20]. This performance gap is due to several aspects, among which the occupant energy behaviour plays a key role, which is often disregarded in the energy simulation process. The human-building interaction is very close: as it can be read in [21]: buildings do not use energy, occupants do. Occupants arenot to be considered as passive recipients of the building in which they live or work, as they actively interact with the indoor environment to search comfort conditions. Therefore, in the HAPPEN framework the behavioural aspects and the interaction between occupants and building are also considered,

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in order to properly evaluate the building energy consumption and to allow improved comfort condions to be achieved.
The other element to be examined is represented by the urban environment at district scale. Urban warming has a serious impact on the energy consumption of buildings, by increasing the energy and the electrical power necessary for cooling needs [22]. In particular, it may be read in [23] that the relation between the daily electricity consumption and the corresponding ambient temperature is not linear. An analysis carried out on eleven studies dealing with the impact of the ambient temperature on the peak electricity demand showed that for each degree of temperature increase, the increase in the peak electricity load varies between 0.45% and 4.6%. This corresponds to an additional electricity penalty of about 21 ± (10.4) W per degree of temperature increase and per person. In parallel, analysis of fifteen studies examining the impact of the ambient temperature on the total electricity consumption, showed that the actual increase of the electricity demand per degree of temperature increase, varies beween 0.5 and 8.5%.
As it can be read in [23,24], the ambient temperature in urban areas is usually several degrees higher than their surrounding suburban and rural areas. This phenomenon is called "urban heat island effect" and plays a key role in changing urban microclimates. Summer Urban Heat Islands with daytime air temperatures of 1°C-6°C higher than the surrounding rural areas are present in many cities around the world, especially in warm climates and in the Mediterranean Countries as for example Greece. Therefore, in order to mitigate urban heat islands and to reduce the cooling energy consumption and to improve the air quality, some strategies are reviewed and proposed in the HAPPEN context, in the following paragraph.

3.1.1 Building

When considering the building, a hierarchical structure was conceived, as depicted in Figure 7. The building is considered as being composed of two main parts: the building envelope and the technical systems.
Both of them are made up of other components for which the BATs are identified. In particular, with regard to the envelope, two main classes of components are individuated, which are placed on the bottom level, that is level two and it deals with:
-Opaque components: roof and ceiling, external/vertical walls, basement/slab;
-Transparent Components: the windows are considered.
When the technical systems are taken into account, the the electric and thermal energy production, the heat recovery are evaluated.

For all the components concerning the building envelope and the technical systems, the BATs will be selected and listed in the next paragraph.

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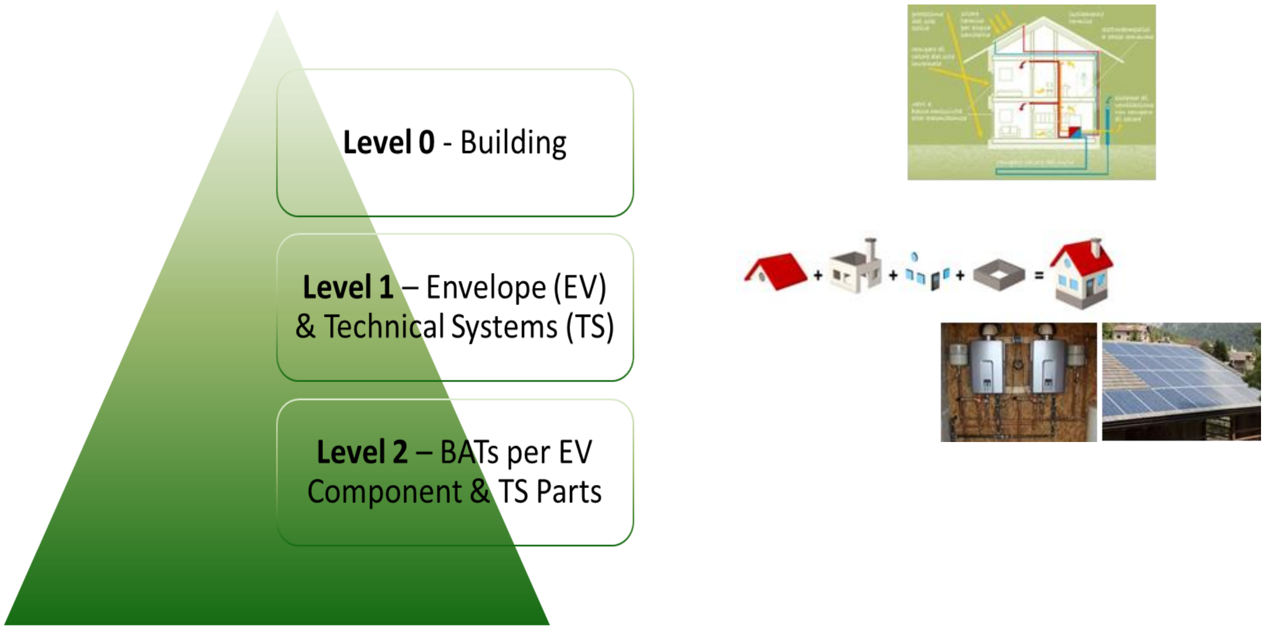

Figure 7- Building and its hierarchical structure

3.1.2 Behavioural effects

As it can be read in [21], the building sector plays an important role regarding the energy consumption, accounting for 40% of total final energy consumption. Out of this percentage, about three-quarters is due to residential sector, while the remaining quarter is due to commercial buildings. Energy consumption of buildings is affected by different factors, as the thermo-physical properties of the building elements, the construction technical details, climatic location characteristics, the quality and maintenance of HVAC and the occupant's behaviour and activities towards energy utilization. Different studies in the literature show that the actual energy consumption of buildings is sometimes up to three times greater than the estimated calculations. As it is maybe found in [25], past studies showed that the difference between predicted energy and real energy use is mainly due to the way that occupants behave in terms of energy use. This behaviour has several direct and indirect factors that may have influence in the way that occupants consume energy. These factors are depicted in [25]

As it can be found in [21], occupants behaviour is referred to the interaction with building systems in order to control the indoor environment for health and to obtain thermal and visual acoustic comfort inside buildings. The total energy consumption of buildings is not only influenced by the metabolic heat produced by occupants passively, by also by their active energy use. Occupants interact with control systems and building elements to reach their own desired level of comfort in different ways: using the building openings (e.g. opening and closing the windows), use of lighting and controlling solar shading (e.g. adjusting the blinds),

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use of HVAC sytems (turning air-conditioning on or off and adjusting thermostat temperature), use of hot water and electrical appliances. In the past decades, the reaseach regarding the energy-related occupant behaviour has developed according to Figure 8.

As described in [26], many models have been developed during the past decades, in order to simulate the users behaviour properly. An interesting application is reported in [21]. It deals with four probabilistic models of occupant adaptive behaviour selected from published literature, with respect to windows opening; shadings; heaters and fans; and artificial lighting system. The models refer to continental climate condtions and to Mediterranean climate conditions. As it can be observed in Figure 9, the behavioural adjustment of the indoor environment is responsible for a twofold variation effect compared to the standardized simulated energy performance.

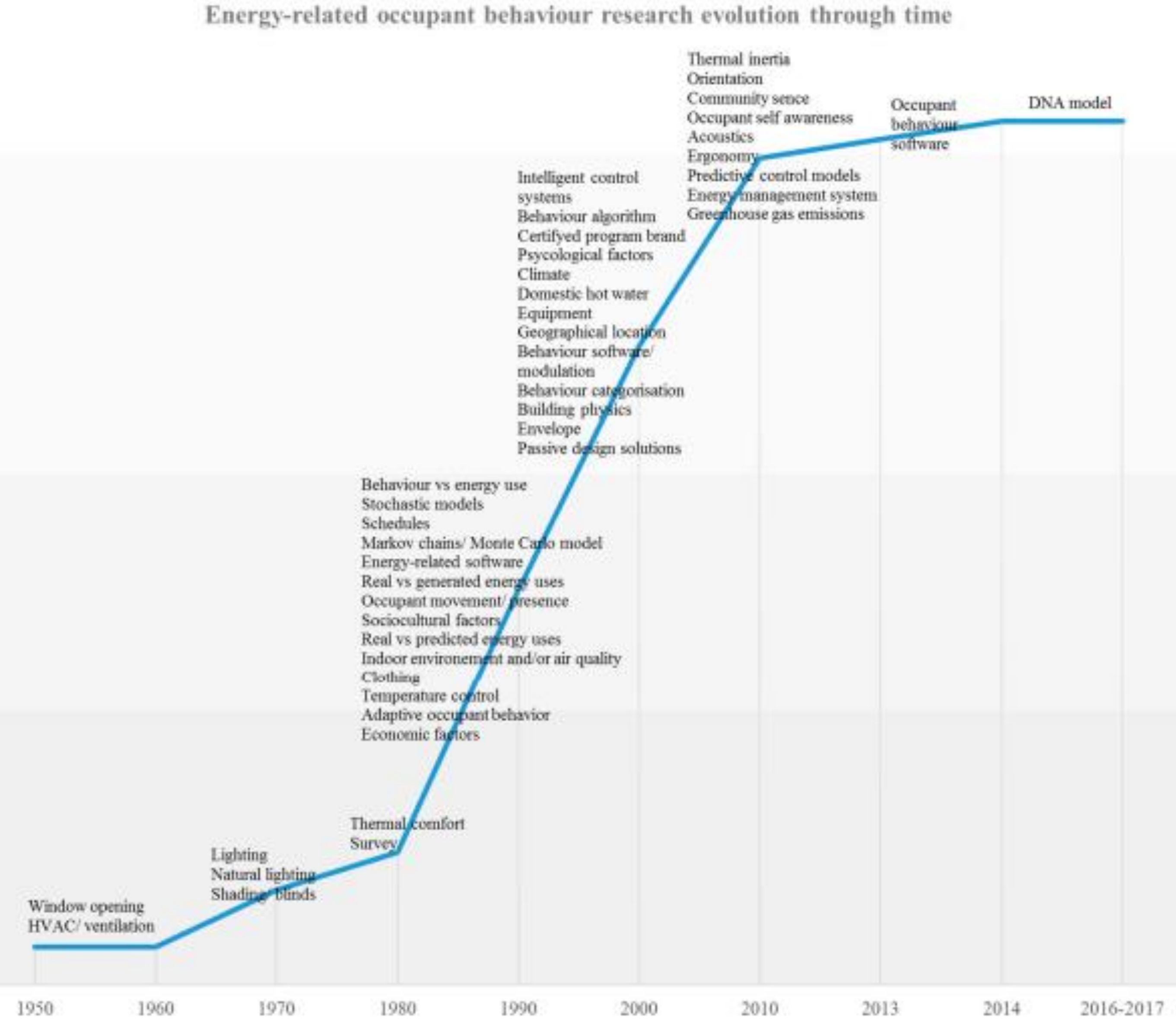

Figure 8- Energy related occupant behaviour evolution through time [26]

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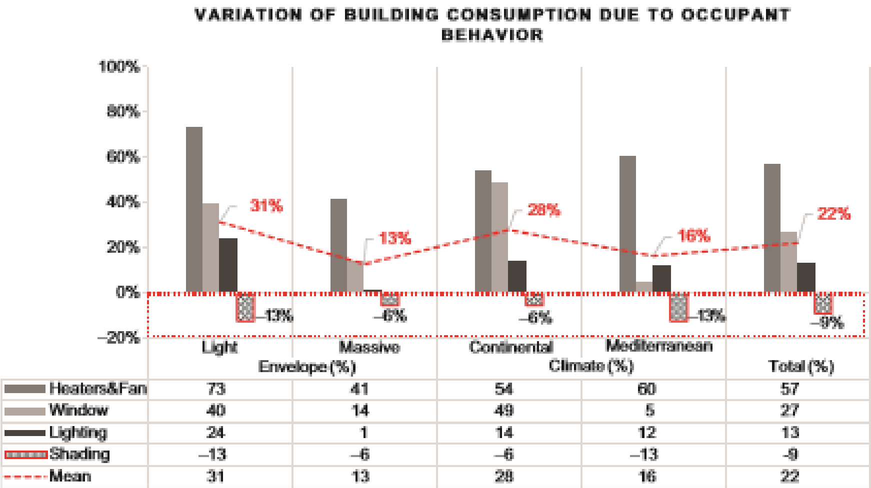
The percentages of the energy consumption reduction, due to a proper energy behaviour of users vary significantly, in dependence on the building use (residential offices, etc..) as stated in [27], where a comprensive review is carried out However, with regard to residential buildings, located in the Mediterranrean Area, in [27], is underlined how the highest variation in RB scenario, instead, corresponds to the behavioural patterns related to the heating/cooling set point and operation profiles of the systems for the low and high consumer setting. In detail, the results show that the high consumer scenario related to this pattern might lead to an increase of the building energy use by 22%.



	Light	Massive	Continental	Mediterranean	Total (%)
Heaters&Fan	73	41	54	60	57
Window	40	14	49	5	27
Lighting	24	1	14	12	13
Shading	−13	−6	−6	−13	-9
Mean	31	13	28	16	22

Figure 9-Variation of building consumption due to occupant behaviour.[21]

3.1.3 District effects

As previously said, the heat island effect affects significantly the urban microclimate. In order to mitigate this effect, several strategies have been presented. Santamouris M. [24] collects, analyzes and classifies existing knowledge regarding the energy impact of urban heating to buildings and calculates preliminary indicators. The variability of the heating and cooling loads of typical buildings is evaluated for the period 1970–2010. The main results of this statistical analysis are the following:

- In average the cooling load of typical urban buildings is by 13% higher compared to similar buildings in rural areas.
- The average increase of the cooling demand is 23% while the corresponding average reduction of the heating is 19%. In total, the average energy consumption of typical buildings for heating and cooling purposes increased by 11% for the same period

Details of all studies and the main results are given in Figure 10 and in Figure 11

Table 1
Characteristics of the heat island energy impact studies using urban and rural data.

No.	City, country	Intensity of the heat island (C)	Characteristics of the used climatic data	Type of energy studies performed	Main results
1	Athens, Greece	Average maximum: 6–8 K	Data of 30 urban and sub urban stations for the summer of 2006	Dynamic simulation of the heating and cooling load of a typical office building	– Increase of the cooling load by 120% in the center of the city compared to the reference zone. – Decrease of the heating load in the center by 38% compared to the reference zone – Increase of the peak electricity demand for cooling in the center by 100% compared to the reference zone – Decrease of the minimum COP of air conditioners for by 25%
2	Western Athens, Greece	For the selected stations the average maximum heat island intensity varied between 4 and 8 K for 1997 and between 3 and 5 K for 1998	Data for 1997 and 1998 of 4 stations in Western Athens, plus two reference stations	Dynamic simulation of the cooling load of a residential building with four apartments	– For 1997, the cooling load in Western Athens for a set point temperature of 26 °C was 41 kWh/m²/y, about 67% higher than in the reference station. For 1998, the load has increased in both areas and it was almost 29% higher in western Athens (45.4 kWh/m²/y) than in the reference station – The peak electricity demand for cooling it was 30.6 W/m² in Western Athens for 1997, almost 100% higher than in the reference zone. For 1998, the peak demand has increased to 38 W/m², almost 30% higher than in the reference
3	Volos, Greece	Average: 3.4 K during winter nights and 3.1 K during summer nights	Data of an urban and one suburban station	Dynamic simulation of a building	– Heating load: the heating load during the night period was 67.7 kWh/m²/y in the suburban area and 58.7 kWh/m²/y in the central part of the city, i.e. a reduction of 13% – The night cooling load was 2.1 kWh/m²/y in the center and 1.1 kWh/m²/y in the reference area
4	Rome, Italy	Maximum: 4.5 K	Data from five stations distributed in urban and suburban areas	Dynamic simulation of the cooling load of a typical apartment during the summer period (part of July and August)	The maximum increase of the cooling load in the urban areas was by 130% higher than in the reference station. The load in the urban zones varied between 18 and 24 kWh/m². While in the reference station it was close to 10 kWh/m²
5	London, UK	Average annual temperature difference: 2 K	Data from 24 different climatic stations in London	Dynamic simulation of the heating and cooling loads of a typical air conditioned office positioned at 24 different locations in London	The urban cooling load is up to 25% higher than the rural load over the year, and the annual heating load is reduced by 22%. In particular the lower cooling load was 23.6 kWh/m²/y and the highest 30.3 kWh/m²/y. The highest heating load was 11 kWh/m²/y and the minimum 9 kWh/m²/y
6	London, UK	Average annual temperature the difference is at 2 K	Data from 20 different weather stations in London	Dynamic simulation of the heating and cooling load of a typical office building with different energy conservation and construction patterns	– The cooling load increased from 27 to 45% between the rural and the urban areas depending on the considered characteristics. The cooling in the central area varied between 24 and 43 kWh/m²/y. – The heating load decreased by 64% in the central area compared to the rural one. The heating load in the central area was close to 13–14 kWh/m²/y.
7	Munich, Germany	For 1982, heating degree hours are by 17% higher in the city center than in an urban area	Data from an urban and a rural station	Simple estimation of the heating needs of a residential building	The heating load at the center of the city was 17% lower than the load in the rural area
8	Boston, USA	1.3–2.8 K	Data from one urban and two rural weather stations	Dynamic simulation of a small office and a single family building	For the small office the cooling load at the center was 20–37% higher than in the rural areas. The cooling load in the rural area was close to 5 kWh/m²/y. The corresponding heating load in the urban area was 38 kWh/m²/y and it was 2–10% lower than in the corresponding rural areas. For the single family house, the cooling load in the urban area was 3 kWh/m²/y and it was almost 3–9% higher than in the rural areas. The heating load in the urban area was 82 kWh/m²/y and it was 14% lower than in the rural areas

Figure 10 Characteristics of the energy heat islands energy impact studies using urban and rural data- first Part [24]

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Table 1 (*Continued*)

No.	City, country	Intensity of the heat island (C)	Characteristics of the used climatic data	Type of energy studies performed	Main results
9	State of New York, USA	Based on the mean temperature data it varies between 0 and 2 K	Data from surface as well as from the NNR[a] stations,	Calculation of the heating and cooling load of buildings using a parametrical model. Calculations are performed for both climatic data sets. The difference is the energy due to the UHI	Cooling load: the primary energy of a household not influenced by the UHI varied between 89 and 209 kWh/y. Because of the heat island it increased to 286–683 kWh/y, i.e. an increase close to 220%. Heating load: the primary energy for a household not influenced by the UHI varied between 10,908 and 33,151 kWh/y. Because of the heat island it decreased to 10,194–30,980 kWh/y, i.e., a decrease of about 7%. Total load: the UHI decreased the annual total primary energy spent for heating and cooling by 5%
10	State of California, USA	Based on the mean temperature data it varies between 0 and 4 K	Data from surface as well as from the NNR[a] stations	As above	Cooling load: the primary energy of a household not influenced by the UHI varied between 623 and 831 kWh/y. Because of the heat island it increased to 1994–2658 kWh/y, i.e. an increase close to 220%. Heating load: the primary energy for a household not influenced by the UHI varied between 4220 and 6618 kWh/y. Because of the heat island it decreased to 2721–4267 kWh/y, i.e., a decrease of about 55%. Total load: the UHI decreased the annual total primary energy spent for heating and cooling by 3–7%
11	State of Texas, USA	Based on the mean temperature data it varies between 0 and 1 K	Data from surface as well as from the NNR[a] stations	As above	Cooling load: the primary energy of a household not influenced by the UHI varied between 9167 and 17,157 kWh/y. Because of the heat island it increased to 9686–18022 kWh/y, i.e. an increase close to 6%. Heating load: the primary energy for a household not influenced by the UHI varied between 3111 and 5169 kWh/y. Because of the heat island it decreased to 2680–4453 kWh/y, i.e., a decrease of about 16%. Total load: the UHI decreased the annual total primary energy spent for heating and cooling by 1%
12	Melbourne, Australia	1.4 K mean annual difference	Data from one urban and one rural weather station	Calculation of the heating and cooling load of a typical existing and a new residential building	For the existing building the cooling load in the central areas was 8 kWh/m^2/y, 10% higher than in the rural area. For the new building, the cooling load in the central area was 5 kWh/m^2/y and was 17% higher than in the rural area. The heating load in the central area was 97 kWh/m^2/y and 24 kWh/m^2/y for the existing and the new building respectively and was 5% and 7% lower compared to the corresponding rural values
13	Bahrain	Average maximum heat island intensity close to 3 K	Climatic data from five weather stations around and in the city	Analysis of real energy consumption data from a quite high number of residential buildings	The average annual increase of the cooling load in the urban area was 18%. The minimum annual cooling in the less urban zone was close to 72 kWh/m^2/y

[a] NNR = (NCEP–NCAR (National Centers for Environmental Prediction/National Center of Atmospheric Research 50-year Reanalysis).

Figure 11- Characteristics of the energy heat islands energy impact studies using urban and rural data- Second part [24]

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In [23] Santamouris et al. collect, analyze and present in a comparative way existing studies investigating the impact of ambient temperature increase on electricity consumption.

- For each degree of temperature increase, the increase of the peak electricity load varies between 0.45% and 4.6%.
- The actual increase of the electricity demand per degree of temperature increase varies between 0.5% and 8.5%.

The Figure 12 and Figure 13 below summarize the existing literature with respect to the impact of ambient overheating on the peak electricity demand and electricity consumption.

Table 1
Findings of studies on the impact of ambient temperature increase on the peak electricity demand and the global electricity consumption.

No	City/country	Reference year	Additional load per K	Percentage increase of the base electricity load per degree of temperature increase	Threshold inflection temperature (°C)
Increase of the peak electricity power demand—impact of 1 K increase of the ambient temperature					
1	Tokyo Japan	2004	Peak additional demand of 180 MW/K	0.45%	22 °C
2	Thailand	2004	An 1 K temperature increase, rises the peak demand by 810 MW and 577 MW the average demand, at 2004 levels	4.6% the peak and 3.8% the average demand	Not reported
3	Ontario East Canada	1991–1995	Above 23 °C, the peak daily electricity demand increases by 233 MW/K	1.5%	23 °C
4	Los Angeles, USA	1986	Increase of the daily peak Electricity demand by 545 MW/K	3.3%	18.3 °C
5	Washington DC, USA	1986	Increase of the daily peak electricity demand by 181 MW/K or 3.6% of the basic peak load	3.6%	
6	Dallas TX, Fort Worth, USA	1986	Increase of the daily peak electricity demand by 454 MW/K	3.1%	13 °C
7	Colorado Springs, CO, USA	1986	Increase of the daily peak electricity demand by 7.3 MW/K	1.8%	13 °C
8	Phoenix, AZ, USA	1986	Increase of the daily peak electricity demand by 101 MW/K	3.6%	24 °C
9	Tuscon AZ, USA	1986	Increase of the daily peak electricity demand by 22 MW/K or 1.8% of the basic peak load	1.8%	21 °C
10	Israel	1987–1988	Increase of the daily peak electricity demand by 90 MW/K	2.9–3.1%	Not reported
11	Part of Carolina USA	1985–1991	Not reported	3.5–4%	18 °C
Increase of the electricity consumption—impact of 1 K increase of the ambient temperature					
1	Spain	1998	Daily additional electricity consumption of 8 GW h/K	1.6%	18 °C
2	Athens, Greece	1993–2001	Increase of the daily energy consumption of 1300 MW h/K,	4.1%	22 °C
3	New Orleans USA	1995	Increase of the daily average electrical load by 15 MW h/K	3%	22 °C
4	Hong Kong	2002	Monthly increase 111 GW h/K	4%	18 °C
5	Ohio, USA	1984–1993	Increase of the monthly consumption by 30 kW h/person/K	7.5%	16 °C
6	California San Hose, Sacramento Pomona and Fresno	2004–2005	Increase of the daily consumption by 18,500 MW h/K	2.9%	15 °C
7	Greece	1993–2002	Increase of the daily electricity consumption between 1.7 and 3 GW h/K	1.1 to 1.9%	18.5 °C
8	Chicago, USA	1993–2004	Increase of hourly load by 200 MW h/K	Not Reported	15–17 °C
9	California, USA	1984–1993	Increase of the monthly consumption by 27 kW h/K	7.7%	17 °C
10	Louisiana	1984–1993	Increase of the monthly consumption by 40 kW h/person/K	8.5%.	20 °C
11	Maryland, USA	1989–2001	Increase of the monthly electricity consumption by 22 kW h/p/K for the residential sector	8.5%	15.6 °C for residential and 11.7 °C for commercial
12	Massachusetts, USA	1977–2001	For residential buildings increase of the monthly electricity demand equal to 9 kW h/person/K For commercial buildings, increase of 12.7 kW h/person/K	Around 6.5% for the residential sector, and 3.0% for the commercial sector	15.5 °C for the residential sector and 12.8 °C for the commercial sector
13	Bangkok, Thailand	1986–2006	Increase of the average monthly electricity consumption by 56.7 GW h/K	7.49%	Not defined
14	Singapore	2003–2012	Data on the hourly electricity demand	1–2.5%	Varies during the day.
15	Netherlands	1970–2007	Data on the daily electricity consumption	0.5%	Variable and below 18 °C

Figure 12- Findings of studies on the impact of ambient temperature increase on the peak electricity demand side and the global electricity consumption Part I [23]

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Table 1 (*Continued*)

No	City/country	Reference year	Additional load per K	Percentage increase of the base electricity load per degree of temperature increase	Threshold inflection temperature (°C)
Increase of the electricity consumption—impact of 1% increase of the ambient temperature					
1	Mild Countries, Austria, Belgium, Denmark, France, Germany, Ireland, Luxembourg, Netherlands, New Zealand, Switzerland, Greece, Hungary, Italy, Japan, Korea, Portugal, South Africa, Spain, Turkey, United Kingdom, United States	1978–2000	Not reported	0.54%	Not reported
2	Hot Countries, Australia, India, Indonesia, Mexico, Thailand, Venezuela.	1978–2000	Increase of the annual electricity demand by 1.659%	1.7%	Not reported
3	Cold Countries Canada, Finland, Norway, Sweden	1978–2000	Decrease of the annual demand by 0.508%	0.51%	Not reported

Figure 13- Findings of studies on the impact of ambient temperature increase on the peak electricity demand side and the global electricity consumption Part II [23]

In [25] the mitigation of the heat island effect may be achieved by means of cool materials, because it is an efficient-low cost and easy to apply solution. Cool materials are characterized by high solar reflectance and infrared emittance values. When reflectance and/ or emittance are increased, the surface's temperature decreases and this contributes to the decrease in temperature of the ambient air as the heat convection intensity from a cooler surface is lower. Therefore, a material is classified as "cool", based on its ability to maintain lower surface temperatures. The study is focused on the evaluation of the potential impact on ambient temperatures of increasing the albedo of building rooftops at city scale. The study was carried out for the city of Athens, which is characterized by a strong energy island effect. The work allowed the significant impact of existing and newly developed cool coloured materials on the UHI mitigation to be shown. The simulations were performed for two different albedo scenario: a moderate and an extreme increase in albedo scenario. It was found hat the implementation of high albedo strategies decreases the heat island intensity by 1-2 °C on average. In [29] the results of a study aimed at measuring and analysing the solar spectral properties and the thermal performances of 5 color (offnawhite, yellow, beige, red and green) thin layer asphalt samples, in comparison to a sample of conventional black asphalt, are shown. All the samples demonstrated higher solar reflectance values and lower surface temperatures compared to conventional black asphalt. CFD simuations demonstrated that by replacing the conventional asphalt in a road, could allow for an average air temperature decrease of about 5 °C, under low wind speed condtions. Therefore, the results achieved demonstrated that when employing color thin layer asphalt in roads and pavements, a significant impact in lowering surface and air temperatures is yielded. This results in a

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mitigation of the heat islands and of its effects. A comprehensive review of the cool materials employed for buildings and urban structures is presented in [30]. The research is divided into four phases: development and assessment of:
- highly reflective and emissive light colored materials;
- cool colored materials;
- phase change materials;
- dynamic ccol materials;

Each technology is reviewed and the benefits and the impacts of these materials at building, city and global scale are described. It is shown how the wide employment of these materials can significantly reduce the heat island effect and improve the environmental air quality.
In [31], the application of 4500 $m^2$of reflective pavements to rehabilitate an urban park in the greater Athens area is considered. These materials were applied to improve thermal comfort conditions, to mitigate the UHI and to improve the airi quality. Computerized fluid dynamic techniques were used to simulate the specific climate conditionsin the area, before and after the installation of the new pavements. It was found that the extensive application of reflective pavements, under specific climate conditions may reduce the peak daily ambient temperature during a typical summer day up to 1.9 K while surface temperatures in the park were decreased by 12 K, while comfort conditions have been improved considerably.
Beyond the cool roofs strategy, also another technology to mitigate the UHI is available and it is represented by the use of vegetative green roofs [30]. As it may be found in [32], the green roof has a long history in architecture, for instance in cities and towns around the Mediterranean Sea, where is has been a commonplace for centuries to use rooftops as living and garden spaces (roof gardens), compensating for lost space on the ground. There are two main types of green roofs: extensive freen roof which are light and are covered by a thin layer of vegetation and intensive roofs, which are heavier and can support small trees and shrubs. Green roofs show different advantages like storm water runnaoff management, increased roof materials durability, decreased energy consumption, possible better air quality and noise reduction. Santamouris [30] presents the state of the art of both the above mentioned technologies, when applied at the city scale. The review, carried out on tenths of publications, shows that most of the available data are based on simulation studies, while important data are provided by the exixting expertimental studies. When considering a global increase in the city's albedo, the expected mean decrease of the average ambient temperature is close to 0.3 K per 0.1 rise of the albedo, while the corresponding average decrease of the peak ambient temperature is close to 0.9 K. When only cool roofs are taken ito account, the existing data shows that the expected depression rate of the average urban ambient temperature varies between 0.1 and 0.33 K, per 0.1 increase in the roof albedo with a mean value of 0.2 K. With regard to the green roofs, existing simulation studies show that, in case of their application on a city scale, the average ambient temperature can be reduced of a quantity ranging from 0.3 and 3 K.

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The advantages of using green roof infrastructes are also described in the framework of the holistic concept of green urbanism [33].

In [34], the design and the experimental evaluation of a large cale implementation of cool asphaltic and concrete pavements in a major traffic axis of Western Athens covering 37000 m^2 is described. Extended monitoring was performed in the area during the summer period, while CFD was used to evaluate the thermal impact of the application. It was concluded that the use of cool non-aged asphalt can reduce the ambient temperature by up to 1.5 °C and the maximum temperature reduction could reach 11.5 °C, while the thermal comfort conditions can improve considerably. Aging phenomena may reduce substantially and up to 50% the mitigation potential of cool asphaltic materials.

Finally, in [35], it can be read that, since most of the existing studies assess the impact of the high albedo pavements at the pedestrian's height and with respect to thermal comfort, differently, Tsoka et al examine the effect of the application of highly reflective pavements on the heating and cooling energy needs of a building unit, located inside a dense urban area. The application of cool materials on the ground surfaces only marginally affects the energy performance of the examined building unit, both for the design and the aged albedo value; changes on the annual heating and cooling energy demand, for both albedo scenarios did not exceed 1.5% revealing the limited potential of cool pavements regarding the improvement of the energy performance of urban building units.

4 IDENTIFICATION OF THE BEST AVAILABLE TECHNOLOGIES (BATS) FOR RENOVATION MEASURES

In this section, the BATs available for each component of the building are described in detail. The selection of the BATs was carried out on the basis of the literature investigated and summarized in the previous paragraph 2. The first assembly of the abacus of the renovation measures is herewith presented. The opaque and transparent components of the building envelope are split and analysed into different tables. The same procedure has been applied for technical systems. This is to provide a comprehensive framework of the BATs available, which will be shared with all the Partners in the Consortium.

4.1 – Building Components

4.1.1 Building Envelope

4.1.1.1 External Walls

With regard to the building, the first component to be examined is represented by the external walls. In order to reduce the building energy consumption, in particular to reduce the energy needed for heating and cooling, the insulation of the external/vertical walls has to be improved. Several alternatives are listed in Table 1

For each measure, labelled as "EW", the thickness of the insulating material, the thermal resistance and the cost of the materials and the installation are introduced. It is important to note that the tables listed in this section are the first version of the renovation measures list. Therefore, in this case, the costs for each measure are not reported. The evaluation of the thermal bridge is included in the tables. In the next paragraphs the costs as well as the thermo-physical properties of the materials selected and the main parameters for HVAC will be listed for all the renovation measures will be clarified and inserted and the thermal bridges considered apart from the walls and the windows, in a separate table, and also their evaluation. Moreover, different thickness values of the insulation materials are considered. This is because, depending on the building and its orientation, an optimum thickness of the material may be selected, as reported in [36], in order to have low costs and high thermal insulation. An example of this evaluation is reported in Figure 14 and it is carried out for EPS. Both walls with external insulation and internal insulation are considered. The installation of ventilated facades is also taken into account. The external insulation with high solar reflectance index coatings is also presented. Finally, the air chamber insulation with different materials is also listed.

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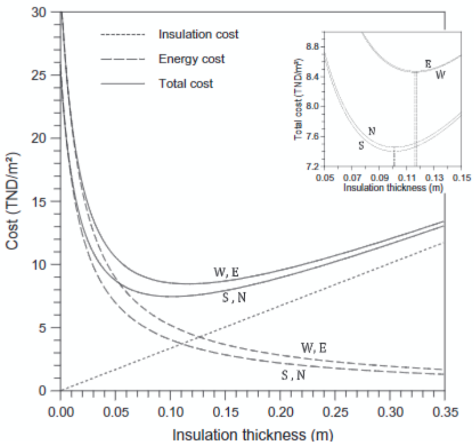

Figure 14 Insulation cost, energy cost and total cost versus insulation thickness for different wall orientations [34].

Different insulating materials are adopted, in particular, according to the classification reported in [21] among the organic materials the expanded polystyrene in (EPS) is one of the most common option employed. It is fairly resistant to water absorption and moisture damage; it is less expensive than other organic materials and it may be adjusted without loss of thermal resistance.

Another material considered is the mineral wool, which will be replaced by the rock wool, which is more widespread in all the partner countries and presents the same thermal performance as the mineral wool, also keeping its price low.

The presence of low emission coatings is also taken into account. Some measurement results in [37] show that "they will have a positive effect on the energy balance of a house especially for the renovation of older buildings with full brick walls which have a high heat capacity. Low emission exterior walls with an outer layer of styrofoam or rockwool insulation will not reach dew point temperatures as often as standard walls".

For the internal insulation another material employed is Aerogel. As it may be read in [33], "as an alternative to traditional thermal insulators, the market now offers innovative products in the form of panels, rolls, or loose granulates that exploit the latest advances of nanotechnology in the fields of materials science, and are thus able to provide high levels of thermal protection with very low thickness, allowing architectural quality to be combined with energy efficiency. These nanotechnological insulating products are made of aerogel (air þlus gel), a solid nanoporous material with ultra-low density obtained through the dehydration of a colloidal gel by replacing the liquid component with a gaseous one.

However, it is important to underline that internal insulation is taken into account to provide an alternative for the cases in which external insulation is not applicable as for example buildings under constrains. This is because moisture movement, especially in porous walls has to be taken into account when considering internal wall insulation. If not properly made, it can give rise to the formation of condensation and mold: the steam inside the rooms, migrating from the inside to the outside in the cold season, condense just behind the insulation, where it meets the cold masonry. Adding insulation to the inside of a solid wall reduces heat loss and has an effect on its natural ability to dry. When a wall is insulated internally it greatly reduces the heat loss from the inside of the house preventing natural drying. This prolonged wetting on the inside of the wall can lead to long term problems. Even natural insulating materials like wood fibre will start to degrade with prolonged dampness.

External walls insulation adding also coatings with high solar reflectance index is also investigated, because, as stated in [38], when exposed to solar radiation, the high solar reflectance and high thermal emittance of reflective materials keeps them at a lower temperature than conventional materials, leading to energy savings in air-conditioned buildings. “

Another solution for the external walls taken into account is represented by 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.

Finally, a solution which forsees the air chamber insulation is listed. Thermal insulation will be installed into the existing air chamber. The thickness of the thermal insulation will depend on the dimentions of the air chamber. Materials as perlite, vermiculite and cellulose are considered in this case.

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Code External Wall (EW)	Description	Typology	Insulation material	Thickness	Other (coating + thermal bridge)	Thermal conductivity [W/mK]	Thermal Rsistance [m2K/W]	Emissivity	SRI Solar Reflecytance Index
EW_0	No insulation	No insulation							
EW_1	External insulation with 4 cm of EPS and + thermal bridges correction	External insulation	EPS	4 cm	+ thermal bridges correction	0,036	1,1	-	-
EW_2	External insulation with 8 cm of EPS and + thermal bridges correction	External insulation	EPS	8 cm	+ thermal bridges correction	0,036	2,2	-	-
EW_3	External insulation with 12 cm of EPS and + thermal bridges correction	External insulation	EPS	12 cm	+ thermal bridges correction	0,036	3,3	-	-
EW_4	External insulation with 4 cm of MW and + thermal bridges correction	External insulation	MW	4 cm	+ thermal bridges correction	0,040	1,0	-	-
EW_5	External insulation with 8 cm of MW and + thermal bridges correction	External insulation	MW	8 cm	+ thermal bridges correction	0,040	2,0	-	-
EW_6	External insulation with 12 cm of MW and + thermal bridges correction	External insulation	MW	12 cm	+ thermal bridges correction	0,040	3,0	-	-
EW_7	External insulation with 4 cm of WF and + thermal bridges	External insulation	WF	4 cm	+ thermal bridges	0,038	1,1	-	-

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	correction				correction				
EW_8	External insulation with 8 cm of WF and + thermal bridges correction	External insulation	WF	8 cm	+ thermal bridges correction	0,038	2,1	-	-
EW_9	External insulation with 12 cm of WF and + thermal bridges correction	External insulation	WF	12 cm	+ thermal bridges correction	0,038	3,2	-	-
EW_10	Internal insulation with 2 cm of MW and low emission coating + thermal bridges correction	Internal insulation	MW	2 cm	low emission coating + thermal bridges correction	0,040	1,0	0,51	0,87
EW_11	Internal insulation with 4 cm of MW and + thermal bridges correction	Internal insulation	MW	4 cm	+ thermal bridges correction	0,040	2,0	0,51	0,87
EW_12	Internal insulation with 4 cm of MW and low emission coating + thermal bridges correction	Internal insulation	MW	4 cm	low emission coating + thermal bridges correction	0,040	3,0	0,51	0,87
EW_13	Internal insulation with 2 cm of WF and low emission coating + thermal bridges correction	Internal insulation	WF	2 cm	low emission coating + thermal bridges correction	0,038	0,52	0,51	0,87
EW_14	Internal insulation with 4 cm of WF and + thermal bridges correction	Internal insulation	WF	4 cm	+ thermal bridges correction	0,038	1,1	0,51	0,87

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EW_15	Internal insulation with 4 cm of WF and low emission coating + thermal bridges correction	Internal insulation	WF	4 cm	low emission coating + thermal bridges correction	0,038	1,1	0,51	0,87
EW_16	Internal insulation with 2 cm of AEROGEL and + thermal bridges correction	Internal insulation	AEROGEL	2 cm	+ thermal bridges correction	0,014	1,4	-	-
EW_17	Internal insulation with 2 cm of AEROGEL and low emission coating + thermal bridges correction	Internal insulation	AEROGEL	2 cm	low emission coating + thermal bridges correction	0,014	1,4	0,51	0,87
EW_18	Ventilated Facade with 4 cm of EPS and + thermal bridges correction	Ventilated façade	EPS	4 cm	+ thermal bridges correction	-	-	-	-
EW_19	Ventilated Facade with 8 cm of EPS and + thermal bridges correction	Ventilated façade	EPS	8 cm	+ thermal bridges correction	-	-	-	-
EW_20	Ventilated Facade with 4 cm of MW and + thermal bridges correction	Ventilated façade	MW	4 cm	+ thermal bridges correction	-	-	-	-
EW_21	Ventilated Facade with 8 cm of MW and + thermal bridges correction	Ventilated façade	MW	8 cm	+ thermal bridges correction	-	-	-	-
EW_22	External insulation with 4 cm of EPS and high SRI coating	External insulation	EPS	4 cm	high SRI coating	0,036	1,1	0,51	0,87

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EW_23	External insulation with 8 cm of EPS and high SRI coating	External insulation	EPS	8 cm	high SRI coating	0,036	2,2	0,51	0,87
EW_24	External insulation with 12 cm of EPS and high SRI coating	External insulation	EPS	12 cm	high SRI coating	0,036	3,3	0,51	0,87
EW_25	External insulation with 4 cm of MW and high SRI coating	External insulation	MW	4 cm	high SRI coating	0,040	1,0	0,51	0,87
EW_26	External insulation with 8 cm of MW and high SRI coating	External insulation	MW	8 cm	high SRI coating	0,040	2,0	0,51	0,87
EW_27	External insulation with 12 cm of MW and high SRI coating	External insulation	MW	12 cm	high SRI coating	0,040	3,0	0,51	0,87
EW_28	External insulation with 4 cm of WF and high SRI coating	External insulation	WF	4 cm	high SRI coating	0,038	1,1	0,51	0,87
EW_29	External insulation with 8 cm of WF and high SRI coating	External insulation	WF	8 cm	high SRI coating	0,038	2,1	0,51	0,87
EW_30	External insulation with 12 cm of WF and high SRI coating	External insulation	WF	12 cm	high SRI coating	0,038	3,2	0,51	0,87
EW_31	Air Chamber Insulation with 6 cm of Expanded Perlite	Air Chamber Insulation	Expanded Perlite	6 cm		0,043	1,4	-	-
EW_32	Air Chamber Insulation with 12 cm of Expanded Perlite	Air Chamber Insulation	Expanded Perlite	12 cm	-	0,043	2,8	-	-
EW_33	Air Chamber Insulation with	Air Chamber Insulation	Vermiculite	6 cm	-	0,060	1	-	-

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	6 cm of Vermiculite								
EW_34	Air Chamber Insulation with 12 cm of Vermiculite	Air Chamber Insulation	Vermiculite	12 cm	-	0,060	1	-	-
EW_35	Air Chamber Insulation with 6 cm of Expanded Clay	Air Chamber Insulation	Expanded Clay	6 cm	-	0,160	0,38	-	-
EW_36	Air Chamber Insulation with 12 cm of Expanded Clay	Air Chamber Insulation	Expanded Clay	12 cm	-	0,160	0,75	-	-
EW_37	Air Chamber Insulation with 6 cm of Cellulose Insulation	Air Chamber Insulation	Cellulose Insulation	6 cm	-	0,039	1,5	-	-
EW_38	Air Chamber Insulation with 12 cm of Cellulose Insulation	Air Chamber Insulation	Cellulose Insulation	12 cm	-	0,039	3,08	-	-
EW_39	Air Chamber Insulation with 6 cm of Glass Wool	Air Chamber Insulation	Glass Wool	6 cm	-	0,034	176	-	-
EW_40	Air Chamber Insulation with 12 cm of Glass Wool	Air Chamber Insulation	Glass Wool	12 cm	-	0,034	3,52	-	-
EW_41	Air Chamber Insulation with 6 cm of Mineral wool	Air Chamber Insulation	Mineral wool	6 cm	-	0,040	1,5	-	-
EW_42	Air Chamber Insulation with 12 cm of Mineral wool	Air Chamber Insulation	Mineral wool	12 cm	-	0,040	3,0	-	-

Table 1 Renovatione Measures External Walls

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4.1.1.2 Roof and Ceiling

When considering the roof and ceiling, the two main configurations of tilted roof ("TR") and flat roof ("FR") are taken into account. The costs of each renovation measure will be reported in the next section according to [39]. With regard to the tilted roof, different alternatives based on organic insulating material like XPS are listed. PU foam is also considered. The possibility of ventilated tilted roof with external insulation is also taken into account. When considering the case of bent tiles, it may underlined that "a remarkable advantage of clay tiles roof coverings in hot climates is the realization of a ventilated air layer between them and the roofing underlay that allows a natural and forced convection through the tiles joints and the channel from eaves to ridge, thus cooling the roof materials" [40]

Internal insulation with different materials like perlite and aerogel is also described. For both the configurations of tilted roof and flat roof, coatings with high reflectance index are considered". Reflective materials are tipically a low-cost investment.

In fact, as it may be read in [21], "Reflective materials applied to buildings' roofs reflect the solar energy year round, which might be a disadvantage in the winter as they reflect desirable heat. Moreover, if roof is ventilated, "chimney effect" of increased ventilation can additionally lower the temperature of the internal roof layers.

This effect can increase the energy needed for heating. However, during winter the sun is much lower in the sky, the days are shorter, and the skies are often cloudier than in summer, limiting the amount of sunlight available to a roof" and then "the installation of reflective white materials is an energy-efficient retrofitting measure for building roofs. The energy cost savings one can realize from reflective roofs depends on many factors, including local climate, the amount of insulation in the roof, how the building is used, energy prices, and the type and efficiency of the heating and cooling systems.

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Code Roof and Ceiling (TR-FR)	Description	Typology	Insulation material	Thickness[cm]	Thermal conductivity [W/mK]	Thermal resistance [m2K/W]	Other	Emissivity	Solar Reflectance Index (external)
TR_0	No insulation	No insulation							
TR_1	EI _ 3 of XPS	EI	XPS	3	0,032	0,9	-	-	-
TR_2	EI _ 5 of XPS	EI	XPS	5	0,032	1,6	-	-	-
TR_3	EI _ 8 of XPS	EI	XPS	8	0,032	2,5	-	-	-
TR_4	EI _ 12 of XPS	EI	XPS	12	0,032	3,8	-	-	-
TR_6	EI _ 3 of PU Foam	EI	PU Foam	3	0,028	1,1	-	-	-
TR_7	EI _ 5 of PU Foam	EI	PU Foam	5	0,028	1,8	-	-	-
TR_8	EI _ 8 of PU Foam	EI	PU Foam	8	0,028	2,9	-	-	-
TR_9	EI _ 0,5+1,5+0,5 of PU_F_S with 2 layers of WW	EI	PU_F_S with 2 layers of WW	0,5+1,5+0,5	0,661	0,04	-	-	-
TR_10	EI _ 0,5+2,5+0,5 of PU_F_S with 2 layers of WW	EI	PU_F_S with 2 layers of WW	0,5+2,5+0,5	1,375	0,03	-	-	-
TR_11	EI _ 0,5+4+0,5 of PU_F_S with 2 layers of WW	EI	PU_F_S with 2 layers of WW	0,5+4+0,5	1,911	0,03	-	-	-
TR_12	EI _ 0,5+6,5+0,5 of PU_F_S with 2 layers of WW	EI	PU_F_S with 2 layers of WW	0,5+6,5+0,5	2,446	0,03	-	-	-
TR_13	EI _ 5 of Rockwool (RW)	EI	Rockwool (RW)	5	0,035	1,4	-	-	-
TR_14	EI _ 8 of Rockwool (RW)	EI	Rockwool (RW)	8	0,035	2,3	-	-	-
TR_15	VR (5 cm air gap)+ EI _ 5 of XPS Panels	VR (5 cm air gap)+ EI	XPS Panels	5	0,033	1,5	-	-	-
TR_16	VR (5 cm air gap)+ EI _ 8 of XPS Panels	VR (5 cm air gap)+ EI	XPS Panels	8	0,033	2,4	-	-	-

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TR_17	VR (5 cm air gap)+ EI _ 12 of XPS Panels	VR (5 cm air gap)+ EI	XPS Panels	12	0,033	3,6	-	-	-
TR_18	II _ 2 of RW	II	RW	2	0,035	0,6	-	-	-
TR_19	II _ 4 of RW and low emission coating	II	RW	4	0,035	1,1	low emission coating	0,51	-
TR_20	II _ 4 of RW and low emission coating	II	RW	4	0,035	1,1	low emission coating	0,51	-
TR_21	II _ 2 of AE	II	AE	2	0,014	1,4	-	-	-
TR_22	II _ 2 of AE and low emission coating	II	AE	2	0,014	1,4	low emission coating	0,51	-
FR_1	EI_ 3 of XPS	EI	XPS	3	0,034	0,9	-	-	-
FR_2	EI_ 5 of XPS	EI	XPS	5	0,034	1,5	-	-	-
FR_3	EI_ 8 of XPS	EI	XPS	8	0,034	2,4	-	-	-
FR_4	EI with 5 of GW	EI	GW	5	0,037	1,4	-	-	-
FR_5	EI with 8 of GW	EI	GW	8	0,037	2,2	-	-	-
FR_6	EI with 12 of GW	EI	GW	12	0,037	3,2	-	-	-
FR_7	II with 2 of Perlite and low emission coating	II	Perlite	2	0,043	0,5	low emission coating	0,51	-
FR_8	II with 4 of Perlite	II	Perlite	4	0,043	0,9			-
FR_9	II with 4 of Perlite and low emission coating	II	Perlite	4	0,043	0,9	low emission coating	0,51	-
FR_10	II with 2 of GW and low emission coating	II	GW	2	0,037	0,5	low emission coating	0,51	-
FR_11	II with 4 of GW	II	GW	4	0,037	1,1	-	-	-
FR_12	II with 4 of GW and low emission coating	II	GW	4	0,037	1,1	low emission coating	0,51	
FR_13	II with 2 of	II	AEROGEL	2	0,014	1,4			-

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	AEROGEL								
FR_14	II with 2 of AEROGEL and low emission coating	II	AEROGEL	2	0,014	1,4	low emission coating	0,51	-
FR_15	EI with 5 cm of XPS and high SRI coating	EI	XPS	5	0,032	1,6	high SRI coating	-	0,87
FR_16	EI with 8 cm of XPS and high SRI coating	EI	XPS	8	0,032	2,5	high SRI coating	-	0,87
FR_17	EI with 12 cm of XPS and high SRI coating	EI	XPS	12	0,032	3,8	high SRI coating	-	0,87
FR_21	EI with 5 cm of GW and high SRI coating	EI	GW	5	0,037	1,4	high SRI coating	-	0,87
FR_22	EI with 8 cm of GW and high SRI coating	EI	GW	8	0,037	2,2	high SRI coating	-	0,87
FR_23	EI with 12 cm of GW and high SRI coating	EI	GW	12	0,037	3,2	high SRI coating	-	0,87

Table 2- Renovation measures for roof and ceiling

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4.1.1.3 Basement

With regard to the basement, different alternatives, labelled as "B" are listed in

Code Basement (B)	Description	Typology	Insulation material	Thickness[cm]	Thermal conductivity [W/mK]	Thermal Resistance [m2K/W]
B_0	No insulation	No insulation				
B_1	I with 5 of LW-CB with EPS	Insulation	light-weighted cement based with with EPS	5	0,100	0,5
B_2	I with 5 of LW_d cement based with Expanded Perlite	Insulation	LW_d cement based with Expanded Perlite	5	0,088	0,6
B_3	I with 5 of light-weighted cement based with Vermiculite	Insulation	light-weighted cement based with Vermiculite	5	0,080	0,6
B_4	I with 5 of light-weighted cement based with Expanded Clay	Insulation	light-weighted cement based with Expanded Clay	5	0,090	0,6
B_5	I with 5 of light-weighted cement based with Expanded Glass	Insulation	light-weighted cement based with Expanded Glass	5	0,300	0,2
B_6	with 10 of light-weighted cement based with EPS	Insulation	light-weighted cement based with EPS	10	0,100	1,0
B_7	i with 10 of light-weighted cement based with Expanded Perlite	Insulation	light-weighted cement based with Expanded Perlite	10	0,088	1,1
B_8	Insulation with 10 of light-weighted cement based with Vermiculite	Insulation	light-weighted cement based with Vermiculite	10	0,080	1,3
B_9	Insulation with 10 of light-weighted cement based with Expanded Clay	Insulation	light-weighted cement based with Expanded Clay	10	0,090	1,1
B_10	Insulation with 10 of light-weighted cement based with Expanded Glass	Insulation	light-weighted cement based with Expanded Glass	10	0,300	0,3
B_11	Insulation with 15 of light-weighted cement based with EPS	Insulation	light-weighted cement based with EPS	15	0,100	1,5
B_12	Insulation with 15 of light-weighted cement based with Expanded Perlite	Insulation	light-weighted cement based with Expanded Perlite	15	0,088	1,7
B_13	Insulation with 15 of light-weighted cement based with Vermiculite	Insulation	light-weighted cement based with Vermiculite	15	0,080	1,9
B_14	Insulation with 15 of light-weighted cement based with Expanded Clay	Insulation	light-weighted cement based with Expanded Clay	15	0,090	1,7
B_15	Insulation with 15 of light-weighted cement based with Expanded Glass	Insulation	light-weighted cement based with Expanded Glass	15	0,300	0,5
B_16	Insulation with 2 of XPS or PU Panels	Insulation	XPS or PU Panels	2	0,028	0,71
B_17	Insulation with 4 of XPS or PU Panels	Insulation	XPS or PU Panels	4	0,028	1,43
B_18	Insulation with 6 of XPS or PU Panels	Insulation	XPS or PU Panels	6	0,028	2,14

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Table 3.

As it can be found in [41], "Basements can account for about 20 percent of a home's total heat loss. This is due to the large, uninsulated surface area both above and below grade level. Contrary to popular opinion, earth is a poor insulator. There is also a lot of air leakage through basement windows and penetrations (including cracks in these areas) and at the top of the foundation wall (sill area). Many basements have little or no insulation, so this means there is much potential for improvement. Insulating can often be tied in with other repairs or renovation work such as waterproofing, radon remediation or finishing the basement".

The alternatives listed are based on different thicknesses of lightweight cement with a variety of insulating materials as, EPS, expanded glass, perlite and vermiculite.

The advantages of the employment of the inorganic material expanded perlite in lightweight concrete are well known in the literature [42]. The expanded vermiculite is also taken into account because, as stated recently,[43], when replacing sand with expanded vermiculite, thermal resistance and thermal stability are provided.

Moreover, it is important to undeline that in the present analysis, for basement, generally in deep retrofit intervention, the existing pavement, screed and lightweight layer is demolished in order to improve it with more insulating materials self-standing of covered with screed and tiles/wood, etc. Therefore, only internal solutions are considered.

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Code Basement (B)	Description	Typology	Insulation material	Thickness[cm]	Thermal conductivity [W/mK]	Thermal Resistance [m2K/W]
B_0	No insulation	No insulation				
B_1	I with 5 of LW-CB with EPS	Insulation	light-weighted cement based with with EPS	5	0,100	0,5
B_2	I with 5 of LW_d cement based with Expanded Perlite	Insulation	LW_d cement based with Expanded Perlite	5	0,088	0,6
B_3	I with 5 of light-weighted cement based with Vermiculite	Insulation	light-weighted cement based with Vermiculite	5	0,080	0,6
B_4	I with 5 of light-weighted cement based with Expanded Clay	Insulation	light-weighted cement based with Expanded Clay	5	0,090	0,6
B_5	I with 5 of light-weighted cement based with Expanded Glass	Insulation	light-weighted cement based with Expanded Glass	5	0,300	0,2
B_6	with 10 of light-weighted cement based with EPS	Insulation	light-weighted cement based with EPS	10	0,100	1,0
B_7	i with 10 of light-weighted cement based with Expanded Perlite	Insulation	light-weighted cement based with Expanded Perlite	10	0,088	1,1
B_8	Insulation with 10 of light-weighted cement based with Vermiculite	Insulation	light-weighted cement based with Vermiculite	10	0,080	1,3
B_9	Insulation with 10 of light-weighted cement based with Expanded Clay	Insulation	light-weighted cement based with Expanded Clay	10	0,090	1,1
B_10	Insulation with 10 of light-weighted cement based with Expanded Glass	Insulation	light-weighted cement based with Expanded Glass	10	0,300	0,3
B_11	Insulation with 15 of light-weighted cement based with EPS	Insulation	light-weighted cement based with	15	0,100	1,5

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			EPS			
B_12	Insulation with 15 of light-weighted cement based with Expanded Perlite	Insulation	light-weighted cement based with Expanded Perlite	15	0,088	1,7
B_13	Insulation with 15 of light-weighted cement based with Vermiculite	Insulation	light-weighted cement based with Vermiculite	15	0,080	1,9
B_14	Insulation with 15 of light-weighted cement based with Expanded Clay	Insulation	light-weighted cement based with Expanded Clay	15	0,090	1,7
B_15	Insulation with 15 of light-weighted cement based with Expanded Glass	Insulation	light-weighted cement based with Expanded Glass	15	0,300	0,5
B_16	Insulation with 2 of XPS or PU Panels	Insulation	XPS or PU Panels	2	0,028	0,71
B_17	Insulation with 4 of XPS or PU Panels	Insulation	XPS or PU Panels	4	0,028	1,43
B_18	Insulation with 6 of XPS or PU Panels	Insulation	XPS or PU Panels	6	0,028	2,14

Table 3-Different renovation measures for basement

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4.1.1.4 Windows

With regard to the windows, each alternative is labelled with "W". As underlined in [15] windows play a key role in in sustainable buildings because of the impact associated to their material lifecycle and their contribution to the energy performance of a building through it service life.

As it is stated in [36], "the thermal insulation of transparent closures is a prerequisite in the pursuit of thermal comfort of interiors and the reduction of energy consumption in buildings Currently, over 40% of all windows in the European Union are still single glazed, with thermal transmittance Ug values higher than 5.5 W/m^2 K, causing high dispersion of energy and local discomfort due to the low temperature of the glass panes in winter.Another 40% are untreated double glazing with an air-filled cavity, with transmittance values lower than single glazing (3.3-2.7 W/m^2 K) but still higher than standards set by law today. According to the Lawrence Berkeley National Laboratory, energy lost through windows accounts for 4-5% of the total annual consumption of energy in the United States, at a cost of about $50 billion a year. To reduce heat loss through glazing, one can intervene in both conduction and irradiation heat transfer mechanisms".

In order to decrease the passage of heat, it is necessary to interpose an air gap between two glass panes (double glazing), to provide greater resistance to heat flow. Dividing the air cavity into two separate hollow spaces (triple glazing) interrupts convection and further reduces the transport of energy: verall, the majority of windows sold in the European Union are still double glazed.

When filling the cavity of the insulated glass unit with gases having lower conductivity than air (argon, xenon, krypton, for example), higher thermal peformances may be achieved.

In this case, although xenon and krypton present better thermal properties, the most used gas is argon, as it may be easily produced from the environmental air where it is contained in a proportion of about 1%.

Another alternative taken into account is represented by low-emissivity coatings, It deals with thin sheets which are surface coatings with a thickness of 0.01-1 mm can improve the physical properties of glass regarding radiation; depending on layer thickness and composition, energy transmission (ET) can be reflected or absorbed and emissivity reduced These may be employed especially if there is no sunscreen as shutters, blinds, shutters, blinds, awnings, shelters, more in general, anything that allows us to regulate how much light enters through the glass. If there are no shielding and the glass is to the west, south and east this type of glass may be used. Otherwise it could happen that light and heat enter the house and if fixtures and walls arewell insulated, the heat that enters no longer leaves and bad comfort conditions may be experienced. However, it has to be considered also that a selective insulating glass could keep almost unchanged the brightness but lower to 40% the heat that enters. Therefore, there also cases in which the use of this kind of glasses is not advisable, especially for example,

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when the glass is facing north. Putting selective glass will result in less free solar power in winter.

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Code Window (W)	Description	Typology	Insulation material	Cavity Thickness	Frame kind	Uw U-glass [W/m²K]	g value [-]	U frame[W/m²k]
W_0	No replacement	No replacement						
W_1	Double windows with 2 glasses with 1.6 cm of air interspace	Double windows with 2 glasses	air interspace	1.6 cm	ALUMINIUM	2,7	0,77	3,5
W_2	Double windows with 2 glasses window with low-ε with 1.6 cm of air interspace	Double windows with 2 glasses window with low-ε	air interspace	1.6 cm	ALUMINIUM	1,4	0,58	3,5
W_3	2 glasses window with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)	2 glasses window	argon interspace	1.6 cm	ALUMINIUM	2,6	0,77	3,5
W_4	2 glasses window with low-ε with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)	2 glasses window with low-ε	argon interspace	1.6 cm	ALUMINIUM	1,1	0,59	3,5
W_5	3 glasses window with 1.6 cm of argon interspace and ALUMINIUM	3 glasses window	argon interspace	1.6 cm	ALUMINIUM	0,6	0,53	3,5
W_6	3 glasses window medium-ε with 1.6 cm of argon interspace and ALUMINIUM	3 glasses window medium-ε	argon interspace	1.6 cm	ALUMINIUM	0,6	0,54	3,5
W_7	3 glasses window with low-ε with 1.6 cm of argon interspace and ALUMINIUM	3 glasses window with low-ε	argon interspace	1.6 cm	ALUMINIUM	0,6	0,26	3,5
W_8	Double windows with 2 glasses with 1.6 cm of air interspace	Double windows with 2 glasses	air interspace	1.6 cm	WOOD	2,7	0,77	1,43
W_9	Double windows with 2 glasses window with	Double	air	1.6 cm	WOOD	1,4	0,58	1,43

	low-ε with 1.6 cm of air interspace	windows with 2 glasses window with low-ε	interspace					
W_10	2 glasses window with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)	2 glasses window	argon interspace	1.6 cm	WOOD	2,6	0,77	1,43
W_11	2 glasses window with low-ε with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)	2 glasses window with low-ε	argon interspace	1.6 cm	WOOD	1,1	0,59	1,43
W_12	3 glasses window with 1.6 cm of argon interspace and WOOD	3 glasses window	argon interspace	1.6 cm	WOOD	0,6	0,53	1,43
W_13	3 glasses window with 1.6 cm of argon interspace and WOOD	3 glasses window	argon interspace	1.6 cm	WOOD	0,6	0,54	1,43
W_14	3 glasses window with low-ε with 1.6 cm of argon interspace and WOOD	3 glasses window with low-ε	argon interspace	1.6 cm	WOOD	0,6	0,26	1,43
W_15	Double windows with 2 glasses with 1.6 cm of air interspace	Double windows with 2 glasses	air interspace	1.6 cm	PVC	2,7	0,77	1,3
W_16	Double windows with 2 glasses window with low-ε with 1.6 cm of air interspace	Double windows with 2 glasses window with low-ε	air interspace	1.6 cm	PVC	1,4	0,58	1,3
W_17	2 glasses window with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)	2 glasses window	argon interspace	1.6 cm	PVC	2,6	0,77	1,3
W_18	2 glasses window with low-ε with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)	2 glasses window with low-ε	argon interspace	1.6 cm	PVC	1,1	0,59	1,3
W_19	3 glasses window with 1.6 cm of argon interspace and PVC	3 glasses window	argon interspace	1.6 cm	PVC	0,6	0,53	1,3
W_20	3 glasses window with 1.6 cm of argon interspace and PVC	3 glasses window	argon interspace	1.6 cm	PVC	0,6	0,54	1,3

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W_21	3 glasses window with low-ε with 1.6 cm of argon interspace and PVC	3 glasses window with low-ε	argon interspace	1.6 cm	PVC	0,6	0,26	1,3
W_22	3 glasses window with 1.8 cm of air interspace	3 glasses window	air interspace	1.8 cm	ALUMINIUM			
W_23	3 glasses window with 1.8 cm of air interspace	3 glasses window	air interspace	1.8 cm	ALUMINIUM			
W_24	3 glasses window with low-ε with 1.8 cm of air interspace	3 glasses window with low-ε	air interspace	1.8 cm	ALUMINIUM			
W_25	3 glasses window with 1.8 cm of air interspace	3 glasses window	air interspace	1.8 cm	WOOD			
W_26	3 glasses window with 1.8 cm of air interspace	3 glasses window	air interspace	1.8 cm	WOOD			
W_27	3 glasses window with low-ε with 1.8 cm of air interspace	3 glasses window with low-ε	air interspace	1.8 cm	WOOD			
W_28	3 glasses window with 1.8 cm of air interspace	3 glasses window	air interspace	1.8 cm	PVC			
W_29	3 glasses window with 1.8 cm of air interspace	3 glasses window	air interspace	1.8 cm	PVC			
W_30	3 glasses window with low-ε with 1.8 cm of air interspace	3 glasses window with low-ε	air interspace	1.8 cm	PVC			

Table 4- Different renovation measures for windows

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4.1.1.5 Shading

When considering the shading systems, only two alternatives are taken into account, which are the overhang horizontal and vertical. They are fixed shading devices. A screenshot taken by [44] represents the main features of both the systems. If the user of the results of the project could find a shading solution similar to the one contained in the optimal (as for example vegetation like deciduous trees), providing the same solar factor with a equal or lower cost, it could be considered also as part of the optimal package.

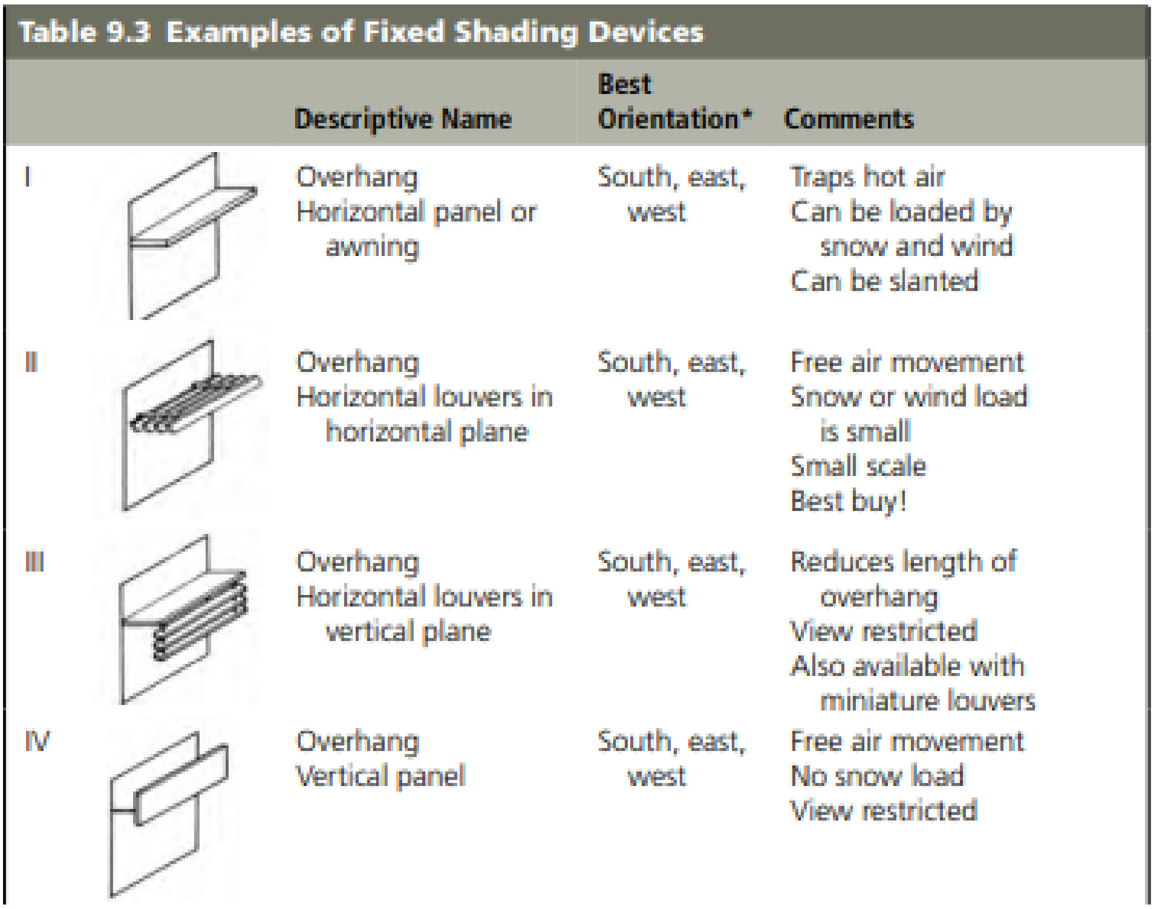

Table 9.3 Examples of Fixed Shading Devices

	Descriptive Name	Best Orientation*	Comments
I	Overhang Horizontal panel or awning	South, east, west	Traps hot air Can be loaded by snow and wind Can be slanted
II	Overhang Horizontal louvers in horizontal plane	South, east, west	Free air movement Snow or wind load is small Small scale Best buy!
III	Overhang Horizontal louvers in vertical plane	South, east, west	Reduces length of overhang View restricted Also available with miniature louvers
IV	Overhang Vertical panel	South, east, west	Free air movement No snow load View restricted

Figure 15- Screenshot describing the most widespread fixed shading devices[44]

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Code Shading (S)	Description	Typology	Solar factor / DeltaR
S_0	No replacement	No replacement	
S_1	Overhang - vertical 50	Overhang - vertical	
S_2	Overhang - horizontal 50	Overhang - horizontal	

Table 5- Shading Device

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4.1.2 Building Technical Systems

In this section the BATs for the building technical systems are described. Firstly, the heating and cooling systems are taken into account, then the ventilation and the Renewable Energy Sources are examined.

4.1.2.1 Heating and Cooling Systems

From a literature survey, some important details may be underlined. As referred in [45], "Almost half of the EU's buildings have individual boilers installed before 1992, with efficiency of 60% or less. 22% of individual gas boilers, 34% of direct electric heaters, 47% of oil boilers and 58% of coal boilers are older than their technical lifetime". Always in [45], there is an indication of the BATs employed for space heating in buildings and it is reported in Figure 16.

	Best Available Technology (BAT) class for space heaters (including packages)
A+++	Packages using renewables
A++	Heat pumps (renewable) Best biomass boiler (renewable)
A+	Gas cogeneration
A	Condensing gas boilers
B	
C	Non-condensing gas boilers
D	Electric resistance

Figure 16- Efficiency rating of new space heating appliances[43]

Moreover, diverse options for refurbishment of HVAC are available in the literature [45] herewith considered in Table 6.

When considering the replacement of traditional gas boilers, different options are available, whose diffusion and employment mostly depend on the Country and or Area examined. The first alternative is represented by the installation of condensing gas boilers. As written in [46], condensing gas boilers are considered one of the best available technology in the market because apart of its well establish state in the market they have only a minor possible efficiency improvements left.

With reference to Countries with increasing trend in RES electric energy production as for example Croatia, which has 45% of electric energy production coming from hydro power plants, the employment of electric boiler can be taken into account instead of the condensing gas boiler. In fact, in this case, the electric boilers can have same or greater control flexibility, are cheaper and more efficient than condensing gas boilers.

The gas boiler has been equipped with a modulating thermostat with an electronic optimizer (a CPU for better control strategy), a high efficiency (class "A") variable speed pump, an improved turndown ratio of 10 %, a standby loss reduced to 0.5 %, a high efficiency fan, a CPU

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with minimal standby power and application of a tertiary heat exchanger. These modifications allows us for reduction of the LCC (Life Cycle Cost) of about 30 % and a reduction of the energy consumption of about 16 % compared to a reference gas boiler. The condensing gas boiler is available for SFH and MFH (condominiums).
In addition to condensing gas boilers, the solar heating systems could be be applied for heating of domestic hot water alone or combined with space heating, as depicted in Figure 17. However, this is only an alternative. There are also other options to produce DHW and as for example, the heat recovery in heat pumps, when heat pumps are taken into account.

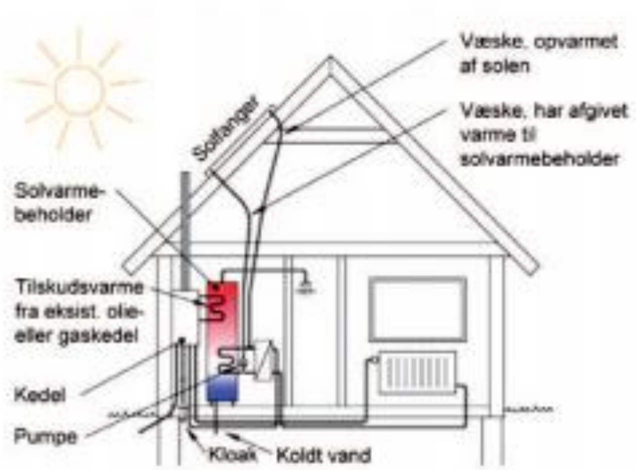

Figure 17- Example of solar thermal heating system [23]

As it can be read in [46], a large number of different design options exist. Collectors can be glazed or non-glazed, flat plate or an evacuated tube (vacu-type). The flow to the collector can be of low-flow type or with pumps providing a high flow. It is assumed that the solar system is supplementary to the primary heating system, because it is most common to have a solar fraction of less than 50 % of the DHW and space heating demand. In this framwork, the solar fraction fort he DHW is 50%. The performance is very dependent on especially the size of the solar collectors in relation to the energy consumption. This is seen as a decreasing output per m^2 of collector if the system size is increased for a specific house. The main advantage of this system ist that a CO_2 free energy source is employed.
Another configuration for heating is provided by the biomass boilers, which have the main advantage to use use a CO_2 neutral energy source.

Another kind of system examined is represented by the heat pumps.
A heat pump is a device used to transfer heat energy from one source of heat (air, ground or water) to another destination for several end energy uses (space heating, water heating, cooling). Mechanical heat pumps exploit the physical properties of a volatile evaporating and condensing fluid known as a refrigerant. The heat pump compresses the refrigerant to make it

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hotter on the side to be warmed, and releases the pressure on the side where heat is absorbed. Some devices are reversible. This kind of heat pump works in either thermal direction to provide heating or cooling to the internal space. It employs a reversing valve to reverse the flow of refrigerant from the compressor through the condenser and evaporation coils. Heat pump technologies can be aerothermal devices, which take energy from the ambient air (indoor or outdoor), geothermal (energy extracted from the ground) or hydrothermal (energy extracted from water - lake or subterranean water sources).
Different criteria may be employed to classify the heat pumps. Heat pumps may be distinguished by their cold source and the heat sink they use.
With reference to the cold source, the external medium from which heat is extracted is called a cold source. In the heat pump, the fluid refrigerator absorbs heat from the cold source through the evaporator.
The main cold sources are:
- The air: outside the room where the heat pump is installed or extracted from the room where the heat pump is installed;
- Water: groundwater, river water, lake water when this is present near the rooms to be heated and at a shallow depth.
- Ground: in which the pipes of the vaporator are placed.
With regard to the heat sink, it is represented by the air or water to be heated
In the condenser, the refrigerant transfers to the hot well both the heat drawn from the cold source and the energy supplied by the compressor.
The heat can be released to the environment through:
- Fan coils, consisting of cabinets in which air is circulated over heating elements;
- Serpentine inserted in the floor, in which hot water circulates;
- Ducts, which directly transfer the heat produced by the heat pump to the several venues.
Therefore, heat pumps can mainly be divided into:
Air-water heat pumps;
Air-Air heat pumps;
Water-water heat pumps;
Water- air heat pumps;
Ground-water heat pumps;

Air as a cold source has the advantage of being available everywhere; however, the power output of the heat pump decreases with the temperature of the source. If the outside air is used, a defrosting system is necessary (around 0°C), which leads to additional energy consumption.
The use of stale indoor air (air with a low temperature) as a cold source is different and more advantageous. The system must be renewed in any case.

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- Water as a cold source guarantees the performance of the heat pump without being affected by external climatic conditions; however, it requires an additional cost due to the supply system.
- The ground, as a cold source, has the advantage of undergoing fewer temperature changes than in the air. Horizontal pipes should be buried at a minimum depth of 1 to 1.5 meters to not be affected by the air-change temperature and to keep the benefits of the insulation Soil extension 2 to 3 times the surface area of the rooms to be heated is required. This is therefore an expensive solution, both for the necessary soil and for the complexity of the plant.

A ground source heat pump (GSHP) circulates a mixture of water and antifreeze around a loop of pipe, called a ground loop, which is buried in the earth. Heat from the ground is absorbed into the fluid and then passes through a heat exchanger inside the heat pump. The ground stays at a fairly constant temperature under the surface, so the heat pump can be used throughout the year whilst maintaining a stable efficiency. The length of the ground loop depends on the size of your home and the amount of heat you need. Longer loops can draw more heat from the ground, but require more space. If space is limited, a vertical borehole can be drilled instead although this carries a higher installation cost.

Efficient combined production of heating power and electricity is provided by the cogeneration option, and when referring to buildings, micro-cogeneration is taken into account. Another viable way for sustainable heating and cooling susyemts is represented by micro-trigeneration. As wiritten in [47], trigeneration systems use waste heat from prime movers to generate heating and cooling along with power. They are more efficient, less polluting & more economic than conventional systems. Small scale trigeneration power plants, typically, below 15 kWe, are called micro-trigeneration plants. In such systems, over 80% of fuel energy is converted to useable energy.

Another solution is represented by district heating. This alternative plays an important role, in the framework of a holistic renovation process. In fact, not only the building is involved, but also the district scale.

The district heating and cooling may be provided by several technologies, in particuar by RES, as depicted in [46], where motivations for their choice as BATs are provided. and reported in Figure 18.

Technology	Arguments for selection as BAT
District heating and cooling technologies	
Solar district heating	Renewable and CO_2 free energy source.
Seasonal storage	Supports a renewable and CO_2 free energy source (solar energy).
Electric boilers in district heating	Utilise superfluous electric energy for heating when the electric production is very high
Heat pump for district heating	Produce heat with a high energy efficiency
Waste for District heating	Uses waste for energy production, which is partly renewable, and has therefore reduced CO_2 emissions
Wood chips	Uses a CO_2 neutral energy source
Natural gas	Flexible, reliable and economical to use as backup capacity in district heating systems.
Geothermal	Nearly a CO_2 free energy source. Can be used in combination with heat pumps and as energy storage for solar energy
Combined heat and power	Produce energy with a high energy efficiency due to the combination of both heat and power.
District cooling	Can be more efficient than individual cooling systems. Can have a large efficiency when combined with district heating and absorption chillers

Figure 18- Motivations to choose district and cooling technologies as BATs [40]

4.1.2.2 Domestic Hot Water (DHW)

With regard tot he DHW, it may be provided by the same sources listed above.
In this latter case, electrical energy is employed to heat water.

Code Heating and Cooling (HC)	Heating	Cooling	DHW	Energy carrier	RES converage of thermal needs[%]	Seasonal Performance (eta)	SCOP	SEER
HC_1	-	-	Electric boiler	Electricity	-		-	-
HC_2	-	-	Gas boiler	Natural gas	-			
HC_3	-	-	Heat pump	Electricity	-		-	-
HC_4	-	-	Solar thermal	RES	-			
HC_5	-	-	Solar thermal + Back-up boiler	RES + Electricity	-		-	-
HC_6	Installation of a oil boiler (90% efficiency)	-	Integrated with Heating	Oil	-	0,85	-	-
HC_7	Installation of a gas boiler (90% efficiency)	-	Integrated with Heating	Natural gas		0,90	-	-
HC_8	Installation of a condensing gas boiler - single dwelling	-	Integrated with Heating	Natural gas			-	-
HC_9	Installation of a condensing gas boiler - single dwelling + solar thermal	-	Integrated with Heating	Natural gas + RES	50%	1,05	-	-
HC_10	Installation of a condensing gas boiler - centralised system for condominium	-	Integrated with Heating	Natural gas		1,05	-	-
HC_11	Installation of a condensing gas boiler - centralised system for condominium + solar thermal	-	Integrated with Heating	Natural gas + RES	50%	1,05	-	-
HC_12	Biomass boiler	-	Integrated with Heating	Biomass	-	0,90	-	-
HC_13	Installation of an electric air-air or air-water HP	Installation of an electric air-air or air-water HP		Electricity		-	4,5	4
HC_14	Ground Source Heat Pump	GSHP - Ground Source Heat Pump-Vertical ground loop				-	4,5	4
HC_15	GSHP - Ground Source Heat Pump	GSHP - Ground Source Heat Pump- Horizontal ground loop	-	-		-	4,5	4

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HC_16	Connection to District Heating						-	-
HC_17	MicroCHP - Gas turbine						-	-
HC_18	MicroCHP - Internal combustion engine						-	-
HC_19	Solar thermal + Absorption chiller	Solar thermal + Absorption chiller					-	-
HC_20	Microtrigeneration with internal combustion engine	Microtrigeneration with internal combustion engine + Absorption chiller					-	-
HC_21	District heating						-	-

Table 6- Heating and Cooling Systems renovation measures

Code (Domestic Hot Water) DHW	Description	Energy vector	Efficiency
DHW_0	Integrated with Heating		
DHW_1	Electric boiler		efficiency=99%
DHW_2	Gas boiler with high efficiency		
DHW_3	Solar thermal		
DHW_4	air-to-water Electric Heat pump		
DHW_5	GSHP		

Table 7 – Domestic Hot Water renovation measures

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4.1.2.3 Ventilation and airtightness

When considering the ventilation, controlled mechanical ventilation is taken into account with heat recovery, when applicable and the free night ventilationis also added.
A solution considered is the free night ventilation which lowers the room temperature in order to improve the thermal comfort by introducing outdoor air and increasing the renovation rate of the indoor air with cooler air. This measure could be implemented either by opening the windows or by using an exhaust fan. It is important to underline that this system is not mandatory linked with the HVAC system.The efficiency of the free night cooling depends on heat storage capacity of the building and on the heat gains. The night ventilation efficiency can be quantified by the thermodynamically cause (energy balance) and by its effect (room temperature).
For the air tightness, the Soudal window system (a Foam) is selected to ensure a correct installation of the window frame and the tightness of the window. The thermal and acoustic performance of this product must be certified together with a high elastic capacity. Thi system is also known as RAL system, used in Passiv House standard [48].
The low permeability to water vapour means that the humidity present in the materials can migrate outwards in search of the cold spot outside the joint. A sealant in the form of a self-expanding gasket with specific performance is applied to the outside of the joint.
A stricter solution is represented by the Passive house criteria according to which" uncontrolled leakage through gaps must be smaller than 0.6 of the total house volume per hour during a pressure test at 50 Pascal (both pressurised and depressurised)" [49]. In this context, the airtightness is verified by means of the blower door test.

Code Ventilation (V)	**Ventilation**	**equivalent air flow (n air change/h - m3/h)**
V_1	Controlled VMC	0.42
V_2	Controlled with thermal exchange (Heat Recovery System)	0.6
V_3	Free night ventilation	10
Code	**Air tightness**	**n50**
A_1	Soudal window system [RAL system for airtightness]	3
A_3	Passive house level	0,5

Table 8-Ventilation renovation measures

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4.1.2.4 Renewable Energy Sources (RES)

The alternatives for the renewable energy sources employed are divided into two categories. The RES used to produce electric energy and the RES for thermal energy. The options are listed in Table 9.

Code Renewable energy sources	**RES electricity**
	Photovoltaic (costs per kWp - up to 20 kWp)
	Photovoltaic (costs per kWp - up to 50 kWp)
	Micro-cogenration
	Wind turbine (costs per kW)
Code	**RES thermal**
	Biomass (woodchips or pellets generators) (cost in kWt)
	Solar thermal (cost per m2)
	Geothermal (HP - cost per kWt)

Table 9- Renewable energy sources renovation measures

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5 OPTIMIZATION OF THE ABACUS OF THE RENOVATION MEASURES

In this paragraph, the optimization of the abacus is presented. Starting from the alternatives and the survey of the related BATs, described in the previous paragraph, a first fine tuning is described, in which all the costs for the alternatives are inserted and a better evaluation of the thermal bridges and HVAC systems is carried out. This first fine tuning of the abacus, described in the paragraph 5.1, has allowed template to be designed, which has been fullfilled by all the Partners in the Consortium, in order to provide an abacus, which is representative for all the Mediterranean Area. The outcomes of all the Partners contributions are described in the Paragraph 5.2. The evaluation of the prices for all the all the alternatives is also performed and the main results are depicted in Par. 5.3. At the end, the final optimization of the abacus, deriving from all the evaluations, is presented in Par.5.4.

5.1 – Building -Step 1-First optimization

Each component of the building envelope and also the technical systems is herewith firstly fine-tuned. Each table described in this paragraph, is a part of the Excel template, which was then sent to all the Partners, in order to have their feedback and to elaborate an abacus which is representative for all the Mediterranean Area from the technical point of view and for what concerns the prices of all the measures.

5.1.1 Building Envelope

5.1.1.1 External walls

With regard to the external walls, the alternatives considered were reduced, when comparing them with **Errore. L'origine riferimento non è stata trovata.**. This first optimization was performed in orfer to manage the calculation time and affects mainly the measures conceived for the external walls. to manage the calculation time The most widespread solutions, according to the investigated litersature and the market survey, were kept. Moreover, the term ETICs has been introduced. It intended as "kits" and regulated by ETAG standards, respectively 004 and 034. It is considered as a "renovation measures" and the prices were inserted according to the different cladding systems and different U-values. With regard to the cost assessment of each renovation measures, the price list of the Milano Municipality was taken into account, because it is the city representing one of the Pilot sites of the Project. An assumption on the literature basis [17] has been done. In particular, the theory is supported by the explanations which can be found in the literature [14] in which it can be read:
"Consistently with the real building practice, each work cost has been composed comprising all the additional charges that are necessary for the supply and installation of the completed intervention, including removal of old components and management of waste materials, work safety equipment, auxiliary temporary structures (e.g. construction site equipment, scaffolds

rental, etc.), overhead and profit for the construction company. For this scope, the detailed Milano Municipality building price-list for public works [10] has been adopted. With this regards, it should be noted that its prices are mainly taken as a reference for public tenders (involving large size works), allowing decreases during the offer phase of the competition (in some case also up to 20-25%). In that study, because of the private perspective, for taking in account, in first analysis, other owner's additional expenses (design, construction supervision, administrative procedures, etc., that usually correspond to at least the 10% of the work costs), the reduction of the prices was limited to the following specifications. In zone E (northern Italy), only for the MFH measures a 10% of reduction has been considered, while for the SFH ones the prices are maintained as they are, in order to consider the economies of scale (small size). In zone B (southern Italy), in order to consider the different (lower) costs of labor, an overall reduction of 10% has been assumed (that consequently corresponds to the 20% for the MFH and to the 10% for the SFH). These criteria have been applied only to the envelope renovation measures, the ones that are strictly affected by the economy of scale and by the share of labor".

In the present work, no reduction of the prices was adopted neither for MFH or for SFH. In the cost assessment herewith performed, there is no consideration of the scaffolds, whose costs are included in the price reduction.

When considering the thermal characteristics, the values deriving from market survey are used.

Moreover, the evaluation of thermal bridges is to performed in this section because a separate sheet is provided and described in the following subparagraphs.

A list of the abbreviations employed in this context is reported in Table 10.

Abbreviations	
Symbol	Meaning
AE	Aerogel
ETICS	External Thermal Insulating Composite System
EPS	Expanded Polystirene
GW	Glass Wool
IACI	Internal Air Chamber Insulation
II	Internal Insulation
PU	Polyurethan
RW	Rock Wool
SRI	Solar reflectance Index
VF	Ventilated Façade
XPS	Extruded Polystirene

Table 10- Abbreviation used for the renovation measures regarding the external walls

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Code Externa Wall (EW)	Description	Typology	Insulation material	Thickness [cm]	Other (coating)	Therm conductivity [W/mK]	R [m2K/W]	emissivity	Solar Reflectance Index (external)	ITALY Cost [€/m2]: materials + installation
EW_0	No insulation	No insulation								
EW_1	E with 4 of EPS	E	EPS	4	-	0,036	1,1	-	-	€ 42,06
EW_2	E_8 of EPS	E	EPS	8	-	0,036	2,2	-	-	€ 46,02
EW_3	E_12 of EPS	E	EPS	12	-	0,036	3,3	-	-	€ 49,98
EW_4	E_4 of RW	E	RW	4	-	0,040	1,0	-	-	€ 47,27
EW_5	E_8 of RW	E	RW	8	-	0,040	2,0	-	-	€ 56,51
EW_6	E_12 of RW	E	RW	12	-	0,040	3,0	-	-	€ 65,75
EW_7	E_4 of GW	E	GW	4	-	0,034	1,2	-	-	€ 46,52
EW_8	E_8 of GW	E	GW	8	-	0,034	2,4	-	-	€ 52,72
EW_9	E_12 of GW	E	GW	12	-	0,034	3,5	-	-	€ 58,92
EW_10	E_4 of EPS and high SRI coating	E	EPS	4	high SRI coating	0,036	1,1	0,51	0,87	€ 72,45
EW_11	E_8 of EPS and high SRI coating	E	EPS	8	high SRI coating	0,036	2,2	0,51	0,87	€ 76,41
EW_12	E_12 of EPS and high SRI coating	E	EPS	12	high SRI coating	0,036	3,3	0,51	0,87	€ 80,37
EW_13	E_4 of RW and high SRI coating	E	RW	4	high SRI coating	0,040	1,0	0,51	0,87	€ 77,66
EW_14	E_8 of RW and high SRI coating	E	RW	8	high SRI coating	0,040	2,0	0,51	0,87	€ 68,42
EW_15	E_12 of RW and high SRI coating	E	RW	12	high SRI coating	0,040	3,0	0,51	0,87	€ 59,18
EW_16	E_4 of GW and high SRI coating	E	GW	4	high SRI coating	0,034		0,51	0,87	€ 76,91
EW_17	E_8 of GW and high SRI coating	E	GW	8	high SRI coating	0,034	2,4	0,51	0,87	€ 83,11
EW_18	E_12 of GW and high SRI coating	E	GW	12	high SRI coating	0,034	3,5	0,51	0,87	€ 89,31
EW_19	V F_4 of EPS	V F	EPS	4	-	0,036	1,1	-	-	€ 212,79

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EW_20	V F_8 of EPS	V F	EPS	8	-	0,036	2,2	-	-	€ 216,75
EW_21	V F_4 of RW	V F	RW	4	-	0,040	1,0	-	-	€ 218,00
EW_22	V F_8 of RW	V F	RW	8	-	0,040	2,0	-	-	€ 208,76
EW_23	IACI_3 of XPS	IACI	XPS	3	-	0,033	0,9	-	-	€ 8,80
EW_24	IACI_5 of XPS	IACI	XPS	5	-	0,033	1,5	-	-	€ 12,46
EW_25	IACI_3 of RW	IACI	RW	3	-	0,034	0,9	-	-	€ 6,27
EW_26	IACI_5 of RW	IACI	RW	5	-	0,034	1,5	-	-	€ 8,37
EW_27	IACI_3 of Expanded Perlite	IACI	Expanded Perlite	3	-	0,043	0,7	-	-	€ 9,36
EW_28	IACI_5 of Expanded Perlite	IACI	Expanded Perlite	5	-	0,043	1,2	-	-	€ 11,32
EW_29	II_2 of AE	II	AE	2	-	0,014	1,4	-	-	€ 83,00
EW_30	II_2 of AE and low emission coating	II	AE	2	low emission coating	0,014	1,4	-	-	€ 83,00

Table 11- First Fine tuning of the Abacus- External walls- Renovation Measures

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5.1.1.2 Roof and Ceiling

With regard to roof and ceiling solutions, only the prices and the thermal performances were inserted. All the details are included in Table 14. For the cost assessment, the Milano municipality price list is taken into account. Some abbreviations were introduced and presented in Table 12.

Abbreviations	
Symbol	Meaning
ETICS	External Thermal Insulating Composite System
EPS	Expanded Polystirene
GW	Glass Wool
PU	Polyurethan
RW	Rock Wool
SRI	Solar reflectance Index
XPS	Extruded Polystirene

Table 12- Abbreviations employed in the description of the renovation measures

5.1.1.3 Basement

Also in this case, the thermal performances and the costs were inserted in Table 15. For the cost assessment, the Milano municipality price list is taken into account, also in this case.

5.1.1.4 Windows

With regard to the windows, the thermal performaces and the costs were added and shown in Table 16. In this case, the thermal performance of the different kinds of the windows are established according to the literature [19]. The costs are established through a market survey.

5.1.1.5 Shading

In this case the values of the thermal parameters were added according to the document in [47].

5.1.1.6 Thermal bridges

In order to properly consider the thermal bridges and their correction, a dedicated sheet has been introduced in this fine-tuning phase. This is to ensure that they are properly considered during the renovation, in order to avoid the lock-in effects. The evaluation of thermal bridges listed in Table 18, has been carried out according to the International Standard ISO 14683, pp 17-37 Thermal bridges in building constructions – Linear thermal transmittance – Simplified methods and default values, in which a comprehensive description of the thermal bridges and their thermal performances may be found.

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5.1.1.7 Heating and Cooling Systems

In this section, an improvement of Table 6 is presented. Starting from the gas boiler, the size of the boiler is specified together with its efficiency. It is also underlined, for each solution, if DHW is provided. Moreover, the measures are targeted for both the SFH and MFH. Wall mounted and floor standing condensing gas boilers are taken into account. The cost assessment is performed mainly by taking into account the literature available. In particular, for the floor standing gas boiler with a size higher than 25 kW, the Emilia Romagna regional price list [51] is considered and an extrapolation was performed. Then, for what concerns the solution from HC 6 until HC 17 the prices were established by considering the literature values in [14], when neglecting the 20% or 10% reduction from price list. When considering the thermal performances of the different solutions, the efficiency is taken into account for boilers. For heat pumps, the SCOP and SEER are reported. When focusing on SEER, the SEER rating of a unit is the cooling output during a typical cooling-season divided by the total electric energy input during the same period. The higher the unit's SEER rating the more energy efficient it is. For biomass boilers, the prices are referred to kW installed. When considering the SCOP, it describes the average COP during a heating season. Depending on definition, the SCOP value could also include other parts of the heating system than the heat pump only.
The symbols used are listed in Table 13.

Abbreviations	
Symbol	Meaning
CHP	Combined Heat and Power
COP	Coefficient of Performance
HP	Heat Pump
GSHP	Ground Source heat Pump
SCOP	Seasonal Coefficient of Performance
SEER	Seasonal Energy Efficiency Ratio

Table 13- Abbreviations used for heating and cooling systems

5.1.1.8 Domestic Hot Water

The alternatives for the DHW, with the related prices are listed in Table 20.

5.1.1.9 Ventilation

The alternatives for ventilation are listed in Table 21. The technical performances have been added, but, unfortunately, no suitable price was available for these solutions.

5.1.1.10 Renewable Energy Sources

When considering the RES available, the RES employed to produce electricity are based on photovoltaic solutions with different sizes, whose prices were taken by the price list of the Milan Municipality.

The RES devoted to produce thermal energy are biomass based boilers, solar thermal to cover 50% DHW and the geothermal heat pumps in different configurations. For this latter solution, also the soil efficiency is needed.

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Code Roof and ceiling (TR/FR)	Description	Typology	Insulation material	Thickness[cm]	Thermal conductivity [W/mK]	Thermal resistance [m²K/W]	Other	Emissivity	Solar Reflectance Index (external)	ITALY Cost (materials+Installation) [€/m²]
TR_0	No insulation	No insulation								
TR_1	EI _ 3 of XPS	EI	XPS	3	0,032	0,9		-	-	€ 9,39
TR_2	EI _ 5 of XPS	EI	XPS	5	0,032	1,6		-	-	€ 13,05
TR_3	EI _ 8 of XPS	EI	XPS	8	0,032	2,5		-	-	€ 18,54
TR_4	EI _ 12 of XPS	EI	XPS	12	0,032	3,8		-	-	€ 25,86
TR_6	EI _ 3 of PU Foam	EI	PU Foam	3	0,028	1,1		-	-	€ 8,96
TR_7	EI _ 5 of PU Foam	EI	PU Foam	5	0,028	1,8		-	-	€ 11,74
TR_8	EI _ 8 of PU Foam	EI	PU Foam	8	0,028	2,9		-	-	€ 15,91
TR_9	EI _ 0,5+1,5+0,5 of PU_F_S with 2 layers of WW	EI	PU_F_S with 2 layers of WW	0,5+1,5+0,5	0,661	0,04		-	-	€ 14,06
TR_10	EI _ 0,5+2,5+0,5 of PU_F_S with 2 layers of WW	EI	PU_F_S with 2 layers of WW	0,5+2,5+0,5	1,375	0,03		-	-	€ 16,63
TR_11	EI _ 0,5+4+0,5 of PU_F_S with 2 layers of WW	EI	PU_F_S with 2 layers of WW	0,5+4+0,5	1,911	0,03		-	-	€ 20,09
TR_12	EI _ 0,5+6,5+0,5 of PU_F_S with 2 layers of WW	EI	PU_F_S with 2 layers of WW	0,5+6,5+0,5	2,446	0,03		-	-	€ 26,11
TR_13	EI _ 5 of Rockwool (RW)	EI	Rockwool (RW)	5	0,035	1,4		-	-	€ 12,48
TR_14	EI _ 8 of Rockwool (RW)	EI	Rockwool (RW)	8	0,035	2,3		-	-	€ 17,52
TR_15	VR (5 cm air gap)+ EI _ 5 of XPS Panels	VR (5 cm air gap)+ EI	XPS Panels	5	0,033	1,5		-	-	€ 33,48
TR_16	VR (5 cm air gap)+ EI _ 8 of	VR (5 cm air gap)+ EI	XPS Panels	8	0,033	2,4		-	-	€ 39,54

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	XPS Panels									
TR_17	VR (5 cm air gap)+ EI _ 12 of XPS Panels	VR (5 cm air gap)+ EI	XPS Panels	12	0,033	3,6			-	€ 47,62
TR_18	II _ 2 of RW	II	RW	2	0,035	0,6			-	€ 10,80
TR_19	II _ 4 of RW and low emission coating	II	RW	4	0,035	1,1	low emission coating	0,51	-	€ 41,19
TR_20	II _ 4 of RW and low emission coating	II	RW	4	0,035	1,1	low emission coating	0,51	-	€ 41,19
TR_21	II _ 2 of AE	II	AE	2	0,014	1,4			-	€ 83,00
TR_22	II _ 2 of AE and low emission coating	II	AE	2	0,014	1,4	low emission coating	0,51	-	€ 83,00
FR_1	EI_ 3 of XPS	EI	XPS	3	0,034	0,9			-	€ 8,89
FR_2	EI_ 5 of XPS	EI	XPS	5	0,034	1,5			-	€ 12,47
FR_3	EI_ 8 of XPS	EI	XPS	8	0,034	2,4			-	€ 17,84
FR_4	EI with 5 of GW	EI	GW	5	0,037	1,4			-	€ 13,30
FR_5	EI with 8 of GW	EI	GW	8	0,037	2,2			-	€ 19,42
FR_6	EI with 12 of GW	EI	GW	12	0,037	3,2			-	€ 27,58
FR_7	II with 2 of Perlite and low emission coating	II	Perlite	2	0,043	0,5	low emission coating	0,51	-	€ 38,37
FR_8	II with 4 of Perlite	II	Perlite	4	0,043	0,9			-	€ 11,90
FR_9	II with 4 of Perlite and low emission coating	II	Perlite	4	0,043	0,9	low emission coating	0,51	-	€ 42,29
FR_10	II with 2 of GW and low emission coating	II	GW	2	0,037	0,5	low emission coating	0,51	-	€ 43,69
FR_11	II with 4 of GW	II	GW	4	0,037	1,1			-	€ 13,30
FR_12	II with 4 of GW	II	GW	4	0,037	1,1	low	0,51	-	€ 43,69

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	and low emission coating						emission coating			
FR_13	II with 2 of AEROGEL	II	AEROGEL	2	0,014	1,4			-	€ 83,00
FR_14	II with 2 of AEROGEL and low emission coating	II	AEROGEL	2	0,014	1,4	low emission coating	0,51	-	€ 83,00
FR_15	EI with 5 cm of XPS and high SRI coating	EI	XPS	5	0,032	1,6	high SRI coating	-	0,87	€ 43,44
FR_16	EI with 8 cm of XPS and high SRI coating	EI	XPS	8	0,032	2,5	high SRI coating	-	0,87	€ 48,93
FR_17	EI with 12 cm of XPS and high SRI coating	EI	XPS	12	0,032	3,8	high SRI coating	-	0,87	€ 56,25
FR_21	EI with 5 cm of GW and high SRI coating	EI	GW	5	0,037	1,4	high SRI coating	-	0,87	€ 43,69
FR_22	EI with 8 cm of GW and high SRI coating	EI	GW	8	0,037	2,2	high SRI coating	-	0,87	€ 111,79
FR_23	EI with 12 cm of GW and high SRI coating	EI	GW	12	0,037	3,2	high SRI coating	-	0,87	€ 138,92

Table 14-Renovation measures for roof and ceiling

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Code Basement (B)	Description	Typology	Insulation material	Thickness[cm]	Thermal conductivity [W/mK]	Thermal Resistance [m2K/W]	ITALY Costs [€/m2]
B_0	No insulation	No insulation					
B_1	I with 5 of LW-CB with EPS	I	light-weighted cement based with with EPS	5	0,100	0,5	€ 21,10
B_2	I with 5 of LW_d cement based with Expanded Perlite	I	LW_d cement based with Expanded Perlite	5	0,088	0,6	€ 20,10
B_3	I with 5 of light-weighted cement based with Vermiculite	I	light-weighted cement based with Vermiculite	5	0,080	0,6	€ 22,20
B_4	I with 5 of light-weighted cement based with Expanded Clay	I	light-weighted cement based with Expanded Clay	5	0,090	0,6	€ 20,10
B_5	I with 5 of light-weighted cement based with Expanded Glass	I	light-weighted cement based with Expanded Glass	5	0,300	0,2	€ 25,13
B_6	with 10 of light-weighted cement based with EPS		light-weighted cement based with EPS	10	0,100	1,0	€ 42,20
B_7	i with 10 of light-weighted cement based with Expanded Perlite	i	light-weighted cement based with Expanded Perlite	10	0,088	1,1	€ 40,20
B_8	Insulation with 10 of light-weighted cement based with Vermiculite	Insulation	light-weighted cement based with Vermiculite	10	0,080	1,3	€ 44,40
B_9	Insulation with 10 of light-weighted cement based with Expanded Clay	Insulation	light-weighted cement based with Expanded Clay	10	0,090	1,1	€ 40,20
B_10	Insulation with 10 of light-weighted cement based with Expanded Glass	Insulation	light-weighted cement based with Expanded Glass	10	0,300	0,3	€ 48,24
B_11	Insulation with 15 of light-weighted cement based with EPS	Insulation	light-weighted cement based with EPS	15	0,100	1,5	€ 63,30

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B_12	Insulation with 15 of light-weighted cement based with Expanded Perlite	Insulation	light-weighted cement based with Expanded Perlite	15	0,088	1,7	€ 60,30
B_13	Insulation with 15 of light-weighted cement based with Vermiculite	Insulation	light-weighted cement based with Vermiculite	15	0,080	1,9	€ 66,60
B_14	Insulation with 15 of light-weighted cement based with Expanded Clay	Insulation	light-weighted cement based with Expanded Clay	15	0,090	1,7	€ 60,30
B_15	Insulation with 15 of light-weighted cement based with Expanded Glass	Insulation	light-weighted cement based with Expanded Glass	15	0,300	0,5	€ 69,35
B_16	Insulation with 2 of XPS or PU Panels	Insulation	XPS or PU Panels	2	0,028	0,71	
B_17	Insulation with 4 of XPS or PU Panels	Insulation	XPS or PU Panels	4	0,028	1,43	
B_18	Insulation with 6 of XPS or PU Panels	Insulation	XPS or PU Panels	6	0,028	2,14	

Table 15- Renovation measures for Basement

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Code Windows (W)	Description	Typology	Insulation material	Cavity Thicknes s	Frame kind	U-glass[W/m2K]	g value [-]	Uframe [W/m^{2}k]	ITALY Cost [€/m2]: materials + replacement		
W_0	No replacement	No replacement								NOTE	Evaluate which kind of windows are necessar y to consider!
W_1	Double windows with 2 glasses with 1.6 cm of air interspace	Double windows with 2 glasses	air interspace	1.6 cm	ALUMINIUM	2,7	0,77	3,5			
W_2	Double windows with 2 glasses window with low-ε with 1.6 cm of air interspace	Double windows with 2 glasses window with low-ε	air interspace	1.6 cm	ALUMINIUM	1,4	0,58	3,5			
W_3	2 glasses window with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)	2 glasses window	argon interspace	1.6 cm	ALUMINIUM	2,6	0,77	3,5	€ 350,00		
W_4	2 glasses window with low-ε with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)	2 glasses window with low-ε	argon interspace	1.6 cm	ALUMINIUM	1,1	0,59	3,5	€ 450,00		
W_5	3 glasses window with 1.6 cm of argon interspace and ALUMINIUM	3 glasses window	argon interspace	1.6 cm	ALUMINIUM	0,6	0,53	3,5	€ 450,00		

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W_6	3 glasses window medium-ε with 1.6 cm of argon interspace and ALUMINIUM	3 glasses window medium-ε	argon interspace	1.6 cm	ALUMINIUM	0,6	0,54	3,5	€ 500,00		
W_7	3 glasses window with low-ε with 1.6 cm of argon interspace and ALUMINIUM	3 glasses window with low-ε	argon interspace	1.6 cm	ALUMINIUM	0,6	0,26	3,5	€ 530,00		
W_8	Double windows with 2 glasses with 1.6 cm of air interspace	Double windows with 2 glasses	air interspace	1.6 cm	WOOD	2,7	0,77	1,43			
W_9	Double windows with 2 glasses window with low-ε with 1.6 cm of air interspace	Double windows with 2 glasses window with low-ε	air interspace	1.6 cm	WOOD	1,4	0,58	1,43			
W_10	2 glasses window with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)	2 glasses window	argon interspace	1.6 cm	WOOD	2,6	0,77	1,43	€ 350,00		
W_11	2 glasses window with low-ε with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)	2 glasses window with low-ε	argon interspace	1.6 cm	WOOD	1,1	0,59	1,43	€ 450,00		
W_12	3 glasses window with 1.6 cm of argon interspace and WOOD	3 glasses window	argon interspace	1.6 cm	WOOD	0,6	0,53	1,43	€ 450,00		
W_13	3 glasses window with 1.6 cm of argon interspace and WOOD	3 glasses window	argon interspace	1.6 cm	WOOD	0,6	0,54	1,43	€ 500,00		
W_14	3 glasses window with low-ε with 1.6 cm of argon interspace and WOOD	3 glasses window with low-ε	argon interspace	1.6 cm	WOOD	0,6	0,26	1,43	€ 530,00		

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W_15	Double windows with 2 glasses with 1.6 cm of air interspace	Double windows with 2 glasses	air interspace	1.6 cm	PVC	2,7	0,77	1,3			
W_16	Double windows with 2 glasses window with low-ε with 1.6 cm of air interspace	Double windows with 2 glasses window with low-ε	air interspace	1.6 cm	PVC	1,4	0,58	1,3			
W_17	2 glasses window with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)	2 glasses window	argon interspace	1.6 cm	PVC	2,6	0,77	1,3	€ 350,00		
W_18	2 glasses window with low-ε with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)	2 glasses window with low-ε	argon interspace	1.6 cm	PVC	1,1	0,59	1,3	€ 450,00		
W_19	3 glasses window with 1.6 cm of argon interspace and PVC	3 glasses window	argon interspace	1.6 cm	PVC	0,6	0,53	1,3	€ 450,00		
W_20	3 glasses window with 1.6 cm of argon interspace and PVC	3 glasses window	argon interspace	1.6 cm	PVC	0,6	0,54	1,3	€ 500,00		
W_21	3 glasses window with low-ε with 1.6 cm of argon interspace and PVC	3 glasses window with low-ε	argon interspace	1.6 cm	PVC	0,6	0,26	1,3	€ 530,00		
W_22	3 glasses window with 1.8 cm of air interspace	3 glasses window	air interspace	1.8 cm	ALUMINIUM						
W_23	3 glasses window with 1.8 cm of air interspace	3 glasses window	air interspace	1.8 cm	ALUMINIUM						
W_24	3 glasses window with low-ε with 1.8 cm of air interspace	3 glasses window with low-ε	air interspace	1.8 cm	ALUMINIUM						
W_25	3 glasses window with 1.8 cm of air interspace	3 glasses window	air interspace	1.8 cm	WOOD						

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W_26	3 glasses window with 1.8 cm of air interspace	3 glasses window	air interspace	1.8 cm	WOOD						
W_27	3 glasses window with low-ε with 1.8 cm of air interspace	3 glasses window with low-ε	air interspace	1.8 cm	WOOD						
W_28	3 glasses window with 1.8 cm of air interspace	3 glasses window	air interspace	1.8 cm	PVC						
W_29	3 glasses window with low-ε with 1.8 cm of air interspace	3 glasses window with low-ε	air interspace	1.8 cm	PVC						

Table 16- Renovation measures for windows

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

Code Shading (S)	Description	Typology	Solar factor	ITALY Cost [€/m2]
S_0	No replacement	No replacement		
S_1	Overhang - vertical 50 0,29 and 70	Overhang – vertical	0,29	€ 50,00
S_2	Overhang - horizontal 50 0,29 and 70	Overhang – horizontal	0,29	€ 50,00

Table 17- Renovation Measures for Shading

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

Code Thermal Bridges (TB)	Typology	Thickness [cm]	Thermal Conductivity [W/mK]	Thermal Resistance [m²K/W]	Linear Thermal Trasmittance [W/mK]			ITALY Cost [€/m]
					Internal	External	Overall Internal	
TB_0	No replacement							
TB_1	Insulation of thermal bridges with panels made of PUR injected in the slabs to go from 1.01 to 0.6 for the Façade-Slabs TB	2	0,09	0,22	0,6			€ 13,78
TB_2	Insulation of thermal bridges with panels made of mineralized wood wool and bound with high-strength cement	3	0,09	0,33	0,25			€ 15,48
TB_3	Insulation of thermal bridges with application on kerbs, lintels, veils, pillars, etc. of polystyrene sheet strips extruded foam, rough surface without skin	3	0,033	0,91	0,35			€ 13,06
TB_4	Insulation of thermal bridges with application between windows and facades	5	0,035	1,43	0,05			€ 17,14
TB_5	Insulation of thermal bridges on vertical and horizontal structures in phase of the casting, realized with application on the formworks of panels in wood wool mineralized with high temperature magnesite;	3,5	0,094	0,37				€ 26,10
TB_6								
TB_7								
TB_8_Roofs_R5					0,6	0,8	0,8	
TB_9_Roofs_R9					0,15	-0,05	0,15	
TB_10_Roofs_R11					0,25	0,05	0,25	

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TB_11_Balconies_B3					1	0,9	0,9	
TB_12_Corners_C5					-0,15	0,05	-0,15	
TB_13_Corners_C1					0,15	-0,05	0,15	
TB_14_Corners_C7					-0,05	0,15	-0,05	
TB_15_Intermediate_Floors_IF1					0,1	0	0	
TB_16_Intermediate Floor_IF8					0,6	0,45	0,45	
TB_17_Internal Walls_IW1					0,1	0	0	
TB_18_Slab-on-ground floors_GF 5					0,75	0,6	0,75	
TB_19_Slab-on-groud floors_GF7					0,1	-0,05	0,1	
TB_20_Slab-on-ground floors_GF 13					0,8	0,6	0,8	
TB_21_Slab-on-groud floors_GF15					0,1	0,1	0,1	
TB_22_Pillars_P1					1,3	1,3	1,3	
TB_22_Pillars_P3					1,15	1,15	1,15	
TB23_Windows and openings_W1					0	0	0	
TB_24_Windows and openings_W6					0,1	0,1	0,1	
TB25_Windows and openings_W11					0	0	0	
TB_26_Windows and openings_W12					0,1	0,1	0,1	
TB27_Windows and openings_W15					0	0	0	
TB_28_Windows and openings_W18					0,2	0,2	0,2	

Table 18- Renovation Measures for Thermal bridges

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

Code Heating and Cooling (HC)	Description	Energy vector	Efficiency	SCOP	SEER	combined DHW?	ITALY Cost [€] - only for equipment procurement & installation	Cost [€]-	SFH-Single dwelling (costs calculated per single apartment)	MFH
HC_1	Wall-mounted gas boiler <= 25 kW NA without DHW	Natural gas	0,96	-	-	No	€ 1.500,00		x	
HC_2	Wall-Amounted gas boiler <= 25 kW	Natural gas	0,96	-	-	Yes	€ 1.700,00		x	
HC_3	Floor-standing gas boiler > 25 kW [INOX]	Natural gas	0,96	-	-	Yes	3.000 €			x
HC_4	Wall-mounted condensing gas boiler <= 25 kW NA without DHW	Natural gas	1,05	-	-	No	€ 2.300,00		x	
HC_5	Wall-mounted condensing gas boiler <= 25 kW	Natural gas	1,05	-	-	Yes	€ 2.500,00		x	
HC_6	Floor-standing condensing gas boiler <= 25 kW without DHW	Natural gas	1,05	-	-	No	€ 4.400,00		x	
HC_7	Floor-standing condensing gas boiler <= 25 kW	Natural gas	1,05	-	-	Yes	€ 4.500,00		x	
HC_8	Floor-standing condensing gas boiler: 100-150 kW	Natural gas	1,05	-	-	No	€ 16.500,00			x
HC_9	Floor-standing condensing gas boiler: 200-250 kW	Natural gas	1,05	-	-	No	€ 19.666,67	70000		x
HC_10	Installation of an electric air-air HP - multisplit <= 15 kW	Electricity	-	4.5	4	No	€ 14.100,00		x	
HC_11	Installation of an electric air-air HP multisplit <= 15 kW - only cooling	Electricity	-			No	€ 1.000,00		x	
HC_12	Installation of an electric air-water HP <= 15kW -without DHW	Electricity	-	4,5	4	No	€ 6.200,00		x	
HC_13	Installation of an electric air-water HP <= 25kW	Electricity	-	4,5	4	No	€ 7.000,00		x	
HC_14	Installation of an electric air-water HP 100-150kW	Electricity	-	4	3	No	€ 38.250,00			x
HC_15	Installation of an electric air-water HP - 200-250kW	Electricity	-	4	3	No	€ 52.222,22* The costs of the heat exchanger are not included			x

HC_16	GSHP - Ground Source Heat Pump -100-150-W	Electricity	-	4.29		No	€ 43.875,00			x
HC_17	GSHP N Ground Source Heat Pump NA 200-250kW	Electricity	-	4,33		No	€ 46.888,89			x
HC_18	Biomass boiler	Woodchips or pellets	0,876				250 €		x	
HC_19	Biomass boiler	Woodchips or pellets	0,92				250 €			x
HC_20	MicroCHP - Gas turbine	Gas	0,8							
HC_21	MicroCH P -Internal combustion engine	Natural gas/Diesel								
HC_22	District heating									
HC_23	Absorption chiller + Solar thermal	RES								
HC_24	Microtrigeneration with internal combustion engine + Absorption chiller	Natural gas/Diesel								

Table 19- Renovation Measures for HVAC

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

Code Domestic Hot Water (DHW)	Description	Energy vector	Efficiency	COP	ITALY Cost [€/UFR] - only for equipment procurement & installation	Cost [€/UFR] - for equipment + auxiliaries	SFH-Single dwelling (costs calculated per single apartment)	MFH
DHW_0	Combined with Heating						x	x
DHW_1	Electric boiler - SFH	Electricity	0,99		600 €		x	
DHW_2	Electric boilers [20 apartments]	Electricity	0,99		5.800 €			x
DHW_3	Gas boiler with high efficiency	Natural gas			2.100 €		x	
DHW_4	Gas boiler with high efficiency [20 apartments]	Natural gas			21.000 €			x
DHW_5	Solar thermal				800 €		x	x
DHW_6	air-to-water Electric Heat pump - SFH	Electricity	-	4,5	3.300 €		x	
DHW_7	air-to-water Electric Heat pump - MFH [20 apartments]	Electricity	-	4,5	28.000 €			x

Table 20- Renovation measures for DHW

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

Code Ventilation (V)	Ventilation	equivalent air flow (n air change/h - m3/h)	Costs [€]
V_1	Controlled VMC	0,42	
V_2	Controlled with thermal exchange (Heat Recovery System)	0,6	
V_3	Free Night ventilation	10	
Code	**Air tightness**	**n50**	
A_1	Soudal window system[-RAL system]	3	
A_2	Passive House level	0,5	

Table 21- Renovation measures for ventilation

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

Code Renewable Energy Sources (RES)	**RES electricity**	**Technical Characteristics**	**ITALY Cost [€/kW]: materials + installation**		
RES_E_1	Photovoltaic (costs per kWp - from 1 kW up to 7 kWp)	1-7 kWp	€ 3.100,00		
RES_E_2	Photovoltaic (costs per kWp - from 7 kW up to 20 kWp)	7-20 kWp	€ 2.700,00		
RES_E_3	Photovoltaic (costs per kWp - from 21 kW up to 50 kWp)	21-50 kWp	€ 2.250,00		
Code	**RES thermal**	**Technical Characteristics**	**Cost [€/xxx]: materials + installation**	**SFH or MFH**	**Notes**
RES_T_1	Biomass (woodchips or pellets generators) (cost in kWt)	efficiency 0,9	€ 5.000,00	SFH	
RES_T_2	Solar thermal (cost per m2)	% DHW covered (e.g. 50% Spain)	€ 800,00		
RES_T_3	Geothermal (HP - cost per kWt)_Ground-Water System	COP / EER 4,5 /5	€ 20.000,00	SFH	Power Needed 8 kW soil efficiency 40 W/mK
RES_T_4	Geothermal (HP - cost per kWt)_Ground-Water System	COP / EER 4,5 /5	€ 55.000,00	MFH	Power Needed 31 kW
RES_T_5	Geothermal (HP - cost per kWt)_Water-Water System	COP / EER 4 /5	€ 15.000,00	SFH	Power Needed 8 kW soil efficiency 40 W/mK
RES_T_6	Geothermal (HP - cost per kWt)_Water-Water System	COP / EER 4 /5	€ 35.000,00	MFH	Power Needed 31 kW

Table 22- Renovation measures for RES

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5.2 – Building Step 2 –Partner contributions

The tables elaborated in the previous paragraph, after completion were sent to all the Partners of the Consortium, in order to build an Abacus representative of the whole Mediterranean Area. The outcomes of the Partners contributions are presented and compared in this section. All the contributions are enclosed in the Appendix.

5.2.1 Building

5.2.1.1 External Walls

When considering all the Partners' contributions regarding the external walls, the main results are shown in Figure 23-Figure 25, whose codes for the renovation measures refer to Table 11.The highest number of measures are available for Italy, Spain, Greece, Croatia and Slovenia. Until the solution EW_18, all the costs are similar to each other and to the average values of all the countries. In particular, they are higher than the average for a quantity in order of magnitude of about 20 €/m^{2},, especiallay for the solutions ranging from EW_1 to EW_8, except for Croatia. The Croatian costs are lower than the average values. The maximum deviation from the average shown by all the countries is less than 20 €/m^{2}, whereas for the Croatian case, the costs are lower than the average for a quantity in order of magnitude of about 30€/m^{2} for all the measures, until the solution EW_18. For the ventilated façades, the costs for Cyprus and Greece were not available. The highest costs for the ventilated façades are those presented by Italy and Spain and they are in order of magnitude of 220€/ m^{2}. With regard to the IACI (Internal Air Chamber Insulation), identified for the solutions from the EW_23 to EW_28, not all the countries provided the costs for the solutions. In particular, the costs for Cyprus and Slovenia are not available. When the solutions from EW_23 to EW_26 are considered, the country with highest costs is Croatia with about 20€/m^{2}; Italy presents the lowest costs with about 10 €/m^{2}. For the measures EW_29-EW_30 concerning the internal insulation, only Italy and Croatia provided the costs for the solutions and they are very similar to each other, about 87€/m^{2}. Slovenia added two other solutions to the Abacus, which are ETICS with 14 RW and ETICS with 14 GW, but the costs can not be compared to the others, because these solutions were mentioned only by this Partner Country and for the other Partners no comparison is available.
A different evaluation has been carried out by France. They provided a separate evaluation. The insulating materials, used for the internal insulation of external walls, are shown in Figure 19.

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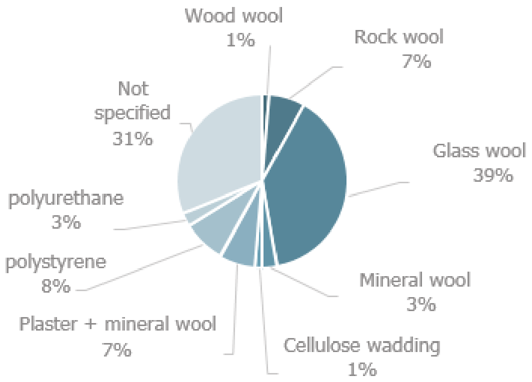

Figure 19-Distribution of materials employed for internal insulation in France

The cost of insulation (material + installation) varies a lot between the various renovations studied. This difference can be linked to several explanatory factors: taking into account the existing, choice of materials, thickness of insulation, etc.

The choice of material seems to have an impact since glass wool has an average cost of 68 € / m² isolated against 56 € / m² insulated polystyrene, and 57 € / m² for a gypsum board system associated with mineral wool.

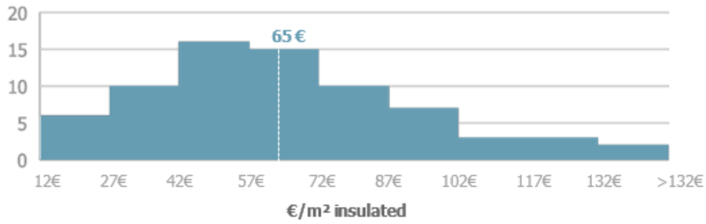

Figure 20- Distribution according to the costs

If the distribution of the operations is observed according to the cost of the insulation of the walls, a majority presents a cost close to the average, between 42 € and 72 € / m² insulated. However, this distribution also shows that the wide range of costs (between € 12 and € 139 / m² insulated) is not due only to a few atypical projects. This is a realistic range of costs faced by households. On the 74 invoices studied, only 4 show a dissociation between the cost of the material used and the cost of installation, the latter representing on average 6 € / m².

With regard tot he external insulation of walls, the distribution of the materilas employed is depicted in Figure 21.

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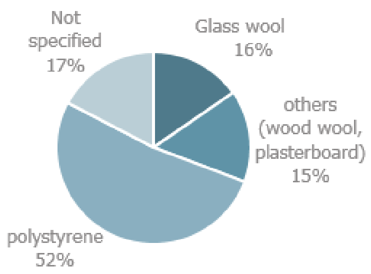

Figure 21- Insulating materials used

The average cost for external insulation is 91 €/m² insulated. Polystyrene is the most expensive material with 123 € / m² insulated on average (from € 30 to € 230). The combined polystyrene and glass wool system costs on average 104 € / m² insulated.

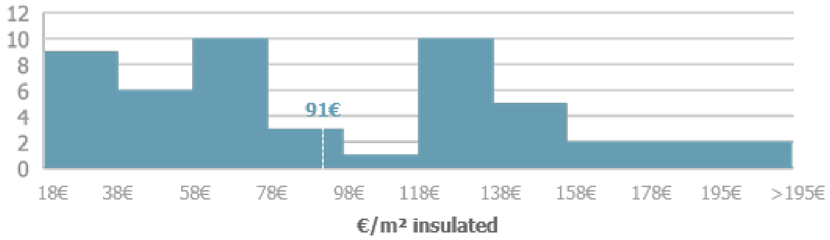

Figure 22-Distribution according to the cost

By observing the distribution of the insulation costs of the various projects, depicted in Figure 22, it can be seen that projects are recorded in all price bands (between 18 € and 230 € / m² isolated). One of the important factors of this scope is the choice of materials.

Of the 52 invoices studied, 7 show a dissociation between the cost of the material used and the cost of installation, the latter representing on average 26% of the total cost of the operation (19 € /m³].

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Legend

EW_1	E with 4 of EPS
EW_2	E_8 of EPS
EW_3	E_12 of EPS
EW_4	E_4 of RW
EW_5	E_8 of RW
EW_6	E_12 of RW
EW_7	E_4 of GW
EW_8	E_8 of GW

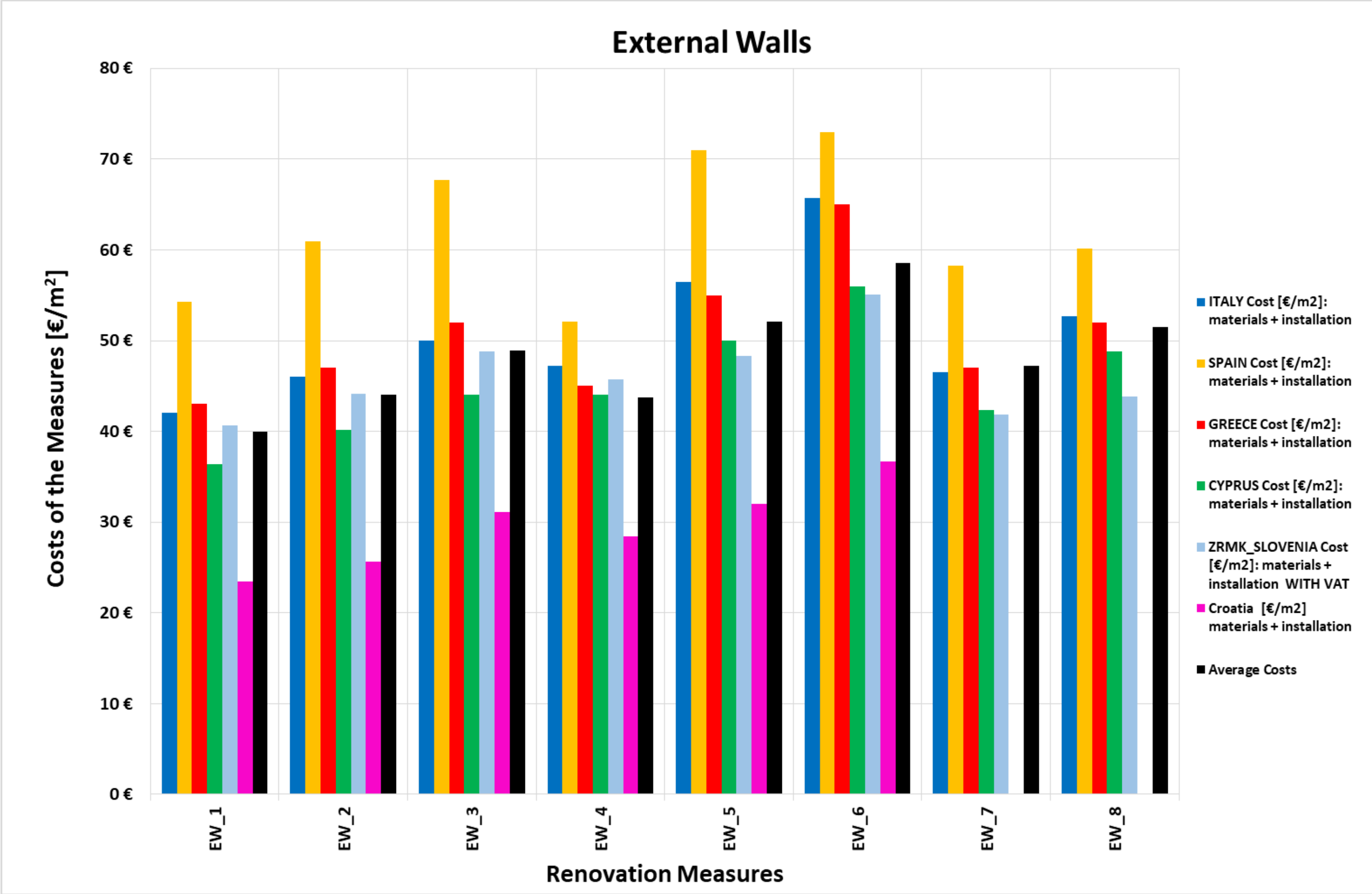

Figure 23- Renovation Measures for External Walls – The Partner Contributions

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

Legend

EW_9	E_12 of GW
EW_10	E_4 of EPS and high SRI coating
EW_11	E_8 of EPS and high SRI coating
EW_12	E_12 of EPS and high SRI coating
EW_13	E_4 of RW and high SRI coating
EW_14	E_8 of RW and high SRI coating
EW_15	E_12 of RW and high SRI coating
EW_16	E_4 of GW and high SRI coating
EW_17	E_8 of GW and high SRI coating
EW_18	E_12 of GW and high SRI coating
EW_19	V F_4 of EPS

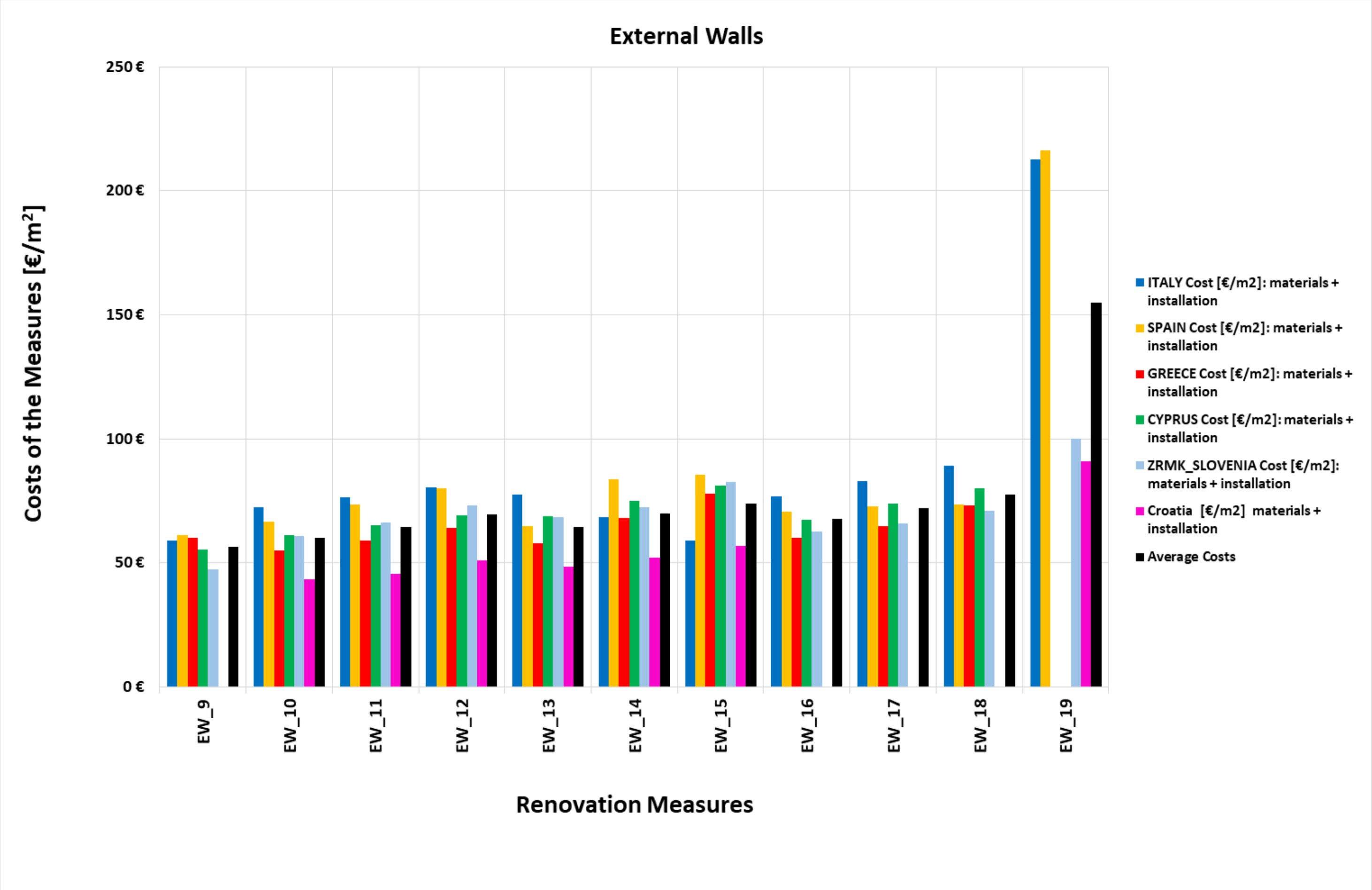

Figure 24- Renovation Measures for External Walls – The Partner Contribution

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

Legend

EW_20	V F_8 of EPS
EW_21	V F_4 of RW
EW_22	V F_8 of RW
EW_23	IACI_3 of XPS
EW_24	IACI_5 of XPS
EW_25	IACI_3 of RW
EW_26	IACI_5 of RW
EW_27	IACI_3 of Expanded Perlite
EW_28	IACI_5 of Expanded Perlite
EW_29	II_2 of AE
EW_30	II_2 of AE and low emission coating

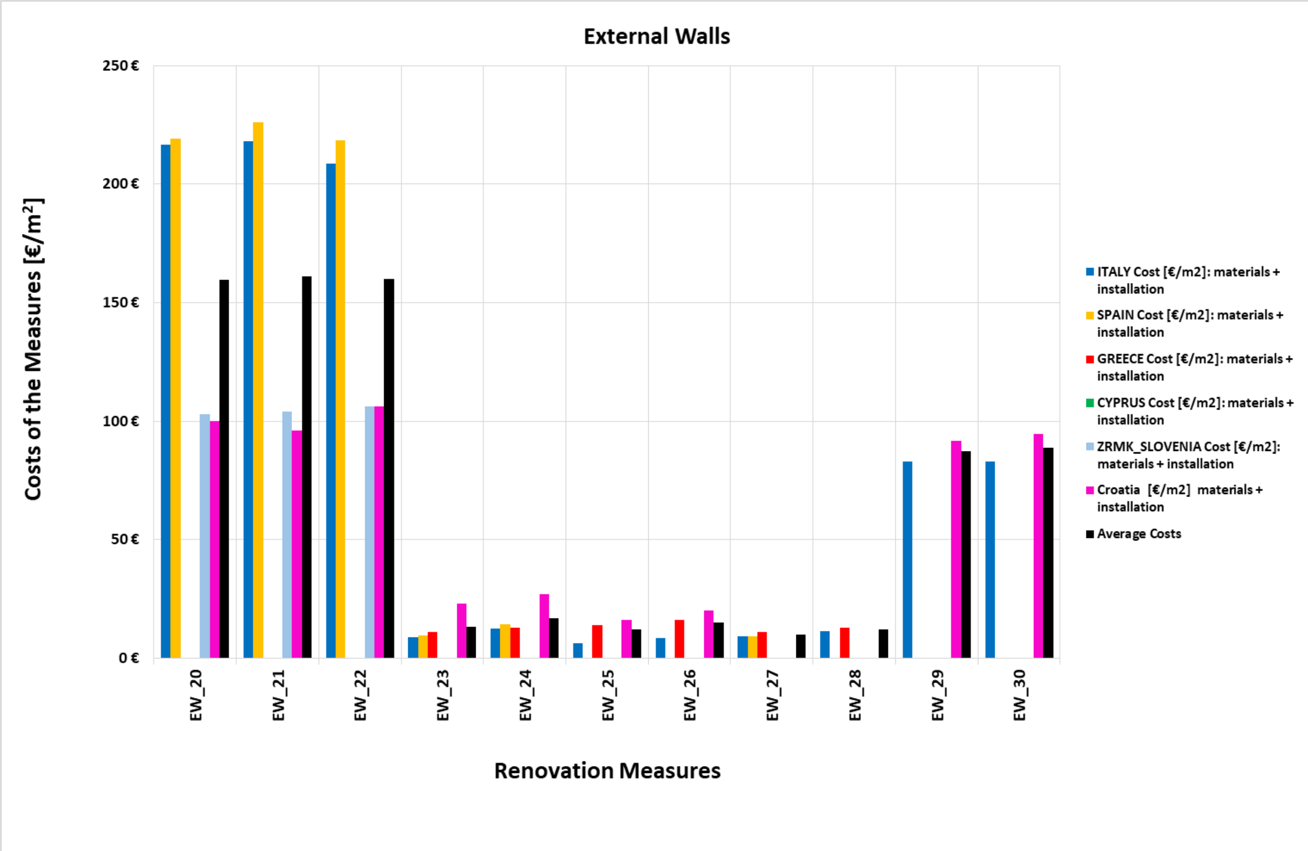

Figure 25- Renovation Measures for External Walls – The Partner Contribution

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5.2.1.2 Roof and Ceiling

The comparison of the results of the different contributions may be carried out by observing Figure 28-Figure 31. The codes of the renovation measures concern Table 14. The costs distribution for both the cases is not homogeneous. In particular, when considering the tilted roof renovation measures, the hghest costs are those available for the Croatian Partner. They provided a range of costs to be assingned to each renovation measure, referred to the BATs, therefore, the average value for the costs in the range provided was assumed for the calculation and for the comparison. For the solutions TR_1-T_7, the Croatian costs are higher than the average for a quanity in order of magnitude of about 20 €.

Conversely, for the same renovation measures, Italy and Spain presents the lowest costs, which are lower than the average values for a quantity of about 15€/m² for Italy and about 20 €/m² for Spain respectively. The solutions TR_8 until TR_11 are available only for Italy. From the TR_12 until the TR_22 the Croatian costs are the highest, followed mainly by Slovenia. Spain presents always the lowest costs for all the solutions. With regard to the renovation measures tailored for the flat roofs, the costs are available only for some partner Countries. The solutions FR_1, FR_2 and FR_3 are present in almost all the Countries, showing the highest costs for Croatia and Cyprus. The results for FR_4 and FR_5 were available only for Cyprus, Slovenia and Italy, which presents the lowest costs. For the solutions FR_7-FR_78, the lowest costs are those referred to Spain and they are in order of magnitude of 10€/m². With regard to the solution FR_11, the costs provided by Greece and Italy are similar (13 and 10€/m²). The solutions FR_12 until FR_16 are available only for Italy and Croatia, which has the highest costs. The solutions FR_17_FR_22 are available only for Italy.

Moreover, Slovenia added two other solutions, which are commonly installed, which are External insulation with 12 and 14 cm RW.

With regard to France, the insulating material used are shown in Figure 26.

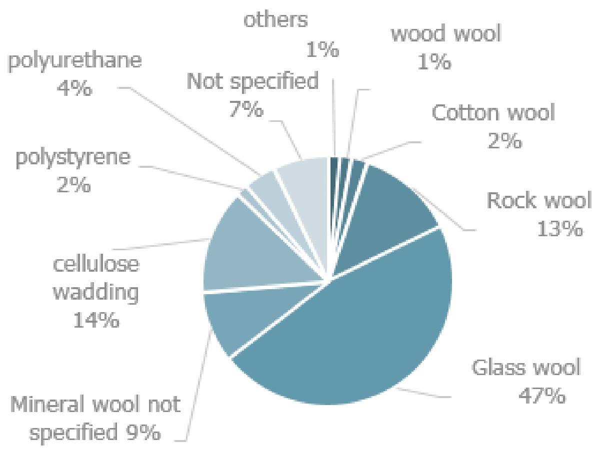

Figure 26- insulating materials used for Roof

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072
The average price observed for the insulation of a roof is 38 € / m² insulated. This average price varies according to the materials used: 33 € / m² insulated in glass wool and 29 € / m² isolated for cellulose wadding. In addition, the cost is lower in individual housing (35 € / m² insulated on average) than in collective (47 € / m² insulated on average).

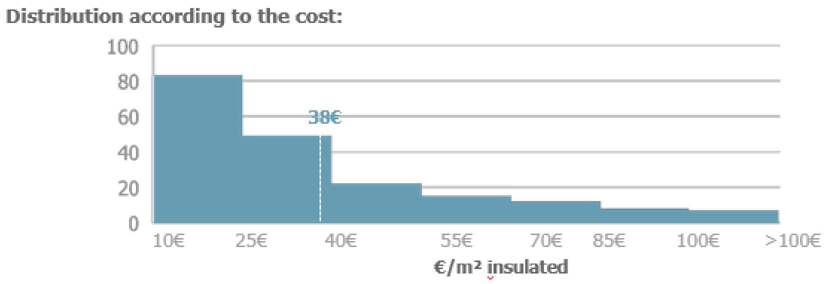

Figure 27- Distribution according to costs

If the distribution of housing is observed according to the cost of the post, a majority of housing is in the lower part, in the range of € 10 to € 40 / m² insulated. The dissociation between the installation and the material used is made in 20% of the invoices. The installation then represents on average 30% of the total amount of work (between 2 and 14 € / m²).
The removal of the old insulation is also invoiced in 8% of the files and corresponds for these files to 27% on average of the amount of work (8 € / m² insulated).

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Legend	
TR_1	EI _ 3 of XPS
TR_2	EI _ 5 of XPS
TR_3	EI _ 8 of XPS
TR_4	EI _ 12 of XPS
TR_6	EI _ 3 of PU Foam
TR_7	EI _ 5 of PU Foam
TR_8	EI _ 8 of PU Foam
TR_9	EI _ 0,5+1,5+0,5 of PU_F_S with 2 layers of WW
TR_10	EI _ 0,5+2,5+0,5 of PU_F_S with 2 layers of WW
TR_11	EI _ 0,5+4+0,5 of PU_F_S with 2 layers of WW

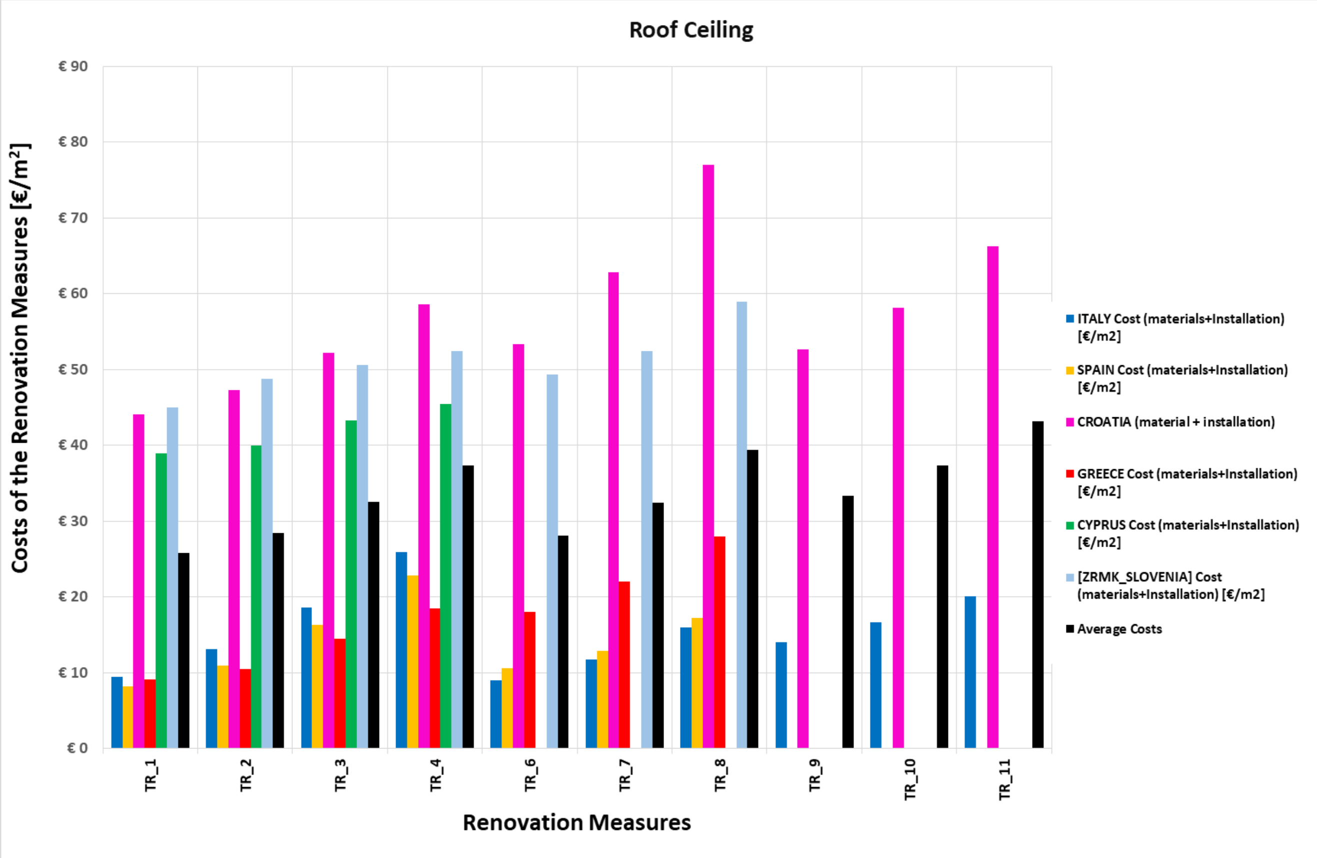

Figure 28-Costs of the renovation Measures- Tilted Roof - Partners Contribution

Legend	
TR_12	EI _ 0,5+6,5+0,5 of PU_F_S with 2 layers of WW
TR_13	EI _ 5 of Rockwool (RW)
TR_14	EI _ 8 of Rockwool (RW)
TR_15	VR (5 cm air gap)+ EI _ 5 of XPS Panels
TR_16	VR (5 cm air gap)+ EI _ 8 of XPS Panels
TR_17	VR (5 cm air gap)+ EI _ 12 of XPS Panels
TR_18	II _ 2 of RW
TR_19	II _ 4 of RW and low emission coating
TR_20	II _ 4 of RW and low emission coating
TR_21	II _ 2 of AE
TR_22	II _ 2 of AE and low emission coating

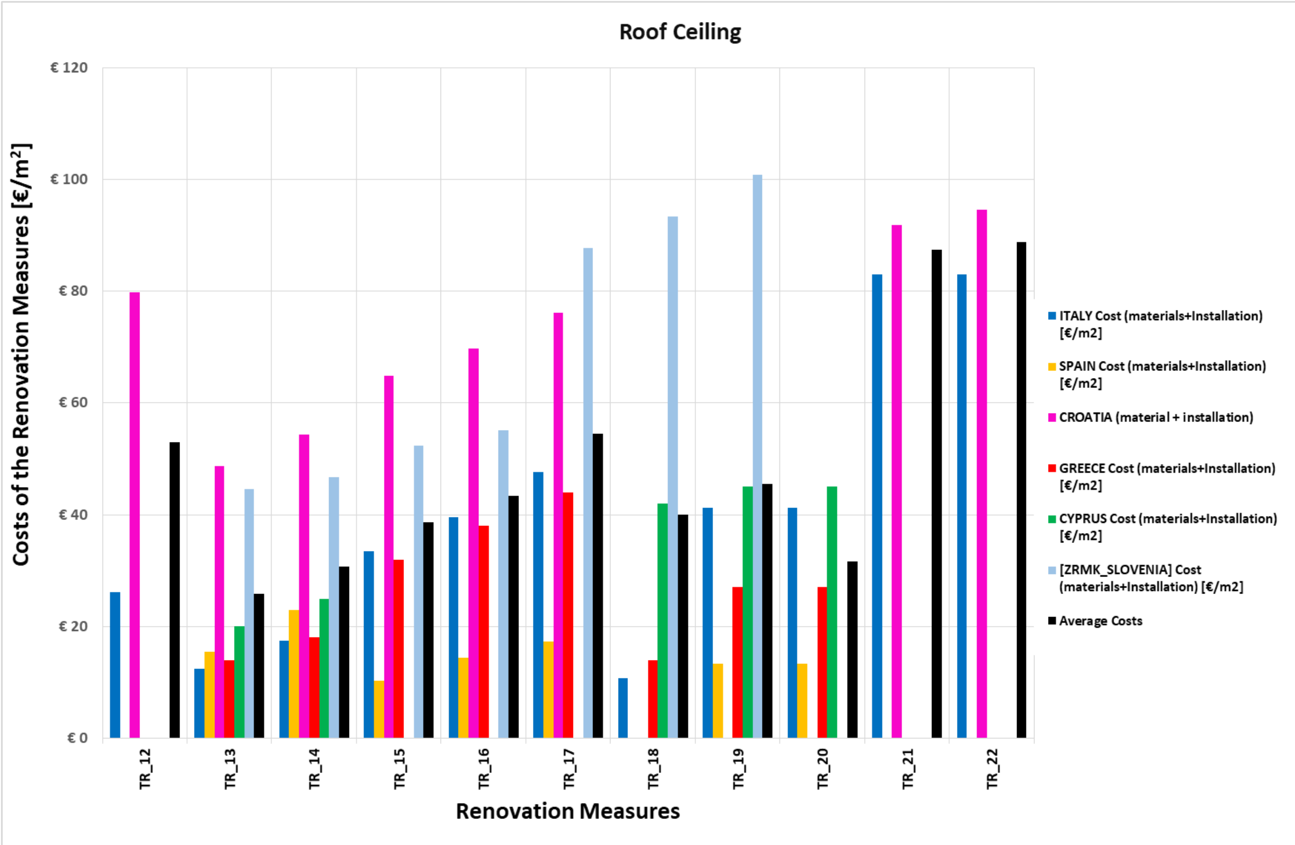

Figure 29 - Costs of the renovation Measures- Tilted Roof - Partners Contribution

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

Legend	
FR_1	EI_ 3 of XPS
FR_2	EI_ 5 of XPS
FR_3	EI_ 8 of XPS
FR_4	EI with 5 of GW
FR_5	EI with 8 of GW
FR_6	EI with 12 of GW
FR_7	II with 2 of Perlite and low emission coating
FR_8	II with 4 of Perlite
FR_9	II with 4 of Perlite and low emission coating
FR_10	II with 2 of GW and low emission coating
FR_11	II with 4 of GW

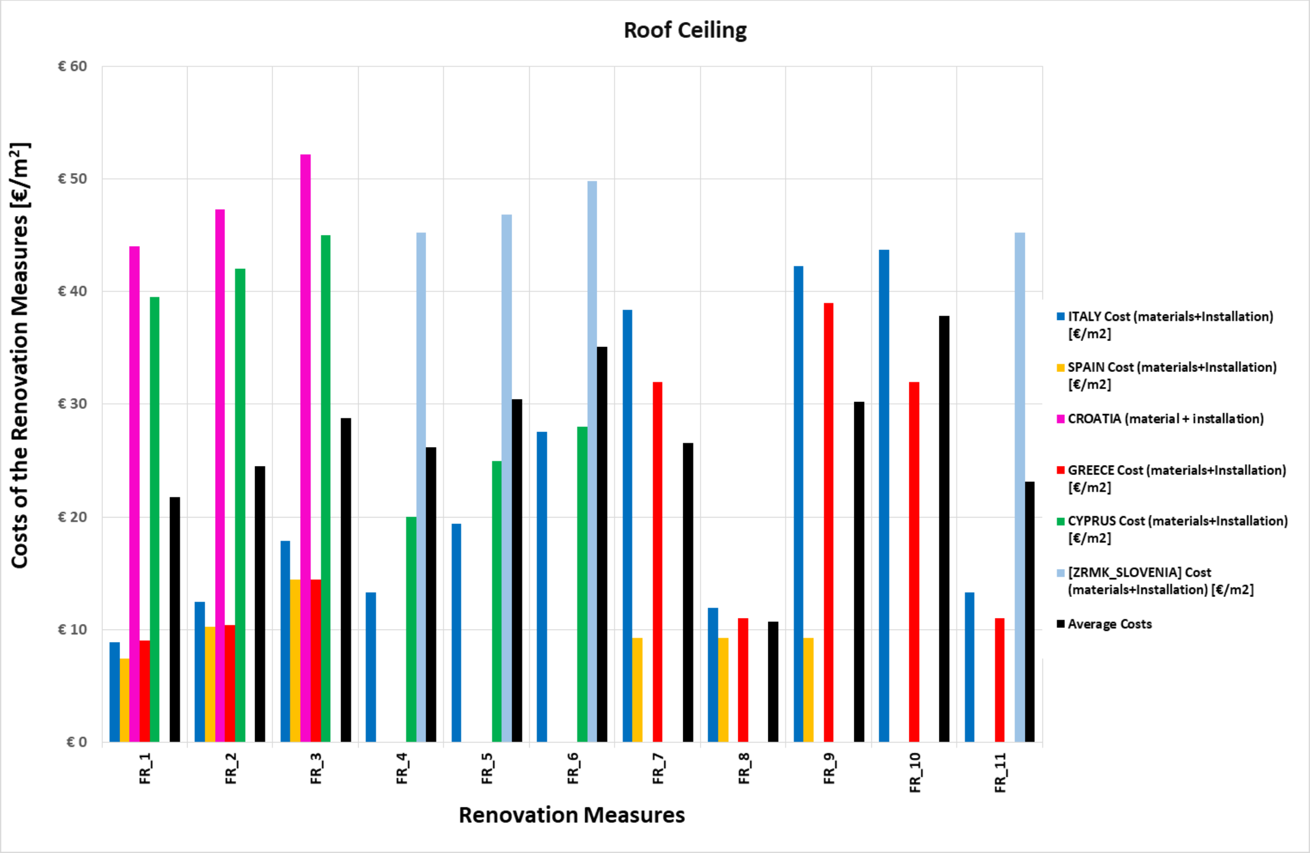

Figure 30-Costs of the renovation Measures- Flat Roof - Partners Contribution

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

Legend

FR_12	II with 4 of GW and low emission coating
FR_13	II with 2 of AEROGEL
FR_14	II with 2 of AEROGEL and low emission coating
FR_15	EI with 5 cm of XPS and high SRI coating
FR_16	EI with 8 cm of XPS and high SRI coating
FR_17	EI with 12 cm of XPS and high SRI coating
FR_21	EI with 5 cm of GW and high SRI coating
FR_22	EI with 8 cm of GW and high SRI coating
FR_23	EI with 12 cm of GW and high SRI coating

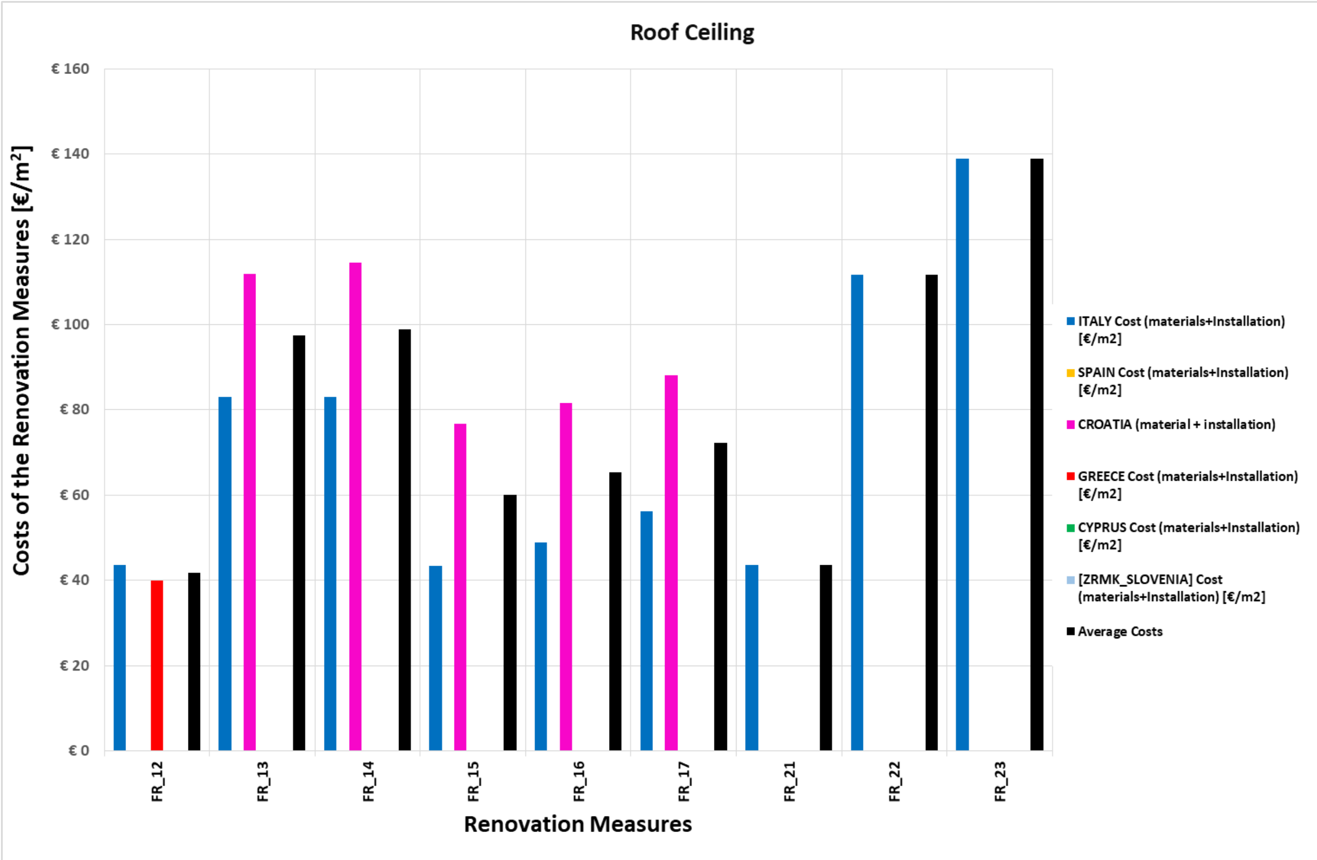

Figure 31-Costs of the renovation Measures- Flat Roof - Partners Contribution

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5.2.1.3 Basement

When considering the basement, the costs for all the solutions were provided only by the Slovenian partner, who added also another renovation measure, which takes into account the increase in the thickness of the PU panels [see the Appendix]. The cods depicted in the figure are those employed in Table 15. The solutions B_2, B_3 and B4 are available only for Italy and Slovenia. The solutions B_5 and B_6 are present in almost al the partner Countries except Cyprus and Croatia. For Cyprus the costs for all the solutions were not available. With reference to the B_6 renovation measure, the lowest price is that provided by Spain (about 30€/m^2, whereas, for Italy, Greece and Slovenia, the costs are vey similar (about 42 €/m^2, 40 and 38, respectively). The slutions B_8 and B_9 are available only for Italy and Slovenia which presents costs very similar to each other (44,90 vs 49 €/m^2)

Spain shows the costs values farest frm the average for the solutions B_5, B_10 and B_15 (36€/m^2 vs 28 €/m^2- 70 vs 58 and 105 vs 87€/m^2). The solutions from B_12 until B_14 are implemented probably only in Italy and in Slovenia and the costs for the two countries are very similar to each other. In fact, the maximunm difference among the costs is in order of magnitude of 6 €/m^2, concerning the solution B_13.

When considering the solutions B_16, B_17 and B_18 the highest costs are those provided by Croatia (about 40 €/m^2, on the average). The costs are higher than the average for a quantity of about 20€/m^2, whereas Slovenia presents the lowest costs, which are far from the average values for a quantity of about 10€/m^2.

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Legend	
B_1	I with 5 of LW-CB with EPS
B_2	I with 5 of LW_d cement based with Expanded Perlite
B_3	I with 5 of light-weighted cement based with Vermiculite
B_4	I with 5 of light-weighted cement based with Expanded Clay
B_5	I with 5 of light-weighted cement based with Expanded Glass
B_6	with 10 of light-weighted cement based with EPS
B_7	i with 10 of light-weighted cement based with Expanded Perlite
B_8	Insulation with 10 of light-weighted cement based with Vermiculite
B_9	Insulation with 10 of light-weighted cement based with Expanded Clay

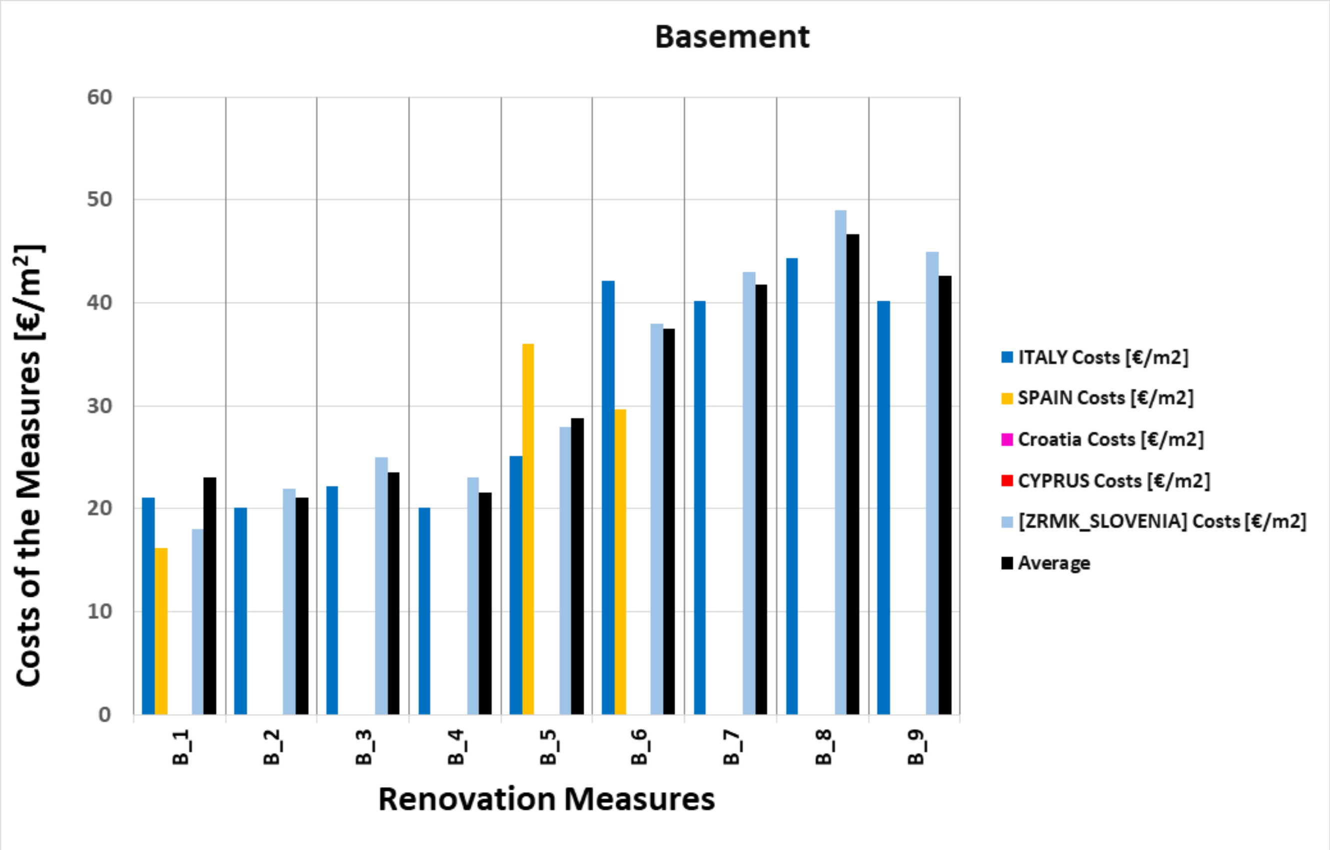

Figure 32-Costs of the renovation measures –Basement- Partners Contributions

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	Lwgend
B_10	Insulation with 10 of light-weighted cement based with Expanded Glass
B_11	Insulation with 15 of light-weighted cement based with EPS
B_12	Insulation with 15 of light-weighted cement based with Expanded Perlite
B_13	Insulation with 15 of light-weighted cement based with Vermiculite
B_14	Insulation with 15 of light-weighted cement based with Expanded Clay
B_15	Insulation with 15 of light-weighted cement based with Expanded Glass
B_16	Insulation with 2 of XPS or PU Panels
B_17	Insulation with 4 of XPS or PU Panels
B_18	Insulation with 6 of XPS or PU Panels
B_19	Insulation with 12 of XPS or PU Panels

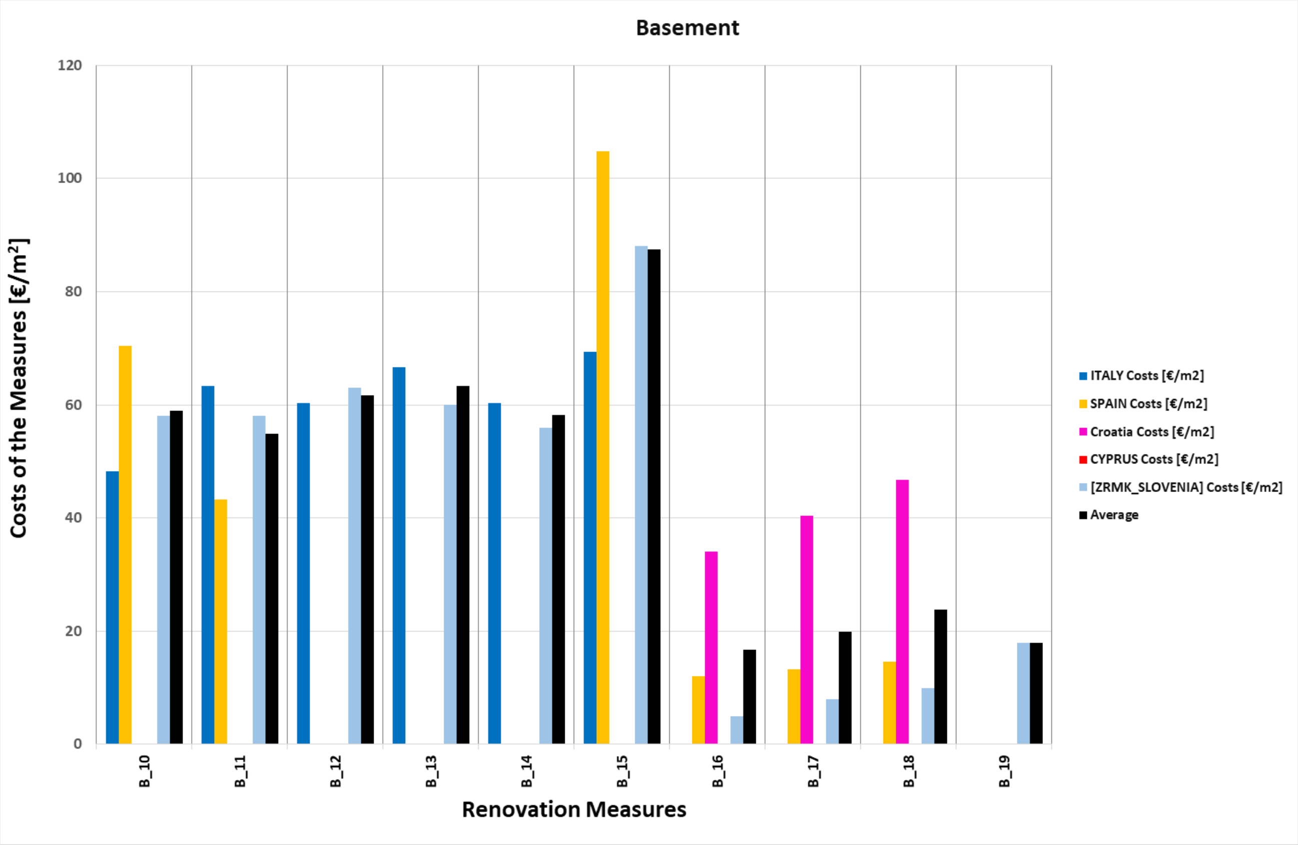

Figure 33 Costs of the renovation measures –Basement- Partners Contributions -

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5.2.1.4 *Windows*
When considering the windows, the main outcomes are depicted in Figure 34- Figure 37 and the codes are related to Table 16. The costs distribution is not homogeneous. In particular, for the solutions from W_2_until W_14, the highest costs are those provided by Italy. The Italian costs are provided by considering a market survey. They are higher than the average values for a quantity up to 200 €/m^2, in particular, this is referred to the solutions W_4 and W_7. When considering Spain, the costs is composed of 90% of the glass cost in €/m^2 and the other 10% is represented by the frame cost in €/m^2 .This is valid for all the solutions except for two, whose costs are available in [51]. The Slovenian Country, provided alternative renovation measures for the windows, listed in Appendix. However, for some measures the either the g-value was too low fo their market, other the U value is not in avvordance with the Slovenian legislation. Cyprus costs are available inly for the solution W_3. The costs of Greece are similar to those of Italy, but lower of maximum 100 €/m^2 for the solution W_3. Spain presents the lowest costs for all the soulitions proposed. When considering the solutions from W_17 to W_21, they are available for four partners the costs trend id similar to the one shown previously. Italy presents the highest costs, whereas Spain always the lowest. The solutions from W_22 until W_29 are provided only by Croatia.

5.2.1.5 Shadings
In this case, the lowest costs are those provided by Italy and Greece, as depicted in Figure 38. The highest costs are those provided by Cyprus, which are higer than the average values for a quantity of about 60 €/m^2.
The lowest costs are those provided by Italy and they are lower than the average values for a quantity of about 40 €/m^2.

5.2.1.6 Thermal Bridges
With reference to the thermal bridges, the costs distribution, also in this case is not uniform, as depicted in Figure 39. Among all the solutions only the costs for the first five are reported, because the other solutions are available only for Italy. The solutions from TB_1, TB_3 and TB_4 are available for all the Countries The highest costs are mainly the Croatian ones. The maximum deviation is dshown for the solution TB_ 1, which is higher than the average of about 68€/m^2. For the solution TB_3 except for Coatia, the other Countries have costs simalt to each other: the maximum difference is in order of magnitude of about 2€/m^2.

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Legend	
W_1	Double windows with 2 glasses with 1.6 cm of air interspace
W_2	Double windows with 2 glasses window with low-ε with 1.6 cm of air interspace
W_3	2 glasses window with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)
W_4	2 glasses window with low-ε with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)
W_5	3 glasses window with 1.6 cm of argon interspace and ALUMINIUM
W_6	3 glasses window medium-ε with 1.6 cm of argon interspace and ALUMINIUM
W_7	3 glasses window with low-ε with 1.6 cm of argon interspace and ALUMINIUM
W_8	Double windows with 2 glasses with 1.6 cm of air interspace

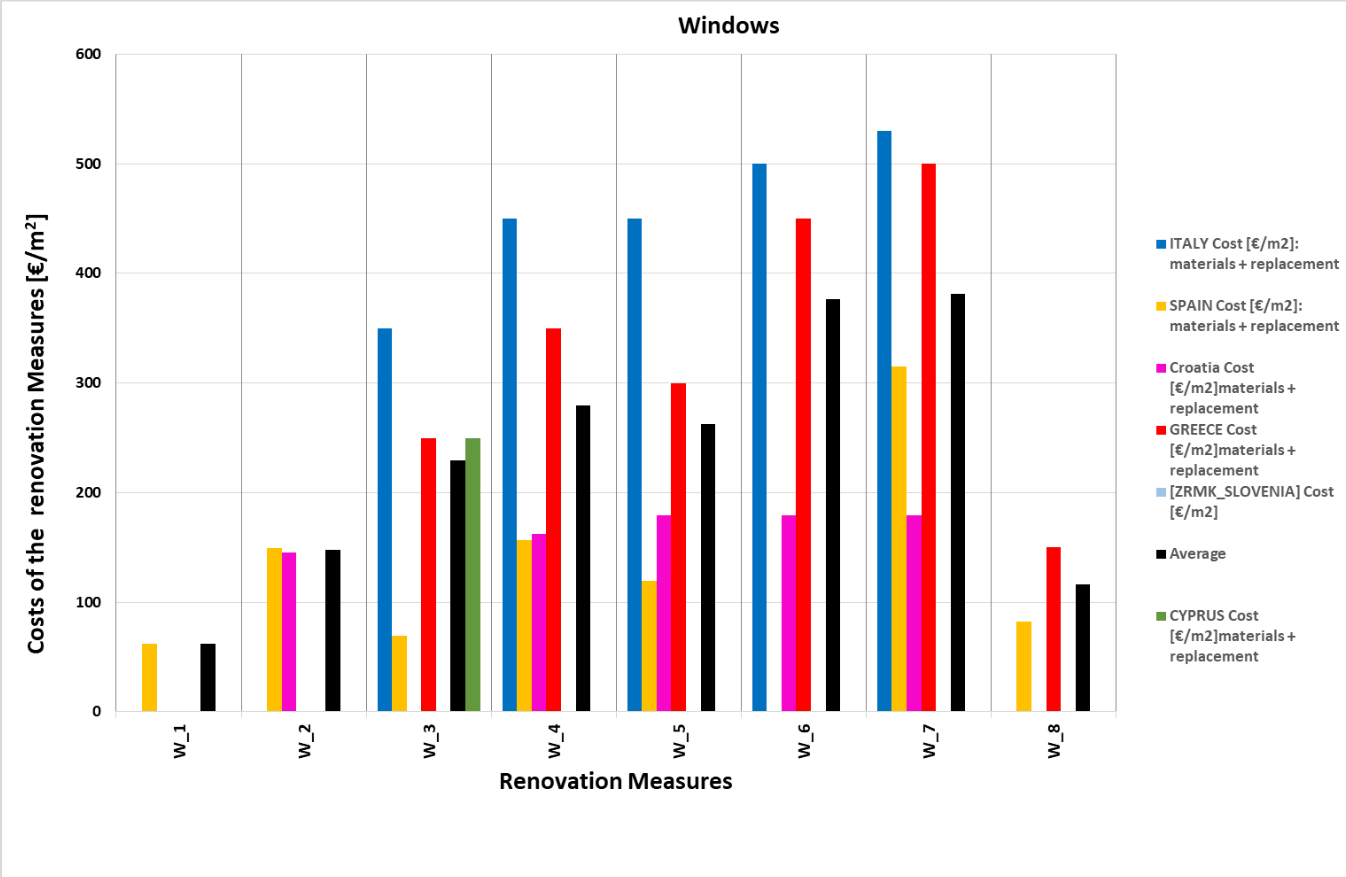

Figure 34- Costs of the renovation Measures- Windows- Partners Contributi

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Legend	
W_9	Double windows with 2 glasses window with low-ε with 1.6 cm of air interspace
W_10	2 glasses window with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)
W_11	2 glasses window with low-ε with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)
W_12	3 glasses window with 1.6 cm of argon interspace and WOOD
W_13	3 glasses window with 1.6 cm of argon interspace and WOOD
W_14	3 glasses window with low-ε with 1.6 cm of argon interspace and WOOD
W_15	Double windows with 2 glasses with 1.6 cm of air interspace
W_16	Double windows with 2 glasses window with low-ε with 1.6 cm of air interspace

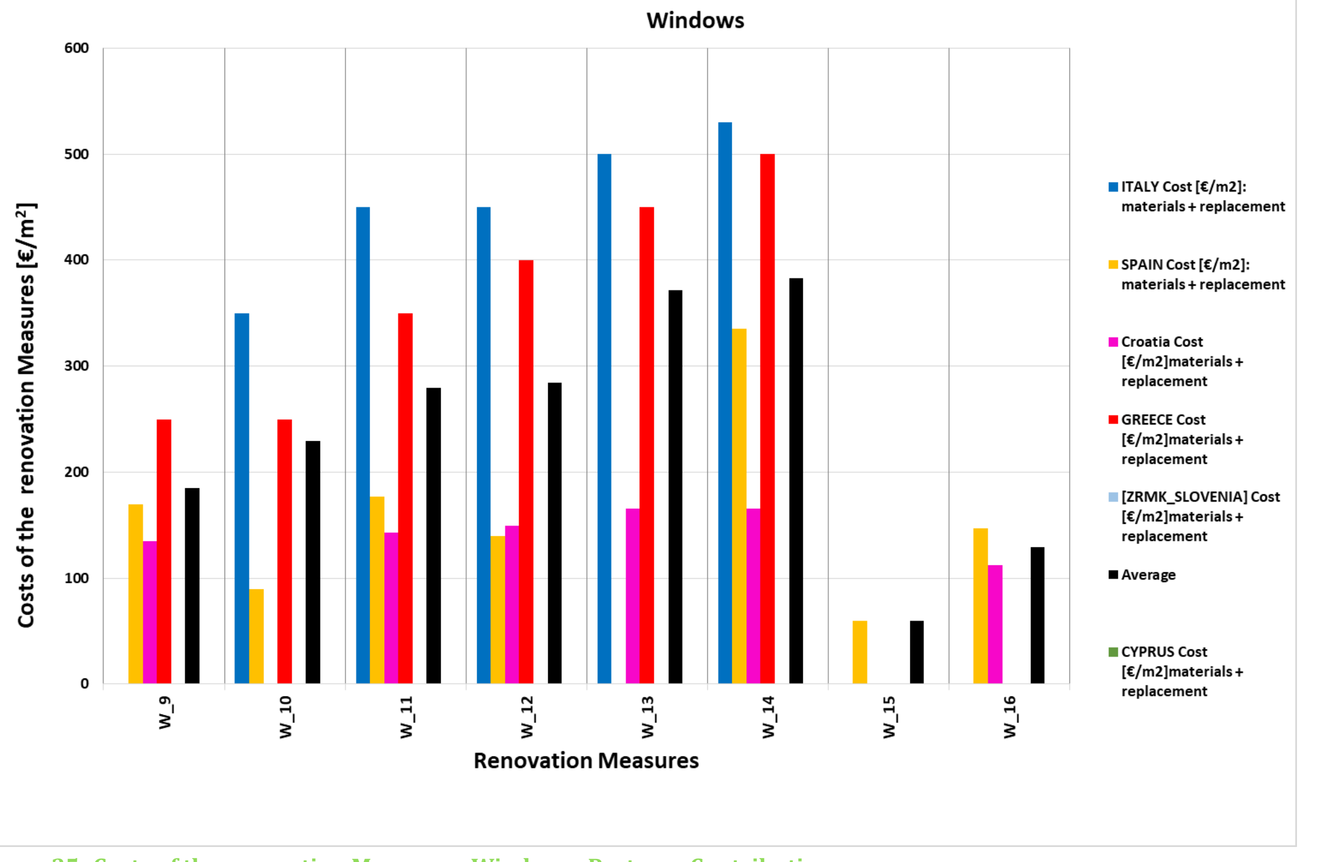

Figure 35- Costs of the renovation Measures- Windows- Partners Contribution

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	Legend
W_17	2 glasses window with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)
W_18	2 glasses window with low-ε with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)
W_19	3 glasses window with 1.6 cm of argon interspace and PVC.g value 0.53
W_20	U value gvalue 0.54- Spain available
W_21	3 glasses window with low-ε with 1.6 cm of argon interspace and PVC
W_22	3 glasses window with 1.8 cm of air interspace
W_23	3 glasses window with 1.8 cm of air interspace

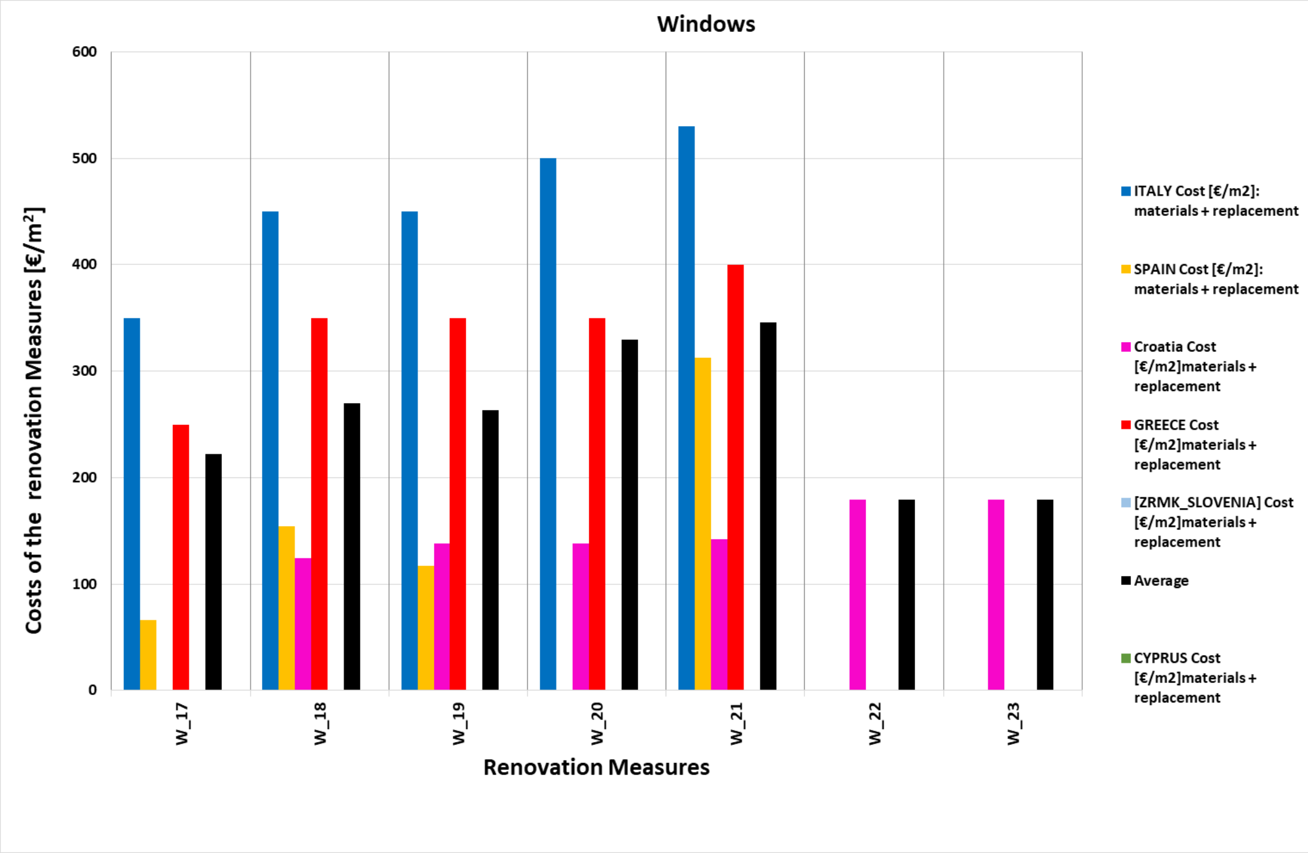

Figure 36- Costs of the renovation Measures- Windows- Partners Contribution

Legend

W_24	3 glasses window with low-ε with 1.8 cm of air interspace
W_25	3 glasses window with 1.8 cm of air interspace
W_26	3 glasses window with 1.8 cm of air interspace
W_27	3 glasses window with low-ε with 1.8 cm of air interspace_Wood Frame
W_28	3 glasses window with 1.8 cm of air interspace
W_29	3 glasses window with 1.8 cm of air interspace with low-ε -_PVC Frame

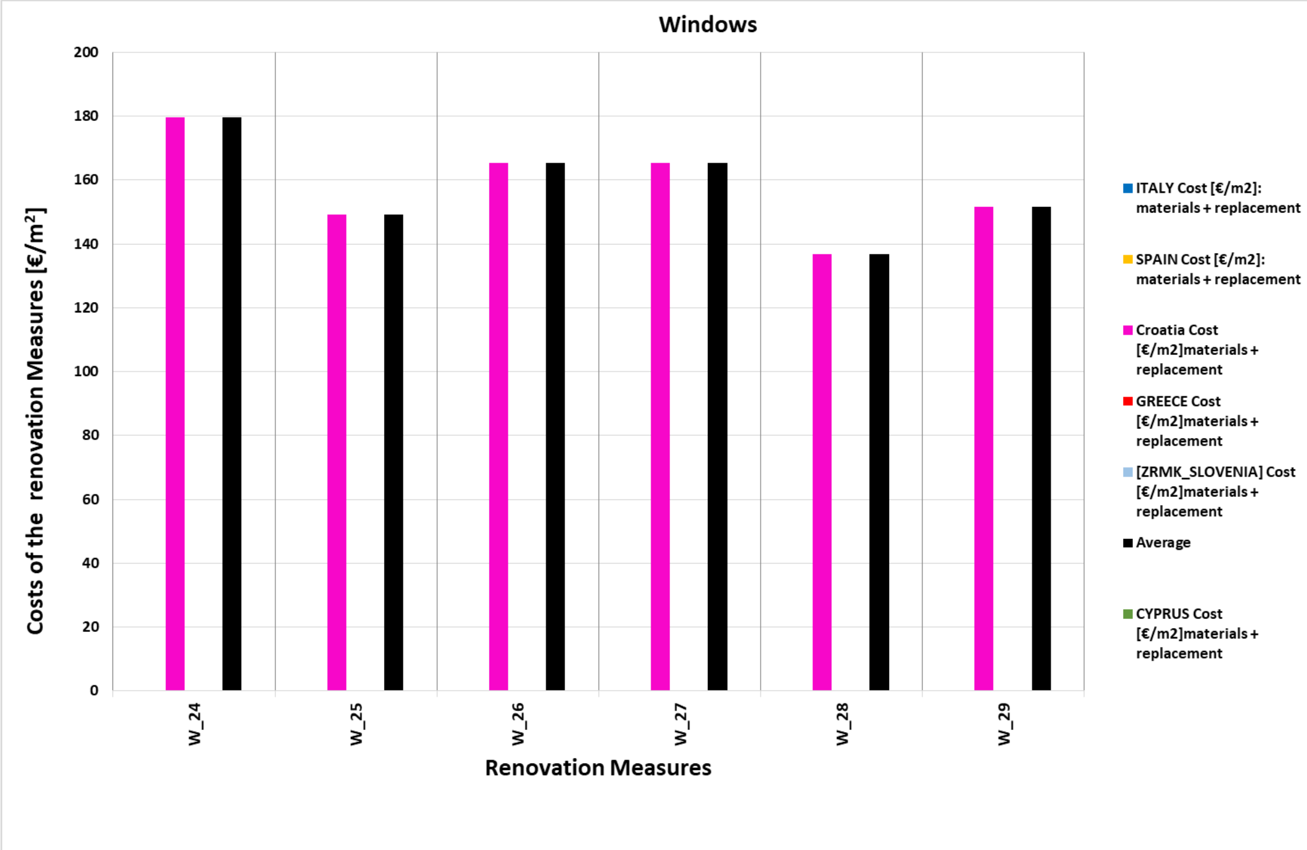

Figure 37 - Costs of the renovation Measures- Windows- Partners Contribution

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Legend

S_0	No replacement
S_1	Overhang - vertical 50 0,29 and 70
S_2	Overhang - horizontal 50 0,29 and 70

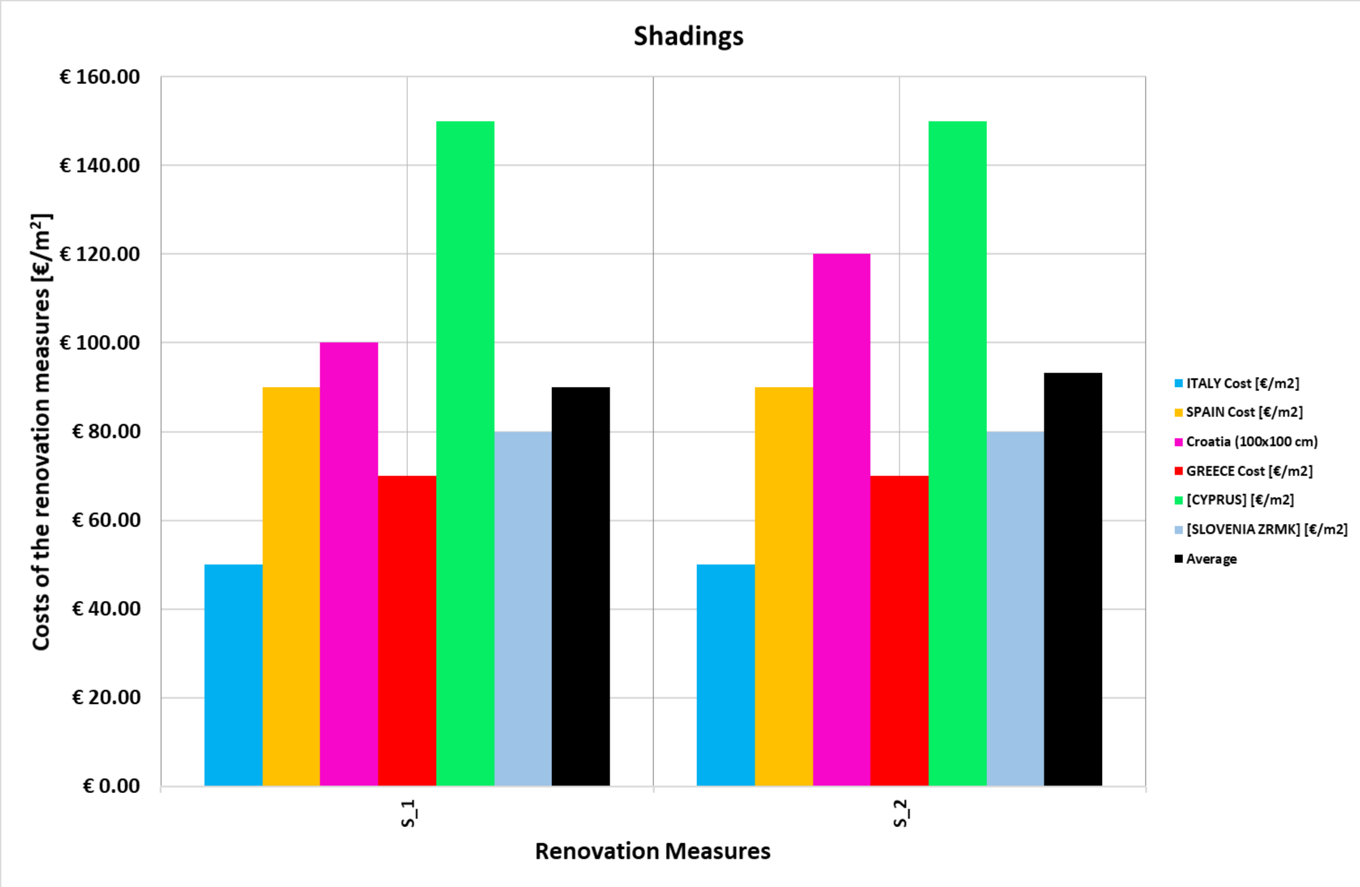

Figure 38- Costs of the renovation Measures- Shadings-Partners Contribution

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Legend	
TB_1	Insulation of thermal bridges with panels made of PUR injected in the slabs to go from 1.01 to 0.6 for the Façade-Slabs TB
TB_2	Insulation of thermal bridges with panels made of mineralized wood wool and bound with high-strength cement
TB_3	Insulation of thermal bridges with application on kerbs, lintels, veils, pillars, etc. of polystyrene sheet strips extruded foam, rough surface without skin
TB_4	Insulation of thermal bridges with application between windows and facades
TB_5	Insulation of thermal bridges on vertical and horizontal structures in phase of the casting, realized with application on the formworks of panels in wood wool mineralized with high temperature magnesite;

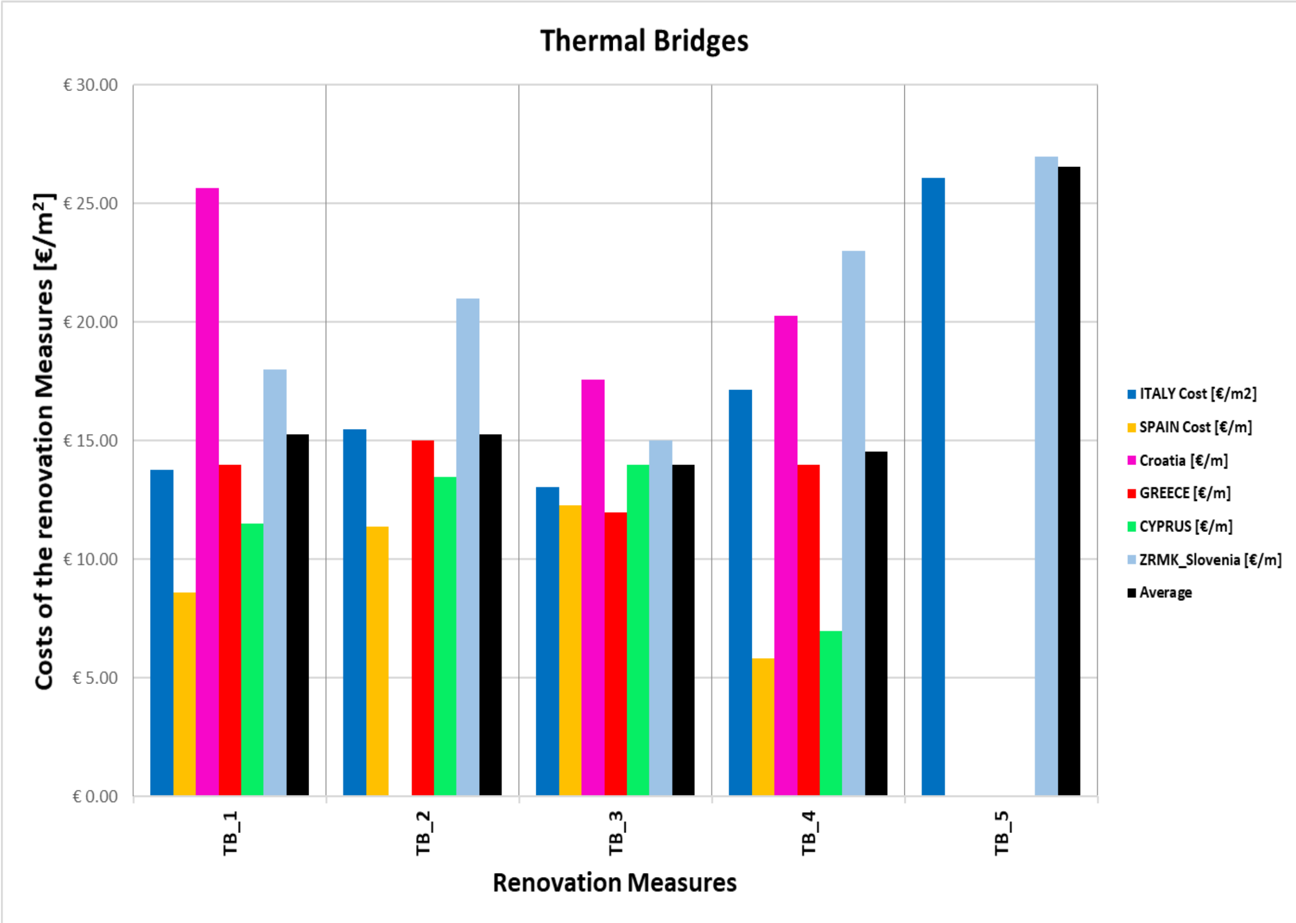

Figure 39- Costs of the renovation Measures- Thermal Bridges-Partners Contribution

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5.2.1.7 *Heating abd Cooling Systems*

The comparison among all the partner Countries is depicted in Figure 43-Figure 45. For the solution HC_3, Spain, Greece and Italy show values, which are similar to each other. Whith regard to the solutions HC_5, HC_6 and HC_7, the costs distribution is quite homogeneous, except for Slovenia, which shows the highest costs, far from the average, for a quantity of about 1000 €. On the other hand, Croatia presents the lowest costs, which are lower than the Slovenian ones for a quantity of about 1500 €. For the solution HC_8, the highest cost is the Slovenian one (19100€), whereas the lowest is the Croatian one (about 6000€). For the solutions from HC_9 to HC_17, the highest costs are almost those provided by the Croatian Country. For the solutions HC_10 and HC_13, the costs distribution is almost homogeneous. The silutions 11 and 12 are not reported in the graph, because they are available only for Italy and no comparison may be carried out. The solution HC_16 in the slovenian case provides only heating. With regard to the HC_18 in the Slovenian case, it iis pointed out that boiler plus pellet and storage tank are included in the cost of the solution The other solutions, which range from the HC_18 until HC_23 are not available for the majority of the Partners. Wih regard to the solution HC_21, the power is of 30 kW.

With regard to France, the different heating Systems adopted are depicted in Figure 40.

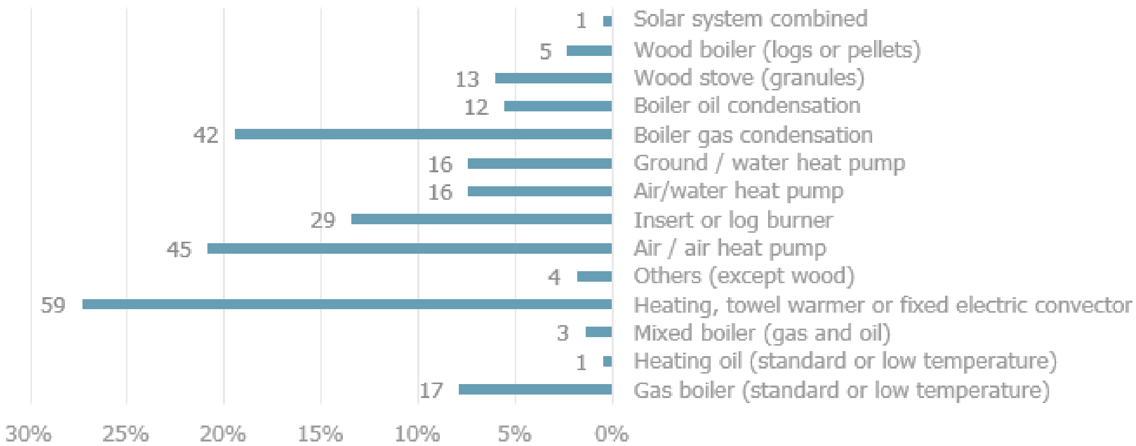

Figure 40- Heating Systems distribution provided by France

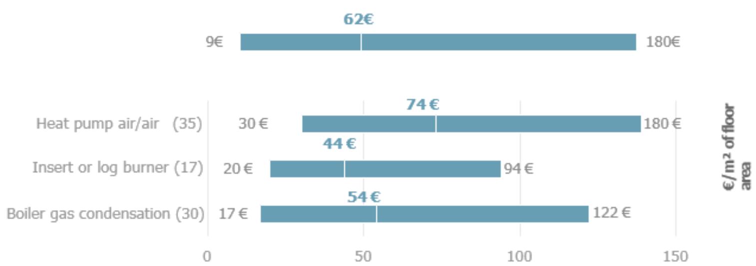

Figure 41- Minimum and maximum works cost, average cost:

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The average cost of work on the heating station varies from 9 to 180 € / m² of floor area with an average of 62 € / m² of floor area.
This significant cost is related to the multitude of equipment that can be installed, and the possibility in some cases to use several complementary heating modes. Thus, 45 homes installed at least two heating systems simultaneously. Combinations of central heating and electric backup heating are the most common (32 files). Some homes, much rarer, install two central heating systems, usually a boiler associated with a reversible air conditioning or a wood stove.
Two cases with excessive costs have been excluded from the analysis: they are wood pellet boilers for 250 € / m² of floor area. The average cost in collective housing is 56 € / m² of floor area, reminding that the electrical system is the most installed; so in individual housing, it is 66 € / m²of floor area, and gas condensing boilers are the most installed.

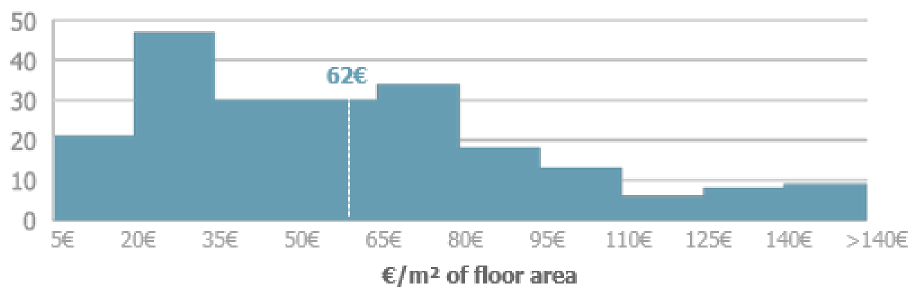

Figure 42 Costs for m² floor area

The dissociation between the installation and the acquisition of the equipment is available in 151 invoices out of the 216 studied. The pose of the installation represents on average 20% of the total amount, ie € 1,130 (from € 150 to € 4,000) or € 12 / m² of floor area.

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Legend

HC_1	Wall-mounted gas boiler <= 25 kW without DHW
HC_2	Wall-mounted gas boiler <= 25 kW
HC_3	FloorNAstanding gas boiler > 25 kW [INOX]
HC_4	Wall-mounted condensing gas boiler <= 25 kW without DHW
HC_5	Wall-mounted condensing gas boiler <= 25 kW
HC_6	Floor-standing condensing gas boiler <= 25 kW without DHW
HC_7	Floor-standing condensing gas boiler <= 25 kW
HC_8	Floor-standing condensing gas boiler: 100-150 kW

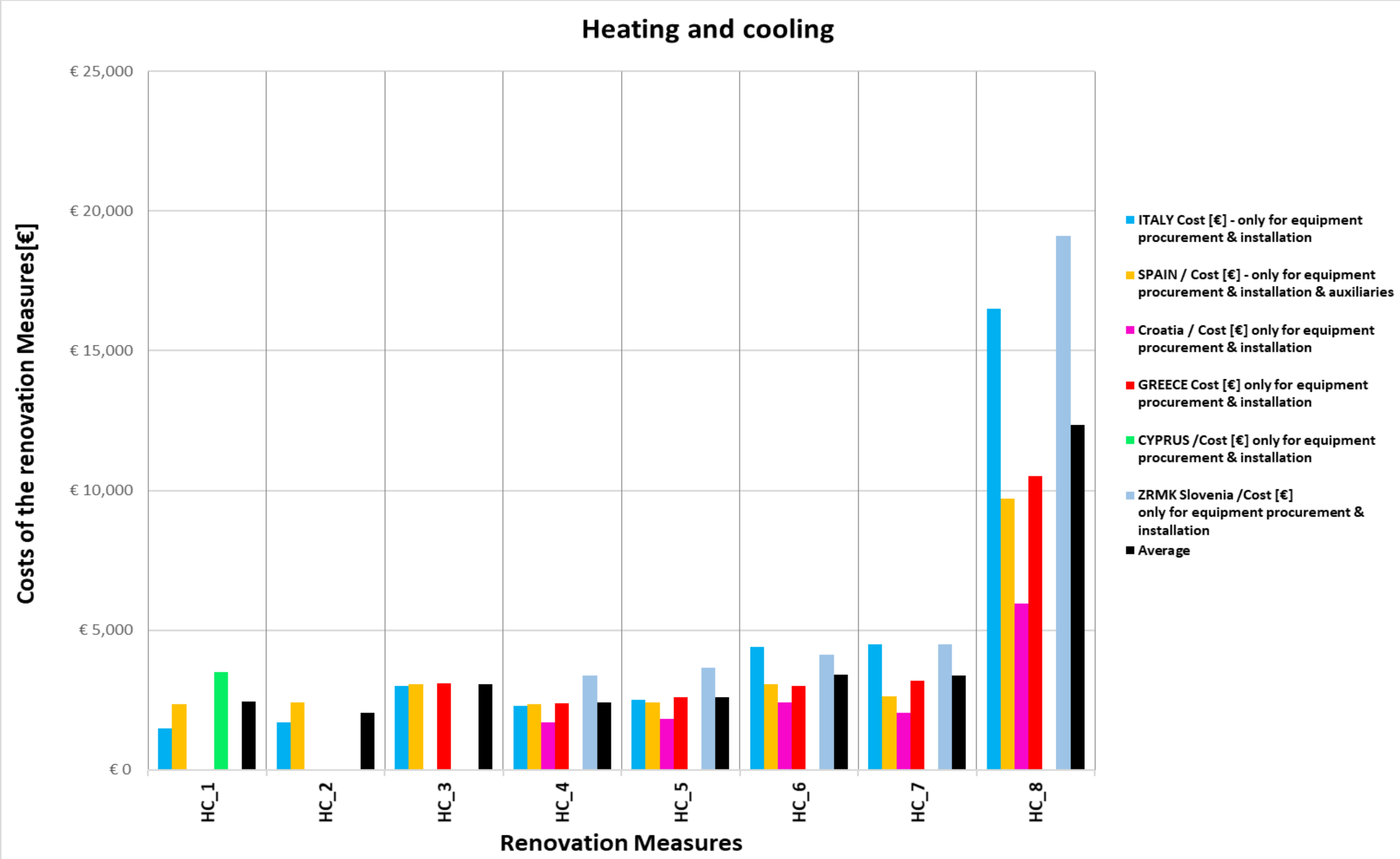

Figure 43- Costs of the renovation Measures-Heating and Cooling systems -Partners Contribution

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Legend

HC_9	Floor-standing condensing gas boiler: 200-250 kW
HC_10	Installation of an electric airNAair HP NA multisplit <= 15 kW
HC_11	Installation of an electric air-air HP NA multisplit <= 15 kW - only cooling
HC_12	Installation of an electric airNAwater HP <= 15kW - without DHW
HC_13	Installation of an electric airNAwater HP <= 25kW
HC_14	Installation of an electric airwater HP - 100NA150kW
HC_15	Installation of an electric air-water HP 200-250kW
HC_16	GSHP Ground Source Heat Pump - 100NA150kW
HC_17	GSHP - Ground Source Heat Pump -200-250kW

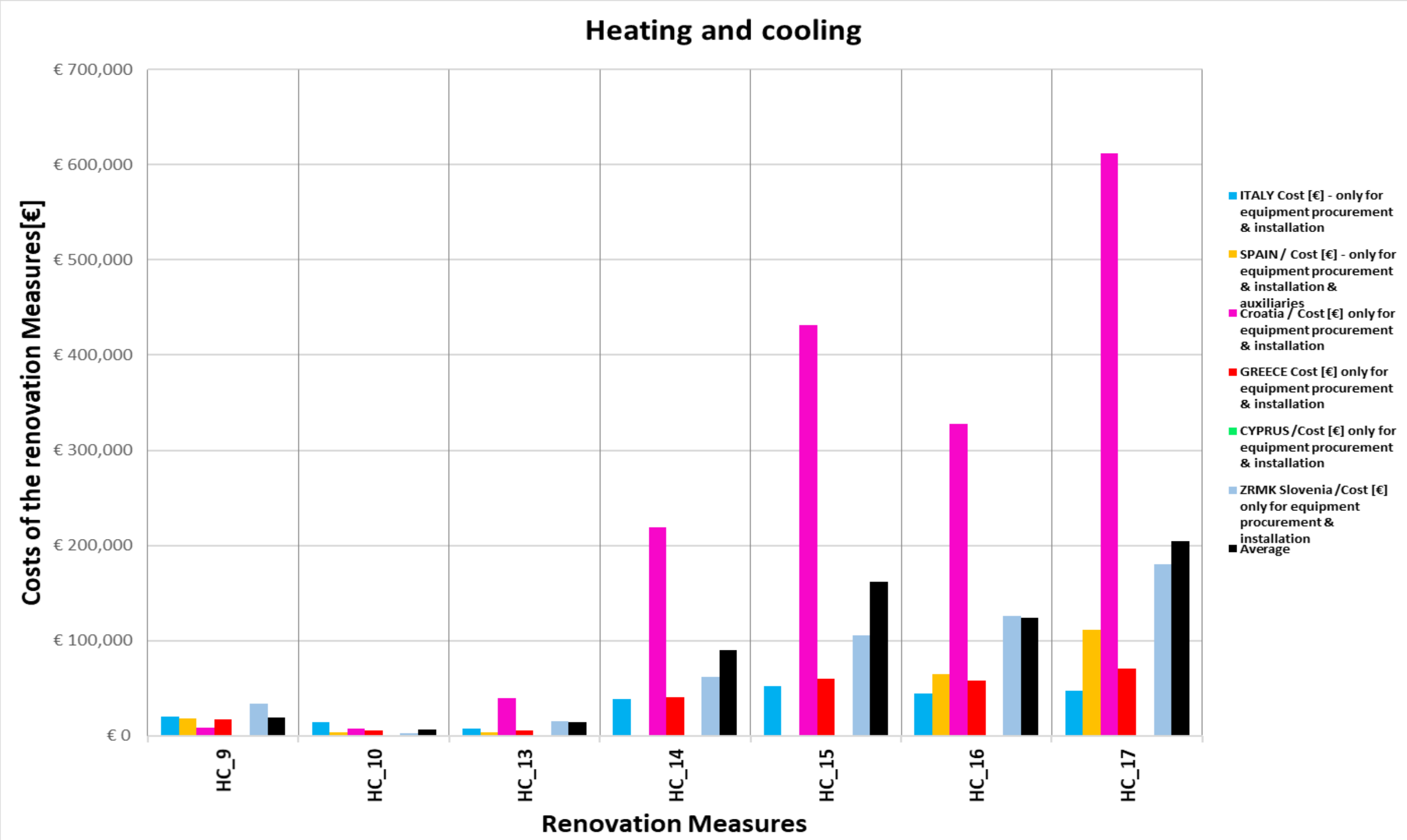

Figure 44- Costs of the renovation Measures-Heating and Cooling systems -Partners Contribution

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

Legend

HC_18	Biomass boiler
HC_19	Biomass boiler
HC_20	MicroCHP - Gas turbine
HC_21	MicroCHP - Internal combustion engine
HC_22	District heating
HC_23	Absorption chiller + Solar thermal

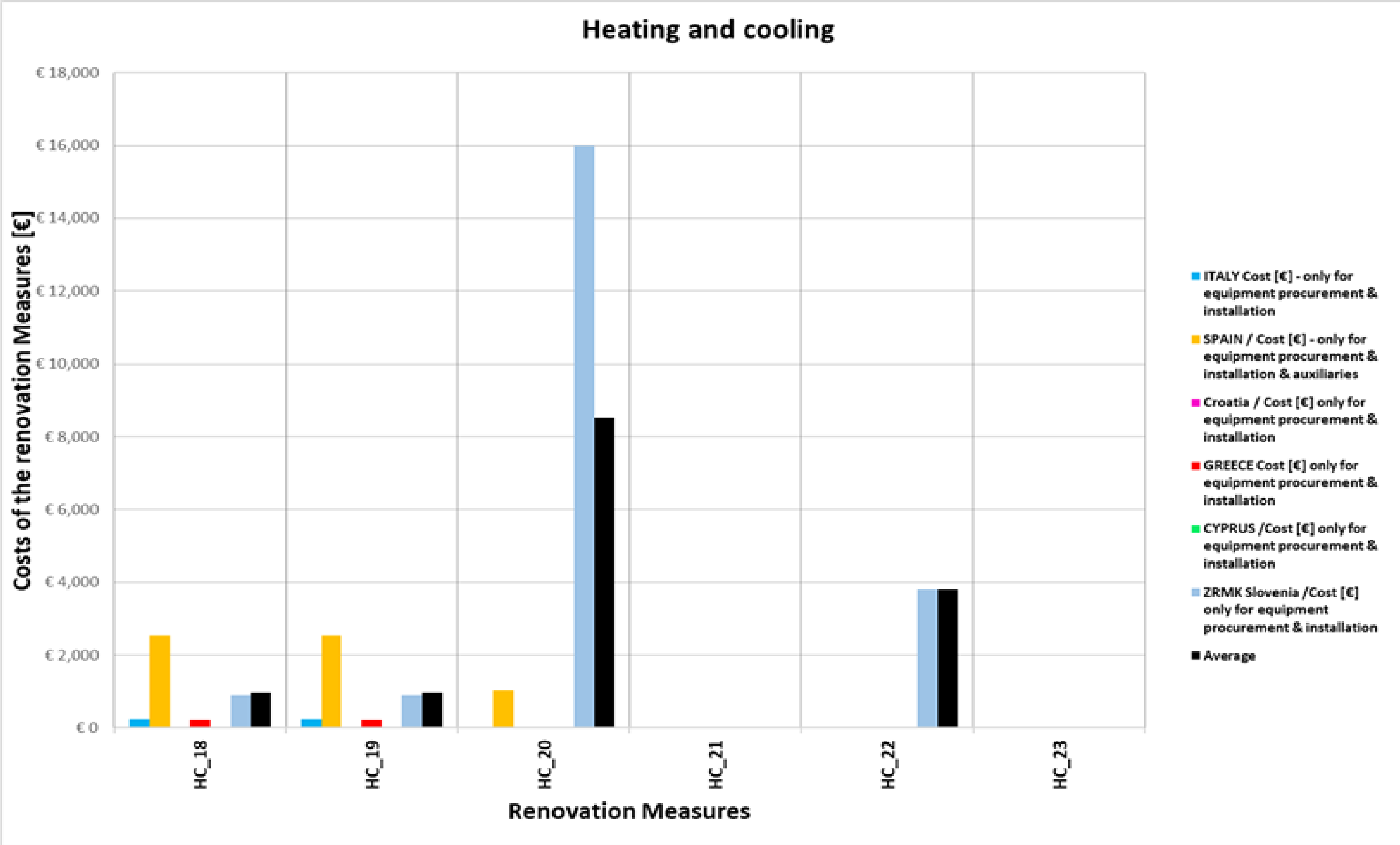

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Figure 45- Costs of the renovation Measures-Heating and Cooling systems -Partners Contribution

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5.2.1.8 *Domestic Hot Water*

With reference to the renovation measures to be applied for the DHW, the costs distribution is not homogeneous, also in thisa case. The solution DHW_5 is present for all the Countries and the lowest costs are those provided by Cyrprus. For that solution, costs are referred per m^2.Also the ffirst solution is the cheapest one, except for Spain, wich has the highest costs (200/€/UFR) vs 400€/UFR available for Greece. The solution DHW_3 is available for all the Countries except for Croatia. The highest costs is the one provided by Cyprus.With regard to Spain, they presents the highest Costs for the solutions DHW_1 and DHW_2.When considering the solution DHW_6, the highest cost is that provided by Cyprus (6500€/UFR), whereas the lowest is that provided By Spain (1150€/UFR).

When considering the French case, the technologies employed to supply DHW are those presented in Figure 46.

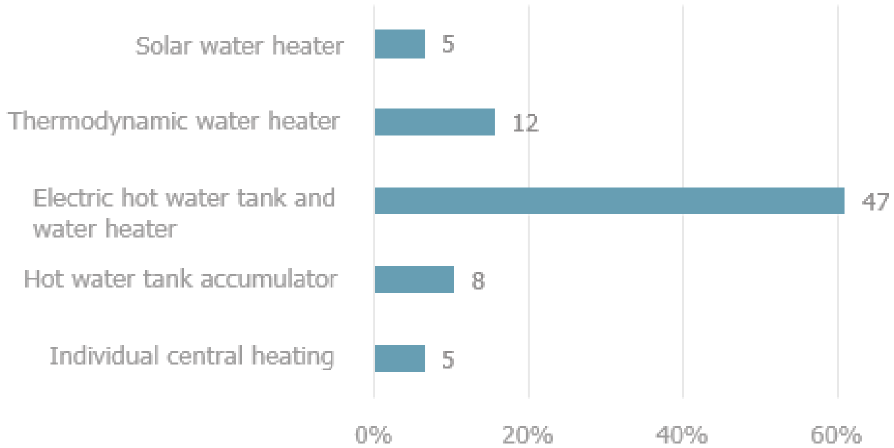

Figure 46- DHW supply technologies employed in France

The solar water heater is the most expensive device, with 47 € / m^2 of floor area on average. The electric water heater has a low cost of 13 € / m^2 of floor area on average, but a low performance.

The average cost is lower in collective housing (34 € / m^2 on average) than in individual housing (43 € / m^2 floor on average). Households tend to install more efficient systems individually and therefore more expensive: 85% of electric water heater in collective against 42% in individual, 6% of thermodynamic or solar water heater in collective against 35% in individual.

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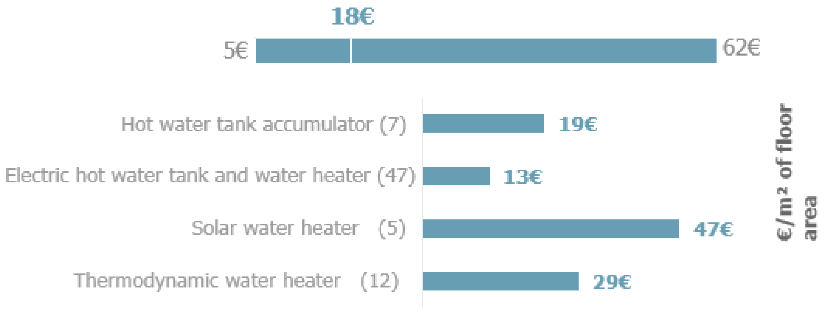

Figure 47- Distribution of the technologies according to the costs

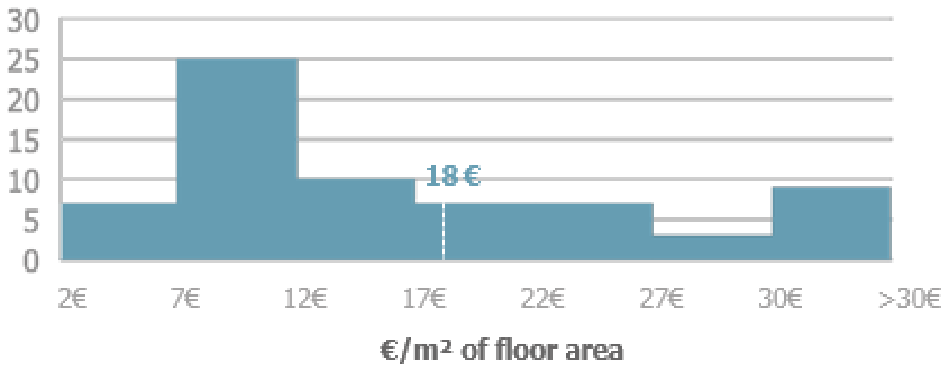

Figure 48- Costs for m2 floor area

By observing the distribution of the costs of work on the domestic hot water station, a strong difference can be seen between the different types of equipment: in the lower slices (between 2 and 17 € / m^2 floor) the vast majority is balloon and electric water heater. In the range 17 € and 27 € / m^2 of floor area, are found mostly thermodynamic water heater. Finally, the last tranche (between 30 and 60 €/m^2 floor) mainly includes solar water heaters and some thermodynamic water heaters.

The dissociation between the installation and the acquisition of the equipment is available in 21 invoices out of the 77 studied. The laying of the installation costs on average 150 € (2 € / m^2 floor) for an electric water heater and 1400 € (12 € / m^2 floor) for a solar water heater.

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Legend	
DHW_1	Electric boiler – SFH
DHW_2	Electric boilers [20 apartments]
DHW_3	Gas boiler with high efficiency
DHW_4	Gas boiler with high efficiency [20 apartments]
DHW_5	Solar thermal
DHW_6	air-to-water Electric Heat pump – SFH
DHW_7	air-to-water Electric Heat pump - MFH [20 apartments]

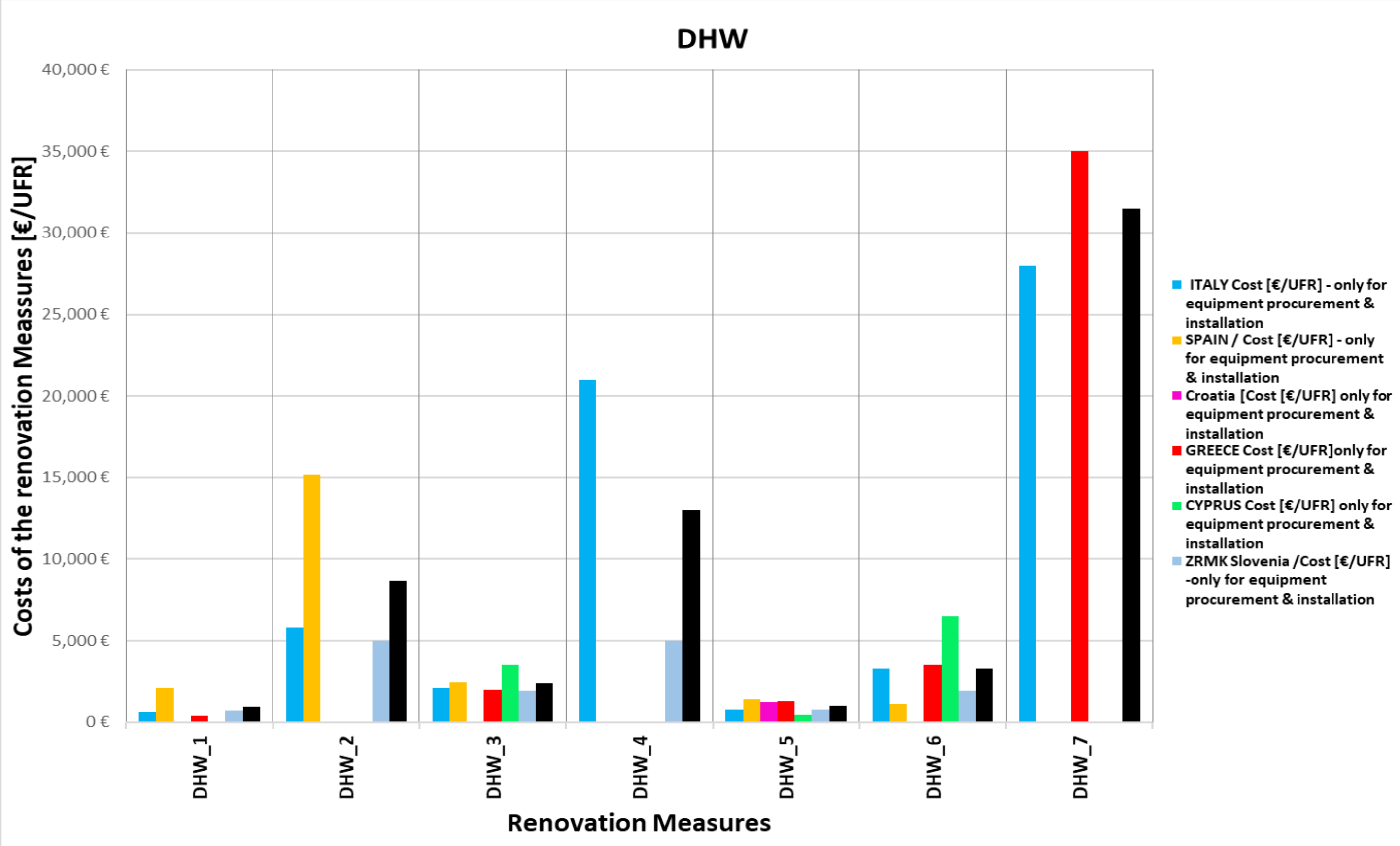

Figure 49- Costs of the renovation Measures-Domestic Hot water -Partners Contribution

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5.2.1.9 *Ventilation*

In this case the costs for the renovation measures provided for the DHW are not available, for Italy, Slovenia provided its own renovation measures, mainly based on VMC - Hygrosensible ventilation and on venetilation controlled with thermal exchange (Heat Recovery System) with two different equivalent air flow (n air change/h - m^3/h). Spain provided the costs of the solutions according to the CYPE and the costs provided by Spain are the lowest in this framework. When considrering the Croatian case, they provided the costs for the solutions to be installed in case of 100 m^2 of room space, considering a single floor. With regard to the French contribution, the installation of VMC costs between 2 and 50 € / m^2. The average cost is 13 € / m^2 floor, as depicted in Figure 52.

Figure 50- Installation costs for VMC-French case

5.2.1.10 Renewable Energy Sources

With reference to the RES, the costs for the first three solutions are provided in €/kWhe, whereas, the other seven solutions are referred to the RES employed to produce thermal energy and they are provided in €/kWht. In particular, for the different photovoltaic solution (RES_E1-RES E_3) are high in case of Greece and Spain. When considering the RES thermal, the costs are uniform for the siolutions RES_T_1 and RES_T_2. With reference to RES_T_3, the highest costs are those provided by Greece and Slovenia, Cypris and Italy present the same costs (20000€/kWht], whiereas Spain has the lowest cost, which is about 12000€/kWht. When considering the Slovenian situation, it is highlighted that the TES_T_4 incliudes the supply of the DHW. For the different geothermal heat pumps, starting from the RES_T_3, the diverse costs refer to idfferent units are considered in the Table 23.

RES_T_3	HP unit (10 kW)+borehole+all connections with elements+heat storage tank
RES_T_4	HP unit (30 kW)+borehole+all connections with elements+heat storage tank
RES_T_5	HP (20 kW)+drilling, suction and drainage well, pipes, source pummp, control
RES_T_6	HP (50 kW)+drilling, suction and drainage well, pipes, source pummp, control

Table 23- Technical details of the different units

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	Legend
V_1	Controlled VMC
V_2	Controlled with thermal exchange (Heat Recovery System)
V_3	Free cooling- Night ventilation
A_1	Soudal window system
A_2	Passive house solution

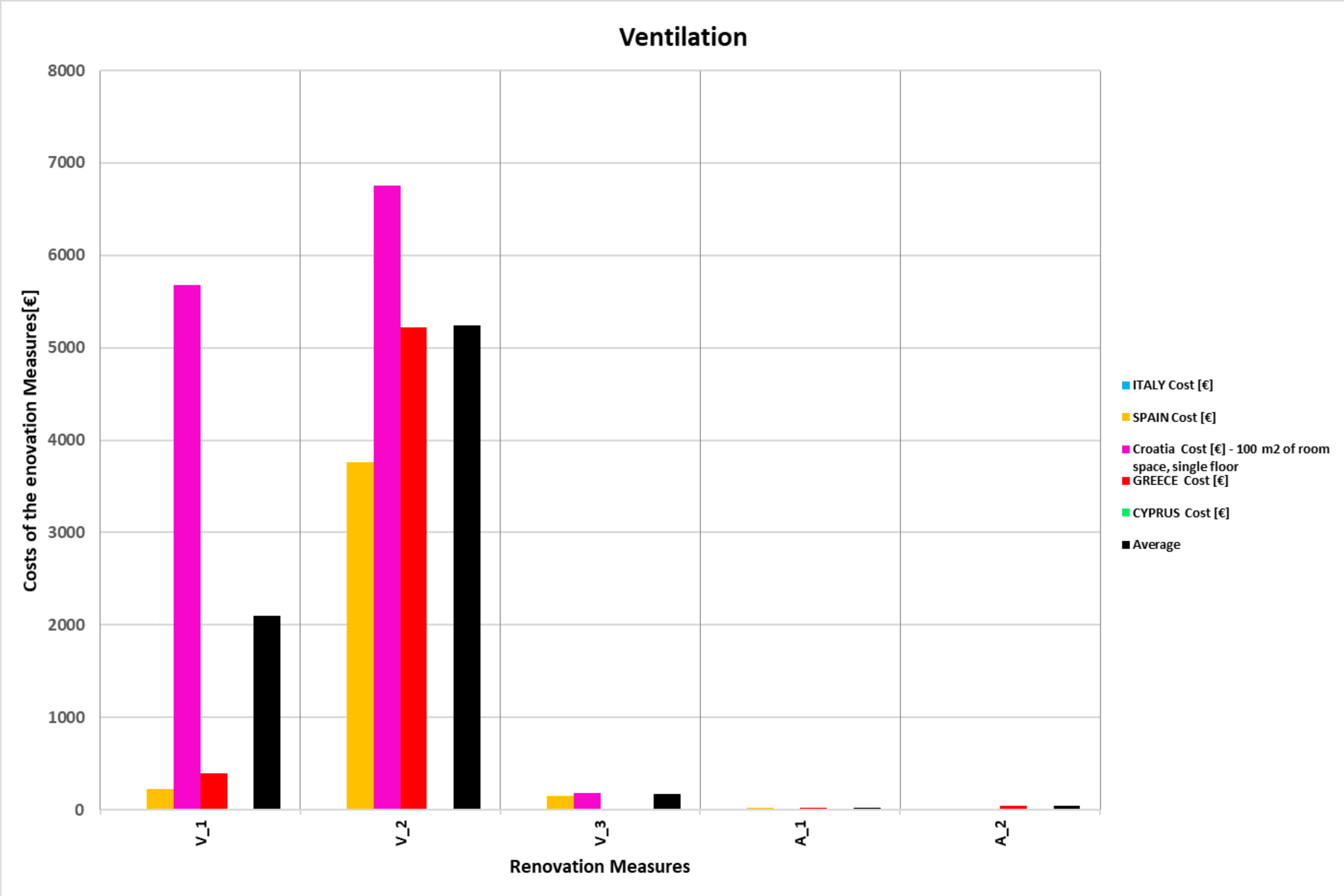

Figure 51- Costs of the renovation Measures-Ventilation Systems-Partners Contribution

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Legend	
RES_E_1	Photovoltaic (costs per kWp - from 1 kW up to 7 kWp)
RES_E_2	Photovoltaic (costs per kWp - from 7 kW up to 20 kWp)
RES_E_3	Photovoltaic (costs per kWp - from 21 kW up to 50 kWp)
RES_T_1	Biomass (woodchips or pellets generators) (cost in kWt)
RES_T_2	Solar thermal (cost per m2)
RES_T_3	Geothermal (HP - cost per kWt)_Ground-Water System
RES_T_4	Geothermal (HP - cost per kWt)_Ground-Water System
RES_T_5	Geothermal (HP - cost per kWt)_Water-Water System
RES_T_6	Geothermal (HP - cost per kWt)_Water-Water System

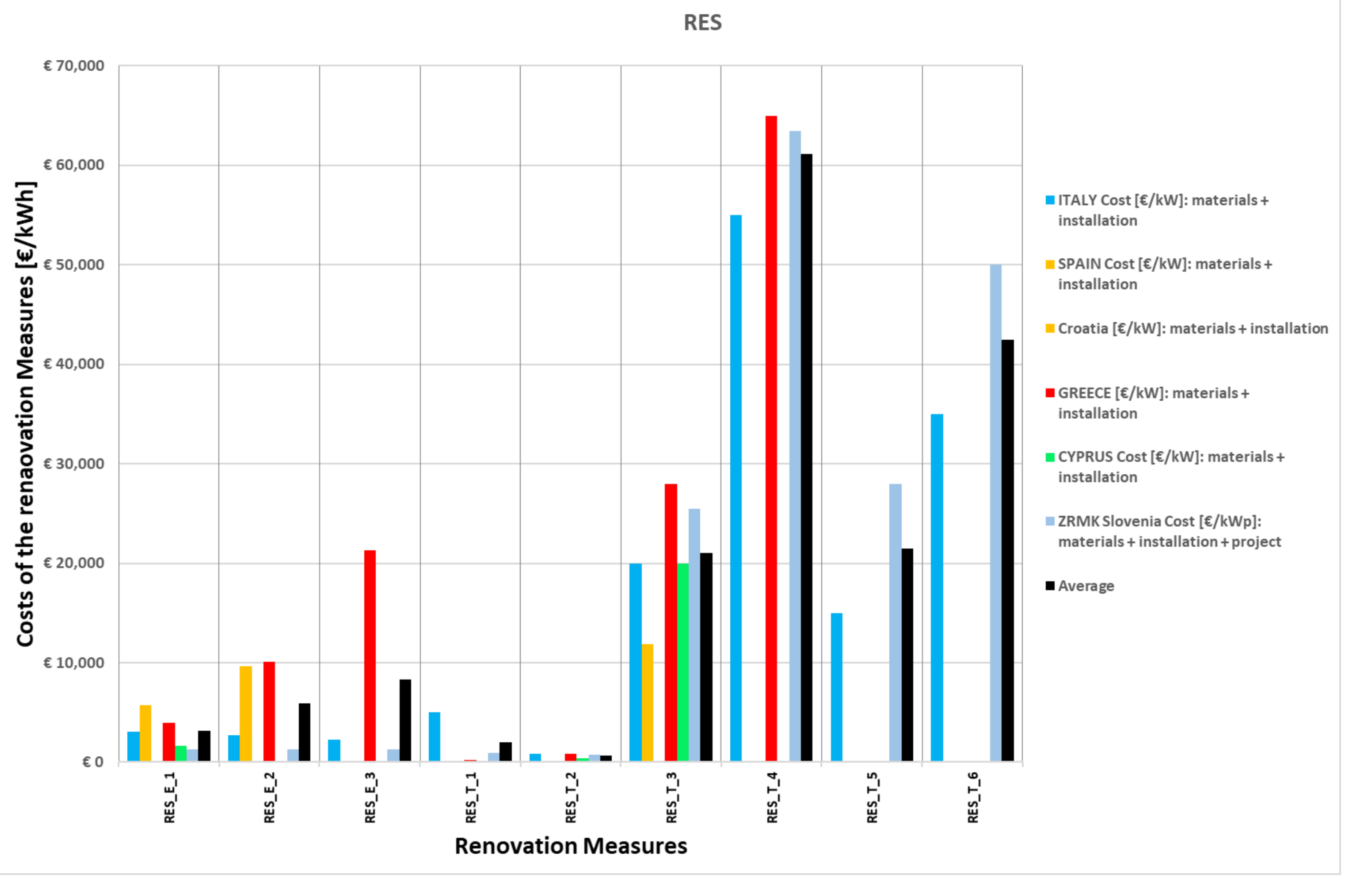

Figure 52- Costs of the renovation Measures-Renewable Energy sources -Partners Contribution

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5.3 Energy Prices

In order to compare the renovation measures, it is necessary to introduce also the energy prices, due to the fact that, in tha later stage, when the cost optimal analysis of the packages of the renovation measures, will be performed, the energy prices play a key role in the determination of the optimum point, when HVAC systems and the RES chosen have to be compared from the energetic and the economici point of view.
With reference to the energy prices, the different tables for all the Counties are reported in Appendix. In particular, regarding to the energy vector, the prices are available for all the countries for elelecricity and natural gas.
For example, for residential building in Italy, the electricity proces are divided in three ranges and they are reported in Table 24. They are taken by [53].

Period 1 January - 31 March 2019	Materia energia			Trasporto e gestione del contatore	Oneri di sistema
	Monorario	Biorario			
Quota energia (euro/kWh)	*fascia unica*	*fascia F1*	*fascia F23*		
kWh/anno: da 0 a 1800	0.09050	0.09709	0.08707	0.00798	0.029531
oltre 1800					0.067323
Quota fissa (euro/anno)	48.0070			20.2800	-
Quota potenza (euro/kW/anno)	-			21.2934	-
Sconto bolletta elettronica	*Ai clienti che ricevono la bolletta in formato elettronico e la pagano con addebito automatico è applicato uno sconto di 6 euro/anno.*				

Table 24- Electricity prices for Italy

When referring to natural gas the prices are reported in Table 25 and their source in [54].

Single prices [€/kWh]	**Prices on two different times in the day**	
	Price for the band F1[€/kWh]	Price for the band F2[€/kWh]
0.189559	0.196149	0.186129

Table 25- Prices for natural gas- Italy

A summary of the enegy prices for all the Partner Countries is shown in Table 37.

5.4 – Integration of the behavioural aspects

In this case, the main strategy employed is to act on the number of hours in which the heaing and the cooling systems work. In this way a significant reduction of the energy consumption can be achieved, as shown in the preliminary evaluatiuons carried out in the framework of the cost optimal analysis. In the case of behavioural aspect, starting from the behavior of a "standard user", the number of hours of operation of the HVAC system may be varied and the influence of opening and closing the windows is considered.

5.5 – Integration of the measures at urban and district level

When considering the measures at urban and district scale, a literature survey was carried out. Among the BATs two ways to consider these aspects are taken into account: the employment od high SRI coatings in the buildings and eventually for the asphalt near the buildings is taken into account. This strategy allows for a significant reduction of the energy consumptions for cooling needs.
When considering the meaurese at district level, the literature survey carried out in the previous section and whose results are reported inTable 26, allows us one to draw the conclusions and to identify the possible measures to be adopted in the HAPPEN framework.

	Heating Demand	**Cooling demand**	**Electricity demand**	**Total consumption**
Cool Coatings	**SR from 0.2 to 0.65** Increase 0.25% to 9.5% (depends on climatic conditions)[4]	**SR from 0.2 to 0.65** Decrease 10.7% to 27% (depends on climatic conditions)[4]	-	-
	-	-	-	**SR from 0.1 to 0.4** Decrease 250Kwh/y (mild climates) to 1000kWh/y (very hot climates)[3]
Cool pavements	-	-	-	Decrease 1.5%[5]

Table 26- Conclusions fro the literature survey regarding the measures at the district level and the impact of the UHI

In particular, cool coatings and coatings with high SRI are forseen among the renovation measures,
With regard to the cool pavements, they are not considered in the first evaluation steps, they will be condidered in a framework of "beyond" retrofitting because they allow a decrease the total energy consumption of about 1.5% to be achieved.
When possible, district heating was also considered to improve not only the energy efficiency of the buildings, but also of the all neighbourhood.

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5.6 – Building Step 3-Outcomes of the analysis

From the analysis carried out ion the basis of the different contributions provided by all the Partners, an extremely heterogeneous Mediterranean framework is depicted, in particular:

-The solutions chosen are not universally appliable for all the countries;
In order to select properly all the renovation measures, the literature available due to the different projects and papers was taken into account. Howevever, it could be pointed out that the number of the renovation measures proposed in each paper or in each projects in the literature, especially for papers, is quite limited. For example, only one or two insulating mateials are chosen in a defined thickness or one or two different heating and cooling systems are taken into account.

-Not all the countries provided the costs for all the solutions proposed.
This aspect is crucial because**,** despite a common work on Mediterranean Countries, probably, due to the market conditions, climate, traditions, typical solutions and habits, several gaps have to be taken into consideration. These gaps make the comparison among the countries exptremely complex.

-Some countries provided their own solutions with their own costs.
This plays a key role because, if on one side there was an interesting enlargement of the solutions proposed, on the other side, the comparison opportunity has been compromised. This was particularly highlighted in case of the renovation measures for windows and for ventilation systems. In some cases, it was written in the previous paragraph that no comparison is available.

Therefore, as not all the countries provided the costs for all the solutions proposed and some countries provided their own solutions with their own costs, the results of this deliveralble refer exclusively to the values gathered among the Partners and the Task Leader and the WP leader are not responsible for the use of the values and it is not guaranteed that all the values reflect the actual values in all the Countries.

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5.7 Costs evaluation and Clusterization Criterion

In order to provide a comprehensive framework for the renovation measures considering all the partner contributions, a dedicated costs evaluation has to be carried out. Costs have to be clusterized, for all the renovation measures considering all the contributions. With reference to the literature, only a set of costs for the renovation measures, generally corresponding to one country, was investigated and few sets of solutions were considered and calculated as also explained in the previous paragraphs. In the HAPPEN Project, different Countries and different costs for all the renovation measures have to be taken into account. In order to manage this complexity and taking into account the outcomes of the analysis in the previous paragraph, this complexity has been managed by means of different hypothesis, in order to provide a unique solution. In particular:Some attempts were made:

1) choose the country, which is nearest to the average (e.g. with minimum deviation from the avg value), for all the solutions in each field (external wall...) But, how to choose the Country? The counting mechanism (i.e. to count how many times each country is nearest to the average) seems not be adequate, because we may have a country with the maximum solutions nearest to the average for external wall, for example, and another country nearest to the average for basement and this is misleading.
2) To choose costs of three countries which are representative for three different Med Zones, like Spain, Croatia and Cyprus and the three sets of costs corresponding to these three countries could be used. However, this solution is not adequate because it is not representative for all the countries.
3) To choose six sets of costs (each set corresponding to each Partner country), but it is not feasible, because costs for each country corresponding to each solution were not provided.
4) Starting from the average value of the costs, a deviation from the average value (plus or minus Δ€) is considered for each country. Although not all the countries have the whole number of solutions (e.g.one country has all the solutions and another country has a few number of solutions), this criterion seems to be the only one, which enables for the quantification of the "country effect" on costs. These percentages were implemented in order to evaluate the global deviation from the average costs and to have an estimation for each country in each field. These deviations are reported in Table 27.

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	Deviation from the average costs (%)					
	Italy	**Spain**	**Croatia**	**Greece**	**Cyprus**	**Slovenia**
External Walls	3.6	17.0	-14.6	-0.4	-1.2	-8.3
Roof and Ceilng	-26.3	-56.1	56.9	-32.2	19.9	66.4
Basement	-3.8	-11.9	101.3	6.9		-9.6
Windows	53.4	-30.4	-27.0	22.7	8.8	
Shadings	-45.4	-1.8	19.8	-23.6	63.7	-12.7
Thermal Bridges	0.2	-35.3	44.4	-7.0	-22.0	24.5
Heating and Cooling	-16.8	-2.6	52.2	-34.8	42.7	13.2
DHW	25.1	60.9	26.3	24.5	67.6	35.5
Ventilation		-33.0	69.3	-18.7		
RES	-3.6	62.6		31.1	-30.4	-21.6
Average (%)	-1.5	-3.0	36.5	-3.1	18.7	10.9

Table 27- Deviations from the average costs in each field

In conclusion, the average value of the costs for each renovation measurres is evaluated. Then, the percentage variation from the average value for each solution and for each country is determined.Finally the estimation of the costs variations for each Country is considered by calculating the average values of all the deviations of all the solutions, as depicted in Table 27.

5.8 - Building Step 4 – Final optimization of the abacus of the renovationmeasures

All the steps performed up to this point, allow for the definition of an abacus of the renovation measures characterized by a number of solutions in order of magniture of:

- 31 renovation measures for Ext Walls x
- 42 renovation measures for Roof element;
- 20 renovation measures for Basement
- 31 renovation measures for Glazing
- 6 renovation measures for Thermal Bridges
- 3 renovation measures for Ventilation
- 2 renovation measures for Air-tightness
- 24 renovation measures for HVAC

All these renovation measure yield, when gathered in packages of solutions, a number of 29,060,640 combinations which should be calculated for a single building in a specific climate, in order to assess the cost optimality. But the time to be employed for all these calculation is not compatible with the project duration and structure.

Therefore, a reduction of the number of the solutions was necessary. The reduction was performed according to the following assumptions:

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-the average Costs of the renovation measures for all MED Area were taken into account. A homogeneous solution, valid for the entire Med region, was obtained with a smaller global error than if the country with the lowest price for each solution or alternative criteria were chosen.

-when considering the materials and performances, the materials and solutions more widespread among the all the MED countries in the Consortium were selected, in order to consider all the Countries;

-with regard to the type of installation, the solutions were reduced in a proportional way with respect to the number of those inserted at the beginning and considering the same heterogeneity, e.g. taking into account the variety of solutions available (external, internal or air gap insulation). This method adopted for the reduction of the catalogue allows the consideration and the representability of all the types of solutions to be guaranteed.
On the basis of these three assumprtion the number of the renovation measures was reduced up to:
-12 renovation measures for Ext Walls;
- 10 renovation measures for Roof;
- 10 renovation measures for basement;
- 9 renovation measures for Glazing;
- 3 renovation measures forthermal bridges;
- 2 renovation measures for Ventilation;
- 2 renovation measures for Air-tightness
- 18 renovation measures for HVAC
After this reduction, 142,560 combinations of packages of renovation measures are now to be evaluated in phase of cost-optimal analysis.
In order to show the reduction of the renovation measures according to the above described criteria, the following tables -Table 28 to Table 36 are reported. It is important to point out that a first run of the calculation for the cost optimal packages of solutions allowed us to modify the equivalent air flow rate, because otherwise it could not be evaluated from the cost-optimal point of view.

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Code External Walls (EW)	Description	Typology	Insulation material	Thickness [cm]	Other (coating)	Therm conductivity [W/mK]	R [m2K/W]	Average costs
EW_1	E with 4 of EPS	E	EPS	4		0.036	1.1	€ 39.95
EW_2	E_8 of EPS	E	EPS	8		0.036	2.2	€ 44.00
EW_8	E_8 of GW	E	GW	8		0.034	2.4	€ 51.51
EW_3	E_12 of EPS	E	EPS	12		0.036	3.3	€ 48.94
EW_9	E_12 of GW	E	GW	12		0.034	3.5	€ 56.54
EW_27	IACI_3 of Expanded Perlite	IACI	Expanded Perlite	3		0.043	0.7	€ 9.88
EW_26	IACI_5 of RW	IACI	RW	5		0.034	1.5	€ 14.88
EW_28	IACI_5 of Expanded Perlite	IACI	Expanded Perlite	5		0.043	1.2	€ 12.16
EW_30	II_2 of AE and low emission coating	II	AE	2	low emission coating	0.014	1.4	€ 88.80
EW_0	No insulation	No insulation						
EW_19	V F_4 of EPS	V F	EPS	4		0.036	1.1	€ 155.02
EW_20	V F_8 of EPS	V F	EPS	8		0.036	2.2	€ 159.73

Table 28- Final optimization of the Abacus of the renovation measures- External Walls

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Code Basement (B)	Description	Typology	Insulation material	Thickness[cm]	Thermal conductivity [W/mK]	Thermal Resistance [m2K/W]	Average
B_2	I with 5 of LW_d cement based with Expanded Perlite	Insulation	LW_d cement based with Expanded Perlite	5	0.088	0.6	€ 21.05
B_16	Insulation with 2 of XPS or PU Panels	Insulation	XPS or PU Panels	2	0.028	0.71	€ 16.71
B_6	with 10 of light-weighted cement based with EPS	Insulation	light-weighted cement based with EPS	10	0.100	1.0	€ 37.47
B_8	Insulation with 10 of light-weighted cement based with Vermiculite	Insulation	light-weighted cement based with Vermiculite	10	0.080	1.3	€ 46.70
B_17	Insulation with 4 of XPS or PU Panels	Insulation	XPS or PU Panels	4	0.028	1.43	€ 19.85
B_14	Insulation with 15 of light-weighted cement based with Expanded Clay	Insulation	light-weighted cement based with Expanded Clay	15	0.090	1.7	€ 58.15
B_13	Insulation with 15 of light-weighted cement based with Vermiculite	Insulation	light-weighted cement based with Vermiculite	15	0.080	1.9	€ 63.30
B_18	Insulation with 6 of XPS or PU Panels	Insulation	XPS or PU Panels	6	0.028	2.14	€ 23.79
B_19	Insulation with 12 of XPS or PU Panels	Insulation	XPS or PU Panels	12	0.028	4.29	€ 18.00
B_0	No insulation	No insulation					

Table 29- Final optimization of the Abacus of the renovation measures- Basement

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Code Windows (W)	Description	Typology	Insulation material	Cavity Thickness	Frame kind	Uw [W/m2K]	g value [-]	Average costs
W_8	3 glasses window with low-ε with 1.6 cm of argon interspace and PVC	3 glasses window with low-ε	argon interspace	1.6 cm	PVC	0.6	0.26	€ 346.164
W_10	2 glasses window with low-ε with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)	2 glasses window with low-ε	argon interspace	1.6 cm	WOOD	1.1	0.59	€ 279.860
W_11	2 glasses window with low-ε with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)	2 glasses window with low-ε	argon interspace	1.6 cm	PVC	1.1	0.59	€ 269.571
W_13	Double windows with 2 glasses window with low-ε with 1.6 cm of air interspace	Double windows with 2 glasses window with low-ε	air interspace	1.6 cm	WOOD	1.4	0.58	€ 184.826
W_14	Double windows with 2 glasses window with low-ε with 1.6 cm of air interspace	Double windows with 2 glasses window with low-ε	air interspace	1.6 cm	PVC	1.4	0.58	€ 129.567
W_15	2 glasses window with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)	2 glasses window	argon interspace	1.6 cm	ALUMINIUM	2.6	0.77	€ 229.770
W_18	Double windows with 2 glasses with 1.6 cm of air interspace	Double windows with 2 glasses	air interspace	1.6 cm	ALUMINIUM	2.7	0.77	€ 62.105
W_19	Double windows with 2 glasses with 1.6 cm of air interspace	Double windows with 2 glasses	air interspace	1.6 cm	WOOD	2.7	0.77	€ 116.169
W_21	No replacement	No replacement						

Table 30 - Final optimization of the Abacus of the renovation measures- Windows

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Code Roof and celing (TR-FR)	Description	Typology	Insulation material	Thickness[cm]	Thermal resistance [m2K/W]	Average
TR_9	EI _ 0,5+1,5+0,5 of PU_F_S with 2 layers of WW	EI	PU_F_S with 2 layers of WW	0,5+1,5+0,5	0.04	€ 33.38
TR_13	EI _ 5 of Rockwool (RW)	EI	Rockwool (RW)	5	1.4	€ 25.87
FR_2	EI_ 5 of XPS	EI	XPS	5	1.5	€ 24.49
FR_3	EI_ 8 of XPS	EI	XPS	8	2.4	€ 28.78
TR_4	EI _ 12 of XPS	EI	XPS	12	3.8	€ 37.29
FR_8	II with 4 of Perlite	II	Perlite	4	0.9	€ 10.73
TR_22	II _ 2 of AE and low emission coating	II	AE	2	1.4	€ 88.80
TR_0	No insulation	No insulation			0	
TR_15	VR (5 cm air gap)+ EI _ 5 of XPS Panels	VR (5 cm air gap)+ EI	XPS Panels	5	1.5	€ 38.58
TR_16	VR (5 cm air gap)+ EI _ 8 of XPS Panels	VR (5 cm air gap)+ EI	XPS Panels	8	2.4	€ 43.36
TR_17	VR (5 cm air gap)+ EI _ 12 of XPS Panels	VR (5 cm air gap)+ EI	XPS Panels	12	3.6	€ 54.56

Table 31 Final optimization of the Abacus of the renovation measures- Roof

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Code Shading (S)	Description	Typology	Solar factor	Average
S_0	No replacement	No replacement		
S_1	Overhang - vertical 50 0,29 and 70	Overhang – vertical	0.29	€ 90.00
S_2	Overhang - horizontal 50 0,29 and 70	Overhang – horizontal	0.29	€ 93.33

Table 32- Final optimization of the Abacus of the renovation measures- Shading

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Code Thermal Bridges (TB)	Typology	Thickness [cm]	Thermal Conductivity [W/mK]	Thermal Resistance [m2K/W]	Linear Thermal Trasmittance Reduction		Average [€/m]
					Perimeter	**Window**	
TB_0	No replacement						
TB_1	Insulation of thermal bridges with panels made of PUR injected in all the Thermal-Bridges to reduce the TB at 40%-50%	2	0.09	0.22	50%	0%	15 €
TB_2	Insulation of thermal bridges with panels made of PUR injected in all the Thermal-Bridges to reduce the TB at 40%-50% + go to 0.05 W/mK in the Glazings	2	0.05	0.40	50%	0.95	15 €

Table 33- Final Optimization of the Abacus of the renovation Measures- Thermal Bridges

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Code Heating and cooling HC)	Description	Energy vector	Efficiency	SCOP	SEER	combined DHW?	Average
HC_2	Wall-mounted gas boiler <= 25 Kw SFH	Natural gas	0.96	-	-	Yes	2,057.65 €
HC_3	Floor-standing gas boiler > 25 kW [INOX] MFH	Natural gas	0.96	-	-	Yes	3,057.32 €
HC_5	Wall-mounted condensing gas boiler <= 25 Kw SFH	Natural gas	1.05	-	-	Yes	2,602.63 €
HC_7	Floor-standing condensing gas boiler <= 25 Kw SFH	Natural gas	1.05	-	-	Yes	3,369.25 €
HC_9	Floor-standing condensing gas boiler: 200to250 Kw MFH	Natural gas	1.05	-	-	No	19,336.27 €
HC_10	Installation of an electric air-air HP - multisplit <= 15 kW SFH	Electricity	-	4,5	4	No	6,530.62 €
HC_11	Installation of an electric air-air HP - multisplit <= 15 kW - only cooling SFH	Electricity	-			No	5,000.00 €
HC_14	Installation of an electric air-water HP - 100to150kW MFH [10 apartments]	Electricity	-	4	3	No	89,792.23 €
HC_17	GSHP - Ground Source Heat Pump - 200to250kW MFH [15 apartments]	Electricity	-	4,33		No	204,173.94 €
HC_18	Biomass boiler SFH	Woodchips or pellets	0.876	-	-	-	978.60 €

Table 34- Final Optimization of the Abacus of the renovation Measures- HVAC Systems

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Code Domestic Hot water (DHW)	Description	Energy vector	Efficiency	COP	Average
DHW_0	Combined with Heating				
DHW_1	Electric boiler – SFH	Electricity	0.99		958 €
DHW_2	Electric boilers [20 apartments]	Electricity	0.99		8,660 €
DHW_3	Gas boiler with high efficiency	Natural gas			2,383 €
DHW_4	Gas boiler with high efficiency [20 apartments]	Natural gas			13,009 €
DHW_5	Solar thermal	-		-	998 €
DHW_6	air-to-water Electric Heat pump – SFH	Electricity	-	4.5	3,270 €
DHW_7	air-to-water Electric Heat pump - MFH [20 apartments]	Electricity	-	4.5	31,500 €

Table 35- Final Optimization of the Abacus of the renovation Measures- DHW

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Code Ventilation (V)	Ventilation	equivalent air flow (n air change/h - m3/h)	Average
V_1	Controlled VMC	0.42	2,095 €
V_2	Controlled with thermal exchange (Heat Recovery System)	0.24	5,245 €
V_3	Free Night ventilation	10	166 €
Code	**Air tightness**	**n50**	**Average [€/m]**
A_1	Soudal window system- RAL System for airtightness	3	17.00 €
A_2	Passive house level	0.5	40.00 €

Table 36- Final Optimization of the Abacus of the renovation Measures- Ventilation

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	Italy	Spain	Croatia	Greece	Cyprus	Slovenia	France	Average
Electricity [€/kWh]	0,128	0,25	0,132	0,095	0,174	0,160	0,158	0,157
Natural Gas [€/kWh]	0,190	0,08	0,049	0,062		0,060	0,079	0,087

Table 37- Energy Prices

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6 THE ABACUS OF THE RENOVATION MEASURES BUILT IN THREE STEPS

In the previous paragraph a comprehensive description of the building renovation measures to be applied in each field was depicted. However, the single measures have to be grouped in packages of measures or packages of solutions in order to be more effective. A solution should be a combination of a certain number of renovation measures, one for each field considered.
Unfortunaltely, the extremely high number of combinations individuated in the previous paragraph, did not allow for the construction of a final abacus or matrix of renovation measures, whose size is 12x12 (as written in the Grant Agreement), in which the terms "renovation measures" stand for "packages of solutions", which are renovation measures assembled, considering each field. The determination of a defined number of pakages of renovation measures will be performed in the future, when the cost optimality of all the packages of the solution will be performed. At this stage, the approach employed to build the Abacus of the packages of solutions in three step is explained.

6.1 Step one: construction of a solution

Starting from the renovation measures individuated, in Paragraph 5, each solution is built by taking into account 12 compatible renovation measures, one for each field, as depicted, for example, in Figure 53. One renovation measure in each field is assembled, together with the others, to build a solution.

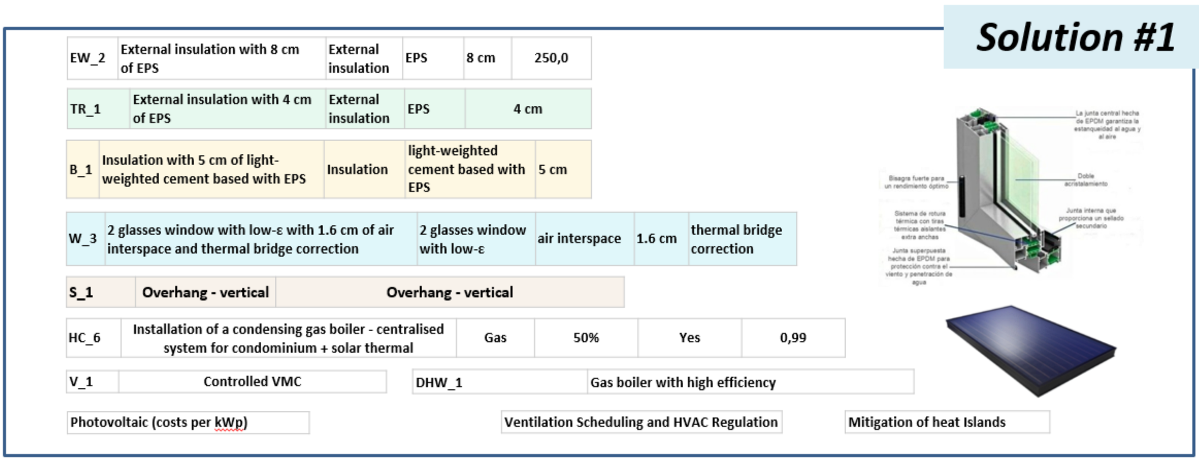

Figure 53- Example of the construction procedure for the solution, starting from the sigle renovation measures in each field

6.2 Step 2: Contrustion of a package of solutions

After the construction of the solutions, a comprehensive set of 12 solutions (S) will provide a «Package of solutions». Each Package is specific for each reference building and for each climate.

Figure 54- Example of the construction procedure for the one package of solutions

6.3 Step 3: Abacus of the renovation measres where renovation measures stand for packages of solutions

Then as a final stage, a comprehensive set of 12 Packages of solutions (P) will provide the Abacus of Renovation Measures, assembled with a holistic approach, considering also the non-technical aspects as behavioural issues and measures to be applied in the urban environment at district scale

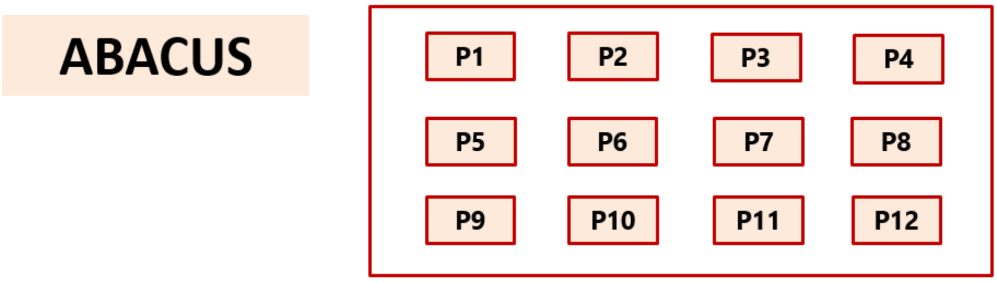

Figure 55--Cconstruction procedure for the final abacus conttitued by the Packages of solutions

7 CONCLUSIONS AND RECOMMENDATIONS

This deliverable is aimed at providing a comprehensive set of integrated renovation measures be assembled in an Abacus or matrix with a holistic approach, considering country-specific peculiarities, combined actions on the building envelope, technological systems and facilities, and non-technological aspects as behavioural issues and measures at urban and district scale. For this purpose, starting from the literature survey, the HAPPEN approach to the Abacus of renovation measures is described. The BATs available in each field have been investigated and the Partner Countries Contributions played a key-role in order to build a common Mediterranean framework of the renovation measures. The different steps for the fine-tuning of the abacus, are presented.

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The analysis carried out has highlighted that, despite a common Mediterranean working framework,

-the solutions chosen are not universally appliable for all the counties;

-Not all the countries provided the costs for all the solutions proposed.

-Some countries provided their own solutions with their own costs.

Moreover, the number of the renovation measures for all the fields considered, is extremely high, in order of magnitude of 142000, has not allowed for the construction of a Matrix of Packages of Solutions. The definition of a limited number of packages of Solutions will be performed in the next phase, during the Cost optimal evaluation. In that case, each set of the renovation measures is assembled and the optimization will be done in terms of the minimum investment and minimum amortization period that will lead to optimal packages for step-by step refurbishment in order to develop a MedZEB step-by-step technical approach, as an alternative to traditional refurbishment approach in order to foster the market uptake.

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9 ANNEX A PARTNER CONTRIBUTIONS

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9.1 Spain

Code	Description	Typology	Insulation material	Thickness [cm]	Other (coating)	Therm conductivity [W/mK]	R [m2K/W]	emissivity	Solar Reflectance Index (external)	SPAIN Cost [€/m2]: materials + installation
EW_0	No insulation	No insulation								
EW_1	ETICS with 4 of EPS	ETICS	EPS	4		0,036	1,1			€ 54,24
EW_2	ETICS with 8 of EPS	ETICS	EPS	8		0,036	2,2			€ 60,98
EW_3	ETICS with 12 of EPS	ETICS	EPS	12		0,036	3,3			€ 67,70
EW_4	ETICS with 4 of RW	ETICS	RW	4		0,040	1,0			€ 52,10
EW_5	ETICS with 8 of RW	ETICS	RW	8		0,040	2,0			€ 70,99
EW_6	ETICS with 12 of RW	ETICS	RW	12		0,040	3,0			€ 73,01
EW_7	ETICS with 4 of GW	ETICS	GW	4		0,034	1,2			€ 58,21
EW_8	ETICS with 8 of GW	ETICS	GW	8		0,034	2,4			€ 60,17
EW_9	ETICS with 12 of GW	ETICS	GW	12		0,034	3,5			€ 61,15
EW_10	ETICS with 4 of EPS and high SRI coating	ETICS	EPS	4	high SRI coating	0,036	1,1	0,51	0,87	€ 66,80
EW_11	ETICS with 8 of EPS and high SRI coating	ETICS	EPS	8	high SRI coating	0,036	2,2	0,51	0,87	€ 73,54
EW_12	ETICS with 12 of EPS and high	ETICS	EPS	12	high SRI coating	0,036	3,3	0,51	0,87	€ 80,26

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	SRI coating									
EW_13	ETICS with 4 of RW and high SRI coating	ETICS	RW	4	high SRI coating	0,040	1,0	0,51	0,87	€ 64,66
EW_14	ETICS with 8 of RW and high SRI coating	ETICS	RW	8	high SRI coating	0,040	2,0	0,51	0,87	€ 83,55
EW_15	ETICS with 12 of RW and high SRI coating	ETICS	RW	12	high SRI coating	0,040	3,0	0,51	0,87	€ 85,57
EW_16	ETICS with 4 of GW and high SRI coating	ETICS	GW	4	high SRI coating	0,034	1,2	0,51	0,87	€ 70,77
EW_17	ETICS with 8 of GW and high SRI coating	ETICS	GW	8	high SRI coating	0,034	2,4	0,51	0,87	€ 72,73
EW_18	ETICS with 12 of GW and high SRI coating	ETICS	GW	12	high SRI coating	0,034	3,5	0,51	0,87	€ 73,71
EW_19	Ventilated Facade with 4 of EPS	Ventilated Facade	EPS	4		0,036	1,1			€ 216,26
EW_20	Ventilated Facade with 8 of EPS	Ventilated Facade	EPS	8		0,036	2,2			€ 219,30
EW_21	Ventilated Facade with 4 of RW	Ventilated Facade	RW	4		0,040	1,0			€ 226,24
EW_22	Ventilated Facade with 8 of RW	Ventilated Facade	RW	8		0,040	2,0			€ 218,69
EW_23	Internal/Air chamber insultation with	Internal/Air chamber insultation	XPS	3		0,033	0,9			€ 9,62

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	3 of XPS									
EW_24	Internal/Air chamber insultation with 5 of XPS	Internal/Air chamber insultation	XPS	5		0,033	1,5			€ 14,32
EW_25	Internal/Air chamber insultation with 3 of RW	Internal/Air chamber insultation	RW	3		0,034	0,9			
EW_26	Internal/Air chamber insultation with 5 of RW	Internal/Air chamber insultation	RW	5		0,034	1,5			
EW_27	Internal/Air chamber insultation with 3 of Expanded Perlite	Internal/Air chamber insultation	Expanded Perlite	3		0,043	0,7			€ 9,29
EW_28	Internal/Air chamber insultation with 5 of Expanded Perlite	Internal/Air chamber insultation	Expanded Perlite	5		0,043	1,2			
EW_29	Internal insultation with 2 cm of AEROGEL	Internal insultation	AEROGEL	2		0,014	1,4			
EW_30	Internal insultation with 2 cm of AEROGEL and low emission coating	Internal insultation	AEROGEL	2	low emission coating	0,014	1,4			

Table 38- External Walls Spain

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

Code	Description	Typology	Insulation material	Thickness[cm]	Thermal conductivity [W/mK]	Thermal resistance [m2K/W]	Emissivity	Solar Reflectance Index (external)	SPAIN Cost (materials+Installation) [€/m2]
TR_0	No insulation	No insulation							
TR_1	External insulation with 3 of XPS	External insulation	XPS	3	0,032	0,9			€ 8,15
TR_2	External insulation with 5 of XPS	External insulation	XPS	5	0,032	1,6			€ 10,94
TR_3	External insulation with 8 of XPS	External insulation	XPS	8	0,032	2,5			€ 16,32
TR_4	External insulation with 12 of XPS	External insulation	XPS	12	0,032	3,8			€ 22,85
TR_6	External insulation with 3 of PU Foam	External insulation	PU Foam	3	0,028	1,1			€ 10,61
TR_7	External insulation with 5 of PU Foam	External insulation	PU Foam	5	0,028	1,8			€ 12,85
TR_8	External insulation with 8 of PU Foam	External insulation	PU Foam	8	0,028	2,9			€ 17,17
TR_9	External insulation with 0,5+1,5+0,5 of PU	External insulation	PU Foam Sintered with 2 layers of WW	0,5+1,5+0,5	0,661	0,04			-

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	Foam Sintered with 2 layers of WW								
TR_10	External insulation with 0,5+2,5+0,5 of PU Foam Sintered with 2 layers of WW	External insulation	PU Foam Sintered with 2 layers of WW	0,5+2,5+0,5	1,375	0,03			-
TR_11	External insulation with 0,5+4+0,5 of PU Foam Sintered with 2 layers of WW	External insulation	PU Foam Sintered with 2 layers of WW	0,5+4+0,5	1,911	0,03			-
TR_12	External insulation with 0,5+6,5+0,5 of PU Foam Sintered with 2 layers of WW	External insulation	PU Foam Sintered with 2 layers of WW	0,5+6,5+0,5	2,446	0,03			-
TR_13	External Insulation with 5 of Rockwool (RW)	External Insulation	Rockwool (RW)	5	0,035	1,4			€ 15,50
TR_14	External Insulation with 8 of Rockwool (RW)	External Insulation	Rockwool (RW)	8	0,035	2,3			€ 22,91
TR_15	Ventilated roof (5 cm air gap) with external insultation with 5	Ventilated roof (5 cm air gap) with	XPS Panels	5	0,033	1,5			€ 10,25

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	of XPS Panels	external insultation							
TR_16	Ventilated roof (5 cm air gap) with external insultation with 8 of XPS Panels	Ventilated roof (5 cm air gap) with external insultation	XPS Panels	8	0,033	2,4			€ 14,45
TR_17	Ventilated roof (5 cm air gap) with external insultation with 12 of XPS Panels	Ventilated roof (5 cm air gap) with external insultation	XPS Panels	12	0,033	3,6			€ 17,25
TR_18	Internal insulation with 2 of RW	Internal insulation	RW	2	0,035	0,6			-
TR_19	Internal insulation with 4 of RW and low emission coating	Internal insulation	RW	4	0,035	1,1	0,51		€ 13,40
TR_20	Internal insulation with 4 of RW and low emission coating	Internal insulation	RW	4	0,035	1,1	0,51		€ 13,40
TR_21	Internal insulation with 2 of AEROGEL	Internal insulation	AEROGEL	2	0,014	1,4			-

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TR_22	Internal insulation with 2 of AEROGEL and low emission coating	Internal insulation	AEROGEL	2	0,014	1,4	0,51		-
FR_1	External insutation with 3 of XPS	External insutation	XPS	3	0,034	0,9			€ 7,45
FR_2	External insulation with 5 of XPS	External insulation	XPS	5	0,034	1,5			€ 10,25
FR_3	External insulation with 8 of XPS	External insulation	XPS	8	0,034	2,4			€ 14,45
FR_4	External insulation with 5 of GW	External insulation	GW	5	0,037	1,4			-
FR_5	External insulation with 8 of GW	External insulation	GW	8	0,037	2,2			-
FR_6	External insulation with 12 of GW	External insulation	GW	12	0,037	3,2			-
FR_7	Internal insulation with 2 of Perlite and low emission coating	Internal insulation	Perlite	2	0,043	0,5	0,51		€ 9,29
FR_8	Internal insulation with 4 of Perlite	Internal insulation	Perlite	4	0,043	0,9			€ 9,29
FR_9	Internal	Internal	Perlite	4	0,043	0,9	0,51		€ 9,29

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	insulation with 4 of Perlite and low emission coating	insulation							
FR_10	Internal insulation with 2 of GW and low emission coating	Internal insulation	GW	2	0,037	0,5	0,51		-
FR_11	Internal insultation with 4 of GW	Internal insultation	GW	4	0,037	1,1			-
FR_12	Internal insultation with 4 of GW and low emission coating	Internal insultation	GW	4	0,037	1,1	0,51		-
FR_13	Internal insultation with 2 of AEROGEL	Internal insultation	AEROGEL	2	0,014	1,4			-
FR_14	Internal insultation with 2 of AEROGEL and low emission coating	Internal insultation	AEROGEL	2	0,014	1,4	0,51		-
FR_15	External insultation with 5 cm of XPS and high SRI coating	External insultation	XPS	5	0,032	1,6		0,87	-
FR_16	External insultation with 8 cm of XPS and high SRI coating	External insultation	XPS	8	0,032	2,5		0,87	-
FR_17	External	External	XPS	12	0,032	3,8		0,87	-

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	insultation with 12 cm of XPS and high SRI coating	insultation							
FR_21	External insultation with 5 cm of GW and high SRI coating	External insultation	GW	5	0,037	1,4		0,87	-
FR_22	External insultation with 8 cm of GW and high SRI coating	External insultation	GW	8	0,037	2,2		0,87	-
FR_23	External insultation with 12 cm of GW and high SRI coating	External insultation	GW	12	0,037	3,2		0,87	-

Table 39- Roof and Ceiling_Spain

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

Code	Description	Typology	Insulation material	Thickness[cm]	Thermal conductivity [W/mK]	Thermal Resistance [m2K/W]	SPAIN Costs [€/m2]
B_0	No insulation	No insulation					
B_1	Insulation with 5 of light-weighted cement based with EPS	Insulation	light-weighted cement based with EPS	5	0,100	0,5	€ 16,15
B_2	Insulation with 5 of light-weighted cement based with Expanded Perlite	Insulation	light-weighted cement based with Expanded Perlite	5	0,088	0,6	
B_3	Insulation with 5 of light-weighted cement based with Vermiculite	Insulation	light-weighted cement based with Vermiculite	5	0,080	0,6	
B_4	Insulation with 5 of light-weighted cement based with Expanded Clay	Insulation	light-weighted cement based with Expanded Clay	5	0,090	0,6	
B_5	#RIF!	Insulation	light-weighted cement based with Expanded Glass	5	0,300	0,2	€ 36,00
B_6	Insulation with 10 of light-weighted cement based with EPS	Insulation	light-weighted cement based with EPS	10	0,100	1,0	€ 29,67
B_7	Insulation with 10 of light-weighted cement based with Expanded Perlite	Insulation	light-weighted cement based with Expanded Perlite	10	0,088	1,1	
B_8	Insulation with 10 of light-weighted cement based with Vermiculite	Insulation	light-weighted cement based with Vermiculite	10	0,080	1,3	
B_9	Insulation with 10 of light-weighted cement based with Expanded Clay	Insulation	light-weighted cement based with Expanded Clay	10	0,090	1,1	
B_10	#RIF!	Insulation	light-weighted cement based with Expanded Glass	10	0,300	0,3	€ 70,42
B_11	Insulation with 15 of light-weighted cement based with EPS	Insulation	light-weighted cement based with EPS	15	0,100	1,5	€ 43,19
B_12	Insulation with 15 of light-weighted cement based with Expanded Perlite	Insulation	light-weighted cement based with Expanded Perlite	15	0,088	1,7	

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B_13	Insulation with 15 of light-weighted cement based with Vermiculite	Insulation	light-weighted cement based with Vermiculite	15	0,080	1,9	
B_14	Insulation with 15 of light-weighted cement based with Expanded Clay	Insulation	light-weighted cement based with Expanded Clay	15	0,090	1,7	
B_15	#RIF!	Insulation	light-weighted cement based with Expanded Glass	15	0,300	0,5	€ 104,85
B_16	#RIF!	Insulation	XPS or PU Panels	2	0,028	0,71	€ 12,03
B_17	#RIF!	Insulation	XPS or PU Panels	4	0,028	1,43	€ 13,30
B_18	#RIF!	Insulation	XPS or PU Panels	6	0,028	2,14	€ 14,60

Table 40-basement Spain

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

Code	Description	Typology	Insulation material	Cavity Thickness	Frame kind	Uw [W/m2K]	g value [-]	Uf (W/M2k)	SPAIN Cost [€/m2]: materials + replacement
W_0	No replacement	No replacement							
W_1	Double windows with 2 glasses with 1.6 cm of air interspace	Double windows with 2 glasses	air interspace	1.6 cm	ALUMINIUM	2,7	0,77	3,5	62,11 €
W_2	Double windows with 2 glasses window with low-ε with 1.6 cm of air interspace	Double windows with 2 glasses window with low-ε	air interspace	1.6 cm	ALUMINIUM	1,4	0,58	3,5	149,67 €
W_3	2 glasses window with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)	2 glasses window	argon interspace	1.6 cm	ALUMINIUM	2,6	0,77	3,5	69,08 €
W_4	2 glasses window with low-ε with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)	2 glasses window with low-ε	argon interspace	1.6 cm	ALUMINIUM	1,1	0,59	3,5	156,64 €
W_5	3 glasses window with 1.6 cm of argon interspace and ALUMINIUM	3 glasses window	argon interspace	1.6 cm	ALUMINIUM	0,6	0,53	3,5	119,57 €

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W_6	3 glasses window medium-ε with 1.6 cm of argon interspace and ALUMINIUM	3 glasses window medium-ε	argon interspace	1.6 cm	ALUMINIUM	0,6	0,54	3,5	
W_7	3 glasses window with low-ε with 1.6 cm of argon interspace and ALUMINIUM	3 glasses window with low-ε	argon interspace	1.6 cm	ALUMINIUM	0,6	0,26	3,5	315,45 €
W_8	Double windows with 2 glasses with 1.6 cm of air interspace	Double windows with 2 glasses	air interspace	1.6 cm	WOOD	2,7	0,77	1,43	82,34 €
W_9	Double windows with 2 glasses window with low-ε with 1.6 cm of air interspace	Double windows with 2 glasses window with low-ε	air interspace	1.6 cm	WOOD	1,4	0,58	1,43	169,90 €
W_10	2 glasses window with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)	2 glasses window	argon interspace	1.6 cm	WOOD	2,6	0,77	1,43	89,31 €
W_11	2 glasses window with low-ε with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)	2 glasses window with low-ε	argon interspace	1.6 cm	WOOD	1,1	0,59	1,43	176,87 €
W_12	3 glasses window with 1.6 cm of argon interspace and WOOD	3 glasses window	argon interspace	1.6 cm	WOOD	0,6	0,53	1,43	139,80 €
W_13	3 glasses window with 1.6	3 glasses window	argon	1.6 cm	WOOD	0,6	0,54	1,43	

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	cm of argon interspace and WOOD		interspace						
W_14	3 glasses window with low-ε with 1.6 cm of argon interspace and WOOD	3 glasses window with low-ε	argon interspace	1.6 cm	WOOD	0,6	0,26	1,43	335,68 €
W_15	Double windows with 2 glasses with 1.6 cm of air interspace	Double windows with 2 glasses	air interspace	1.6 cm	PVC	2,7	0,77	1,3	59,43 €
W_16	Double windows with 2 glasses window with low-ε with 1.6 cm of air interspace	Double windows with 2 glasses window with low-ε	air interspace	1.6 cm	PVC	1,4	0,58	1,3	146,99 €
W_17	2 glasses window with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)	2 glasses window	argon interspace	1.6 cm	PVC	2,6	0,77	1,3	66,40 €
W_18	2 glasses window with low-ε with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)	2 glasses window with low-ε	argon interspace	1.6 cm	PVC	1,1	0,59	1,3	153,96 €
W_19	3 glasses window with 1.6 cm of argon interspace and PVC	3 glasses window	argon interspace	1.6 cm	PVC	0,6	0,53	1,3	116,89 €
W_20	3 glasses window with 1.6 cm of argon interspace and PVC	3 glasses window	argon interspace	1.6 cm	PVC	0,6	0,54	1,3	

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W_21	3 glasses window with low-ε with 1.6 cm of argon interspace and PVC	3 glasses window with low-ε	argon interspace	1.6 cm	PVC	0,6	0,26	1,3	312,77 €
W_22	3 glasses window with 1.8 cm of air interspace	3 glasses window	air interspace	1.8 cm	ALUMINIUM				-
W_23	3 glasses window with 1.8 cm of air interspace	3 glasses window	air interspace	1.8 cm	ALUMINIUM				-
W_24	3 glasses window with low-ε with 1.8 cm of air interspace	3 glasses window with low-ε	air interspace	1.8 cm	ALUMINIUM				-
W_25	3 glasses window with 1.8 cm of air interspace	3 glasses window	air interspace	1.8 cm	WOOD				-
W_26	3 glasses window with 1.8 cm of air interspace	3 glasses window	air interspace	1.8 cm	WOOD				-
W_27	3 glasses window with low-ε with 1.8 cm of air interspace	3 glasses window with low-ε	air interspace	1.8 cm	WOOD				-
W_28	3 glasses window with 1.8 cm of air interspace	3 glasses window	air interspace	1.8 cm	PVC				-
W_29	3 glasses window with 1.8 cm of air interspace	3 glasses window	air interspace	1.8 cm	PVC				-
W_30	3 glasses window with low-ε with 1.8 cm of air interspace	3 glasses window with low-ε	air interspace	1.8 cm	PVC				-

Table 41- Windows Spain

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

Description	Typology	Solar factor ? / DeltaR ?	SPAIN Cost [€/m2]
No replacement	No replacement		
Overhang - vertical 50 0.29	Overhang - vertical	0.29	90.00 €
Overhang - horizontal 50 0.29	Overhang - horizontal	0.29	90.00 €

Table 42- Shadings Spain

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

	A	B	C	D	E	F	G	H	I	J
1	Code	Typology	Thickness [cm]	Thermal Conductivity [W/mK]	Thermal Resistance [m2K/W]	Linear Thermal Trasmittance [W/mK]			ITALY Cost [€/m	SPAIN Cost [€/m]
2						Internal	External	Overall Internal		
3	TB_0	No replacement								
4	TB_1	Insulation of thermal bridges with panels made of PUR injected in the slabs to go from 1.01 to 0.6 for the Façade-Slabs TB	2	0.09	0.22	0.6			€ 13.78	8.63 €
5	TB_2	Insulation of thermal bridges with panels made of mineralized wood wool and bound with high-strength cement	3	0.09	0.33	0.25			€ 15.48	11.37 €
6	TB_3	Insulation of thermal bridges with application on kerbs, lintels, veils, pillars, etc. of polystyrene sheet strips extruded foam, rough surface without skin	3	0.033	0.91	0.35			€ 13.06	12.27 €
7	TB_4	Insulation of thermal bridges with application between windows and facades	5	0.035	1.43	0.05			€ 17.14	5.83 €
8	TB_5	Insulation of thermal bridges on vertical and horizontal structures in phase of the casting, realized with application on the formworks of panels in wood wool mineralized with high temperature magnesite;	3.5	0.094	0.37	?			€ 26.10	
9	TB_6									
10	TB_7									
11	TB_8_Roofs_R5					0.6	0.8	0.8		11
12	TB_9_Roofs_R9					0.15	-0.05	0.15		11
13	TB_10_Roofs_R11					0.25	0.05	0.25		11
14	TB_11_Balconies_B3					1	0.9	0.9		11
15	TB_12_Corners_C5					-0.15	0.05	-0.15		11
16	TB_13_Corners_C1					0.15	-0.05	0.15		11
17	TB_14_Corners_C7					-0.05	0.15	-0.05		11
18	TB_15_Intermediate_Floors_IF1					0.1	0	0		11
19	TB_16_Intermediate Floor_IF8					0.6	0.45	0.45		11
20	TB_17_Internal Walls_IW1					0.1	0	0		11
21	TB_18_Slab-on-ground floors_GF 5					0.75	0.6	0.75		11
22	TB_19_Slab-on-groud floors_GF7					0.1	-0.05	0.1		11
23	TB_20_Slab-on-ground floors_GF 13					0.8	0.6	0.8		11
24	TB_21_Slab-on-groud floors_GF15					0.1	0.1	0.1		11
25	TB_22_Pillars_P1					1.3	1.3	1.3		14
26	TB_22_Pillars_P3					1.15	1.15	1.15		14
27	TB23_Windows and openings_W1					0	0	0		7
28	TB_24_Windows and openings_W6					0.1	0.1	0.1		7
29	TB25_Windows and openings_W11					0	0	0		7
30	TB_26_Windows and					0.1	0.1	0.1		7
31	TB27_Windows and openings_W15					0	0	0		7
32	TB_28_Windows and					0.2	0.2	0.2		7

Table 43- Thermal Bridges Spain

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

	Description	Energy vector	Efficiency	COP	SEER	combined DHW?	SFH-Single dwelling (costs calculated per single apartment)	MFH	SPAIN / Cost [€] - only for equipment procurement & installation & auxiliaries
HC_1	Wall-mounted gas boiler <= 25 kW - without DHW	Natural gas	0,96	-	-	No	x		2.357,16 €
HC_2	Wall-mounted gas boiler <= 25 kW	Natural gas	0,96	-	-	Yes	x		2.415,30 €
HC_3	Floor-standing gas boiler > 25 kW [INOX]	Natural gas	0,96	-	-	Yes		x	3.071,97 €
HC_4	Wall-mounted condensing gas boiler <= 25 kW - without DHW	Natural gas	1,05	-	-	No	x		2.357,16 €
HC_5	Wall-mounted condensing gas boiler <= 25 kW	Natural gas	1,05	-	-	Yes	x		2.415,30 €
HC_6	Floor-standing condensing gas boiler <= 25 kW- without DHW	Natural gas	1,05	-	-	No	x		3.071,97 €
HC_7	Floor-standing condensing gas boiler <= 25 kW	Natural gas	1,05	-	-	Yes	x		2.623,17 €
HC_8	Floor-standing condensing gas boiler: 100-150 kW	Natural gas	1,05	-	-	No		x	9.702,27 €

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

HC_9	Floor-standing condensing gas boiler: 200-250 kW	Natural gas	1,05	-	-	No		x	18.241,71 €
HC_10	Installation of an electric air-air HP - multisplit <= 15 kW	Electricity	-	4,5	4	No	x		3.474,94 €
HC_11	Installation of an electric air-air HP - multisplit <= 15 kW - only cooling	Electricity	-	-	4	No	x		
HC_12	Installation of an electric air-water HP <= 15kW - without DHW	Electricity	-	4,5	4	No	x		
HC_13	Installation of an electric air-water HP <= 25kW	Electricity	-	4,5	4	No	x		3.306,82 €
HC_14	Installation of an electric air-water HP - 100-150kW	Electricity	-	4	3	No		x	
HC_15	Installation of an electric air-water HP - 200-250kW	Electricity	-	4	3	No		x	-
HC_16	GSHP - Ground Source Heat Pump - 100-150kW	Electricity	-	4,29		No		x	64.177,04 €
HC_17	GSHP - Ground Source Heat Pump - 200-250kW	Electricity	-	4,33		No		x	111.593,42 €

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

HC_18	Biomass boiler	Woodchips or pellets	0,876		-		x		2.534,40 €
HC_19	Biomass boiler	Woodchips or pellets		-	-			x	2.534,40 €
HC_20	MicroCHP - Gas turbine	Gas	0,8						1050 €/kW
HC_21	MicroCHP - Internal combustion engine	Natural gas/Diesel							-
HC_22	District heating								-
HC_23	Absorption chiller + Solar thermal	RES							-
HC_24	Microtrigeneration with internal combustion engine + Absorption chiller	Natural gas/Diesel							-

Table 44- HVAC Spain

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

Description	Energy vector	Efficiency	COP	SFH-Single dwelling (costs calculated per single apartment)	MFH	SPAIN / Cost [€/UFR] - only for equipment procurement & installation
Combined with Heating				x	x	
Electric boiler - SFH	Electricity	0.99		x		2,106.02 €
Electric boilers [20 apartments]	Electricity	0.99			x	15,180.00 €
Gas boiler with high efficiency	Natural gas			x		2,415.30 €
Gas boiler with high efficiency [20 apartments]	Natural gas				x	-
Solar thermal				x	x	1,429.20 €
air-to-water Electric Heat pump - SFH	Electricity	-	4.5	x		1,150.00 €
air-to-water Electric Heat pump - MFH [20 apartments]	Electricity	-	4.5		x	-

Table 45- DHW- Spain

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

Ventilation	equivalent air flow (n air change/h - m3/h)	SPAIN Cost [€]
Controlled VMC	0.42	220.48 €
Controlled with thermal exchange (Heat Recovery System)	0.6	3,762.00 €
Free cooling- Night ventilation	10	152.70 €
Air tightness	**n50**	**SPAIN Cost [€/m]**
Soudal window system	3	16.00 €
Passive house solution	0.5	?

Table 46- Ventilation Spain

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

Code	RES electricity	Technical Characteristics			SPAIN Cost [€/kW]: materials + installation
RES_E_1	Photovoltaic (costs per kWp - from 1 kW up to 7 kWp)	1-7 kWp			€ 5,708.54
RES_E_2	Photovoltaic (costs per kWp - from 7 kW up to 20 kWp)	7-20 kWp			€ 9,658.54
RES_E_3	Photovoltaic (costs per kWp - from 21 kW up to 50 kWp)	21-50 kWp			-
Code	**RES thermal**	**Technical Characteristics**	**SFH or MFH**	**Notes**	-
RES_T_1	Biomass (woodchips or pellets generators) (cost in kWt)	efficiency 0,9	SFH		-
RES_T_2	Solar thermal (cost per m2)	% DHW covered (e.g. 50% Spain)			-
RES_T_3	Geothermal (HP - cost per kWt)_Ground-Water System	COP / EER 4,5 /5	SFH	Power Needed 8 kW soil efficiency 40 W/mK	€ 11,859.25
RES_T_4	Geothermal (HP - cost per kWt)_Ground-Water System	COP / EER 4,5 /5	MFH	Power Needed 31 kW	-
RES_T_5	Geothermal (HP - cost per kWt)_Water-Water System	COP / EER 4 /5	SFH	Power Needed 8 kW soil efficiency 40 W/mK	-
RES_T_6	Geothermal (HP - cost	COP / EER 4 /5	MFH	Power Needed 31 kW	-

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	per kWt)_Water-Water System				

Table 47-RES Spain

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9.1.1 Energy Prices

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9.2 Croatia

Code	Description	Typology	Insulation material	Thickness [cm]	Other (coating)	Therm conductivity [W/mK]	R [m2K/W]	emissivity	Solar Reflectance Index (external)	Croatia materials + installation
EW_0	No insulation	No insulation								
EW_1	ETICS with 4 of EPS	ETICS	EPS	4		0.036	1.1			€ 23.44
EW_2	ETICS with 8 of EPS	ETICS	EPS	8		0.036	2.2			€ 25.69
EW_3	ETICS with 12 of EPS	ETICS	EPS	12		0.036	3.3			€ 31.09
EW_4	ETICS with 4 of RW	ETICS	RW	4		0.040	1.0			€ 28.48
EW_5	ETICS with 8 of RW	ETICS	RW	8		0.040	2.0			€ 32.00
EW_6	ETICS with 12 of RW	ETICS	RW	12		0.040	3.0			€ 36.66
EW_7	ETICS with 4 of GW	ETICS	GW	4		0.034	1.2			
EW_8	ETICS with 8 of GW	ETICS	GW	8		0.034	2.4			
EW_9	ETICS with 12 of GW	ETICS	GW	12		0.034	3.5			
EW_10	ETICS with 4 of EPS and high SRI coating	ETICS	EPS	4	high SRI coating	0.036	1.1	0.51	0.87	€ 43.44
EW_11	ETICS with 8 of EPS and high SRI coating	ETICS	EPS	8	high SRI coating	0.036	2.2	0.51	0.87	€ 45.69
EW_12	ETICS with 12 of EPS and high SRI coating	ETICS	EPS	12	high SRI coating	0.036	3.3	0.51	0.87	€ 51.09
EW_13	ETICS with 4 of RW and high SRI coating	ETICS	RW	4	high SRI coating	0.040	1.0	0.51	0.87	€ 48.48
EW_14	ETICS with 8 of RW and high SRI coating	ETICS	RW	8	high SRI coating	0.040	2.0	0.51	0.87	€ 52.00
EW_15	ETICS with 12 of RW and high SRI coating	ETICS	RW	12	high SRI coating	0.040	3.0	0.51	0.87	€ 56.66
EW_16	ETICS with 4 of GW and high SRI coating	ETICS	GW	4	high SRI coating	0.034	1.2	0.51	0.87	
EW_17	ETICS with 8 of GW and high SRI coating	ETICS	GW	8	high SRI coating	0.034	2.4	0.51	0.87	

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

EW_18	ETICS with 12 of GW and high SRI coating	ETICS	GW	12	high SRI coating	0.034	3.5	0.51	0.87	
EW_19	Ventilated Facade with 4 of EPS	Ventilated Facade	EPS	4		0.036	1.1			€ 91.01
EW_20	Ventilated Facade with 8 of EPS	Ventilated Facade	EPS	8		0.036	2.2			€ 100.01
EW_21	Ventilated Facade with 4 of RW	Ventilated Facade	RW	4		0.040	1.0			€ 96.04
EW_22	Ventilated Facade with 8 of RW	Ventilated Facade	RW	8		0.040	2.0			€ 106.32
EW_23	Internal/Air chamber insultation with 3 of XPS	Internal/Air chamber insultation	XPS	3		0.033	0.9			€ 22.97
EW_24	Internal/Air chamber insultation with 5 of XPS	Internal/Air chamber insultation	XPS	5		0.033	1.5			€ 27.03
EW_25	Internal/Air chamber insultation with 3 of RW	Internal/Air chamber insultation	RW	3		0.034	0.9			€ 16.22
EW_26	Internal/Air chamber insultation with 5 of RW	Internal/Air chamber insultation	RW	5		0.034	1.5			€ 20.27
EW_27	Internal/Air chamber insultation with 3 of Expanded Perlite	Internal/Air chamber insultation	Expanded Perlite	3		0.043	0.7			
EW_28	Internal/Air chamber insultation with 5 of Expanded Perlite	Internal/Air chamber insultation	Expanded Perlite	5		0.043	1.2			
EW_29	Internal insultation with 2 cm of AEROGEL	Internal insultation	AEROGEL	2		0.014	1.4			€ 91.89
EW_30	Internal insultation with 2 cm of AEROGEL and low emission coating	Internal insultation	AEROGEL	2	low emission coating	0.014	1.4			€ 94.59

Table 48- External Walls Croatia

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

Code	Description	Typology	Insulation material	Thickness[cm]	Thermal conductivity [W/mK]	Thermal resistance [m2K/W]	Other	CROATIA (material + installation)
TR_0	No insulation	No insulation						
TR_1	External insulation with 3 of XPS	External insulation	XPS	3	0,032	0,9		34,59 - 53,51 €
TR_2	External insulation with 5 of XPS	External insulation	XPS	5	0,032	1,6		37,83 - 56,75 €
TR_3	External insulation with 8 of XPS	External insulation	XPS	8	0,032	2,5		42,70 - 61,62 €
TR_4	External insulation with 12 of XPS	External insulation	XPS	12	0,032	3,8		49,18 - 68,10 €
TR_6	External insulation with 3 of PU Foam	External insulation	PU Foam	3	0,028	1,1		43,91 - 62,83 €
TR_7	External insulation with 5 of PU Foam	External insulation	PU Foam	5	0,028	1,8		53,37 - 72,29 €
TR_8	External insulation with 8 of PU Foam	External insulation	PU Foam	8	0,028	2,9		67,56 - 86,48 €
TR_9	External insulation with 0,5+1,5+0,5 of PU Foam Sintered with 2 layers of WW	External insulation	PU Foam Sintered with 2 layers of WW	0,5+1,5+0,5	0,661	0,04		44,93 - 60,47 €
TR_10	External insulation with 0,5+2,5+0,5 of PU Foam Sintered with 2 layers of WW	External insulation	PU Foam Sintered with 2 layers of WW	0,5+2,5+0,5	1,375	0,03		51,01 - 65,2 €
TR_11	External insulation with 0,5+4+0,5 of PU Foam Sintered with 2 layers of WW	External insulation	PU Foam Sintered with 2 layers of WW	0,5+4+0,5	1,911	0,03		60,12 - 72,29 €
TR_12	External insulation with 0,5+6,5+0,5 of PU Foam Sintered with 2 layers of WW	External insulation	PU Foam Sintered with 2 layers of WW	0,5+6,5+0,5	2,446	0,03		75,33 - 84,12 €
TR_13	External Insulation with 5 of Rockwool (RW)	External Insulation	Rockwool (RW)	5	0,035	1,4		39,18 - 58,10 €

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TR_14	External Insulation with 8 of Rockwool (RW)	External Insulation	Rockwool (RW)	8	0,035	2,3		44,86 - 63,78 €
TR_15	Ventilated roof (5 cm air gap) with external insultation with 5 of XPS Panels	Ventilated roof (5 cm air gap) with external insultation	XPS Panels	5	0,033	1,5		€ 64,86
TR_16	Ventilated roof (5 cm air gap) with external insultation with 8 of XPS Panels	Ventilated roof (5 cm air gap) with external insultation	XPS Panels	8	0,033	2,4		€ 69,72
TR_17	Ventilated roof (5 cm air gap) with external insultation with 12 of XPS Panels	Ventilated roof (5 cm air gap) with external insultation	XPS Panels	12	0,033	3,6		€ 76,21
TR_18	Internal insulation with 2 of RW	Internal insulation	RW	2	0,035	0,6		-
TR_19	Internal insulation with 4 of RW and low emission coating	Internal insulation	RW	4	0,035	1,1	low emission coating	-
TR_20	Internal insulation with 4 of RW and low emission coating	Internal insulation	RW	4	0,035	1,1	low emission coating	-
TR_21	Internal insulation with 2 of AEROGEL	Internal insulation	AEROGEL	2	0,014	1,4		€ 91,89
TR_22	Internal insulation with 2 of AEROGEL and low emission coating	Internal insulation	AEROGEL	2	0,014	1,4	low emission coating	€ 94,59
FR_1	External insutation with 3 of XPS	External insutation	XPS	3	0,034	0,9		34,59 - 53,51 €
FR_2	External insulation with 5 of XPS	External insulation	XPS	5	0,034	1,5		37,83 - 56,75 €
FR_3	External insulation with 8 of XPS	External insulation	XPS	8	0,034	2,4		42,70 - 61,62 €
FR_4	External insulation with 5 of GW	External insulation	GW	5	0,037	1,4		-
FR_5	External insulation with 8 of GW	External insulation	GW	8	0,037	2,2		-
FR_6	External insulation with 12 of	External insulation	GW	12	0,037	3,2		-

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	GW							
FR_7	Internal insulation with 2 of Perlite and low emission coating	Internal insulation	Perlite	2	0,043	0,5	low emission coating	-
FR_8	Internal insulation with 4 of Perlite	Internal insulation	Perlite	4	0,043	0,9		-
FR_9	Internal insulation with 4 of Perlite and low emission coating	Internal insulation	Perlite	4	0,043	0,9	low emission coating	-
FR_10	Internal insulation with 2 of GW and low emission coating	Internal insulation	GW	2	0,037	0,5	low emission coating	-
FR_11	Internal insultation with 4 of GW	Internal insultation	GW	4	0,037	1,1		-
FR_12	Internal insultation with 4 of GW and low emission coating	Internal insultation	GW	4	0,037	1,1	low emission coating	-
FR_13	Internal insultation with 2 of AEROGEL	Internal insultation	AEROGEL	2	0,014	1,4		€ 111,89
FR_14	Internal insultation with 2 of AEROGEL and low emission coating	Internal insultation	AEROGEL	2	0,014	1,4	low emission coating	€ 114,59
FR_15	External insultation with 5 cm of XPS and high SRI coating	External insultation	XPS	5	0,032	1,6	high SRI coating	€ 76,75
FR_16	External insultation with 8 cm of XPS and high SRI coating	External insultation	XPS	8	0,032	2,5	high SRI coating	€ 81,62
FR_17	External insultation with 12 cm of XPS and high SRI coating	External insultation	XPS	12	0,032	3,8	high SRI coating	€ 88,10
FR_21	External insultation with 5 cm of GW and high SRI coating	External insultation	GW	5	0,037	1,4	high SRI coating	-
FR_22	External insultation with 8 cm of GW and high SRI coating	External insultation	GW	8	0,037	2,2	high SRI	-

							coating	
FR_23	External insultation with 12 cm of GW and high SRI coating	External insultation	GW	12	0,037	3,2	high SRI coating	-

Table 49- Roof and Ceiling Croatia

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

Code	Description	Typology	Insulation material	Thickness[cm]	Thermal conductivity [W/mK]	Thermal Resistance [m2K/W]	Croatia Costs [€/m2]
B_0	No insulation	No insulation					-
B_1	Insulation with 5 of light-weighted cement based with EPS	Insulation	light-weighted cement based with EPS	5	0,100	0,5	-
B_2	Insulation with 5 of light-weighted cement based with Expanded Perlite	Insulation	light-weighted cement based with Expanded Perlite	5	0,088	0,6	-
B_3	Insulation with 5 of light-weighted cement based with Vermiculite	Insulation	light-weighted cement based with Vermiculite	5	0,080	0,6	-
B_4	Insulation with 5 of light-weighted cement based with Expanded Clay	Insulation	light-weighted cement based with Expanded Clay	5	0,090	0,6	-
B_5	#RIF!	Insulation	light-weighted cement based with Expanded Glass	5	0,300	0,2	-
B_6	Insulation with 10 of light-weighted cement based with EPS	Insulation	light-weighted cement based with EPS	10	0,100	1,0	-
B_7	Insulation with 10 of light-weighted cement based with Expanded Perlite	Insulation	light-weighted cement based with Expanded Perlite	10	0,088	1,1	-
B_8	Insulation with 10 of light-weighted cement based with Vermiculite	Insulation	light-weighted cement based with Vermiculite	10	0,080	1,3	-
B_9	Insulation with 10 of light-weighted cement based with Expanded Clay	Insulation	light-weighted cement based with Expanded Clay	10	0,090	1,1	-
B_10	#RIF!	Insulation	light-weighted cement based with Expanded Glass	10	0,300	0,3	-
B_11	Insulation with 15 of light-weighted cement based with	Insulation	light-weighted cement based with EPS	15	0,100	1,5	-

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	EPS						
B_12	Insulation with 15 of light-weighted cement based with Expanded Perlite	Insulation	light-weighted cement based with Expanded Perlite	15	0,088	1,7	-
B_13	Insulation with 15 of light-weighted cement based with Vermiculite	Insulation	light-weighted cement based with Vermiculite	15	0,080	1,9	-
B_14	Insulation with 15 of light-weighted cement based with Expanded Clay	Insulation	light-weighted cement based with Expanded Clay	15	0,090	1,7	-
B_15	#RIF!	Insulation	light-weighted cement based with Expanded Glass	15	0,300	0,5	-
B_16	#RIF!	Insulation	XPS or PU Panels	2	0,028	0,71	30,94-37,16 €
B_17	#RIF!	Insulation	XPS or PU Panels	4	0,028	1,43	34,18-46,62 €
B_18	#RIF!	Insulation	XPS or PU Panels	6	0,028	2,14	37,43-56,08 €

Table 50-basement Croatia

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

Code	Description	Typology	Insulation material	Cavity Thickness	Frame kind	Uw [W/m2K]	g value [-]	Uf (W/M2k)	[PARTNER_NAME] Cost [€/m2]
W_0	No replacement	No replacement							Croatia (100x100 cm, single frame)
W_1	Double windows with 2 glasses with 1.6 cm of air interspace	Double windows with 2 glasses	air interspace	1.6 cm	ALUMINIUM	2,7	0,77	3,5	-
W_2	Double windows with 2 glasses window with low-ε with 1.6 cm of air interspace	Double windows with 2 glasses window with low-ε	air interspace	1.6 cm	ALUMINIUM	1,4	0,58	3,5	145,79 €
W_3	2 glasses window with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)	2 glasses window	argon interspace	1.6 cm	ALUMINIUM	2,6	0,77	3,5	-
W_4	2 glasses window with low-ε with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)	2 glasses window with low-ε	argon interspace	1.6 cm	ALUMINIUM	1,1	0,59	3,5	162,16 €
W_5	3 glasses window with 1.6 cm of argon interspace and ALUMINIUM	3 glasses window	argon interspace	1.6 cm	ALUMINIUM	0,6	0,53	3,5	179,59 €

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W_6	3 glasses window medium-ε with 1.6 cm of argon interspace and ALUMINIUM	3 glasses window medium-ε	argon interspace	1.6 cm	ALUMINIUM	0,6	0,54	3,5	179,59 €
W_7	3 glasses window with low-ε with 1.6 cm of argon interspace and ALUMINIUM	3 glasses window with low-ε	argon interspace	1.6 cm	ALUMINIUM	0,6	0,26	3,5	179,59 €
W_8	Double windows with 2 glasses with 1.6 cm of air interspace	Double windows with 2 glasses	air interspace	1.6 cm	WOOD	2,7	0,77	1,43	-
W_9	Double windows with 2 glasses window with low-ε with 1.6 cm of air interspace	Double windows with 2 glasses window with low-ε	air interspace	1.6 cm	WOOD	1,4	0,58	1,43	134,58 €
W_10	2 glasses window with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)	2 glasses window	argon interspace	1.6 cm	WOOD	2,6	0,77	1,43	-
W_11	2 glasses window with low-ε with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum,	2 glasses window with low-ε	argon interspace	1.6 cm	WOOD	1,1	0,59	1,43	142,57 €

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	PVC)								
W_12	3 glasses window with 1.6 cm of argon interspace and WOOD	3 glasses window	argon interspace	1.6 cm	WOOD	0,6	0,53	1,43	149,19 €
W_13	3 glasses window with 1.6 cm of argon interspace and WOOD	3 glasses window	argon interspace	1.6 cm	WOOD	0,6	0,54	1,43	165,41 €
W_14	3 glasses window with low-ε with 1.6 cm of argon interspace and WOOD	3 glasses window with low-ε	argon interspace	1.6 cm	WOOD	0,6	0,26	1,43	165,41 €
W_15	Double windows with 2 glasses with 1.6 cm of air interspace	Double windows with 2 glasses	air interspace	1.6 cm	PVC	2,7	0,77	1,3	-
W_16	Double windows with 2 glasses window with low-ε with 1.6 cm of air interspace	Double windows with 2 glasses window with low-ε	air interspace	1.6 cm	PVC	1,4	0,58	1,3	112,15 €
W_17	2 glasses window with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)	2 glasses window	argon interspace	1.6 cm	PVC	2,6	0,77	1,3	-
W_18	2 glasses window with low-ε with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames	2 glasses window with low-ε	argon interspace	1.6 cm	PVC	1,1	0,59	1,3	124,32 €

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	(Wood, aluminum, PVC)								
W_19	3 glasses window with 1.6 cm of argon interspace and PVC	3 glasses window	argon interspace	1.6 cm	PVC	0,6	0,53	1,3	137,84 €
W_20	3 glasses window with 1.6 cm of argon interspace and PVC	3 glasses window	argon interspace	1.6 cm	PVC	0,6	0,54	1,3	137,84 €
W_21	3 glasses window with low-ε with 1.6 cm of argon interspace and PVC	3 glasses window with low-ε	argon interspace	1.6 cm	PVC	0,6	0,26	1,3	141,89 €
W_22	3 glasses window with 1.8 cm of air interspace	3 glasses window	air interspace	1.8 cm	ALUMINIUM				179,59 €
W_23	3 glasses window with 1.8 cm of air interspace	3 glasses window	air interspace	1.8 cm	ALUMINIUM				179,59 €
W_24	3 glasses window with low-ε with 1.8 cm of air interspace	3 glasses window with low-ε	air interspace	1.8 cm	ALUMINIUM				179,59 €
W_25	3 glasses window with 1.8 cm of air interspace	3 glasses window	air interspace	1.8 cm	WOOD				149,19 €
W_26	3 glasses window with 1.8 cm of air interspace	3 glasses window	air interspace	1.8 cm	WOOD				165,41 €
W_27	3 glasses window with low-ε with 1.8 cm of air interspace	3 glasses window with low-ε	air interspace	1.8 cm	WOOD				165,41 €
W_28	3 glasses window with 1.8 cm of air interspace	3 glasses window	air interspace	1.8 cm	PVC				136,76 €
W_29	3 glasses window with 1.8 cm of air	3 glasses window	air interspace	1.8 cm	PVC				151,62 €

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	interspace								
W_30	3 glasses window with low-ε with 1.8 cm of air interspace	3 glasses window with low-ε	air interspace	1.8 cm	PVC				151,62 €

Table 51- Windows Croatia

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

Description	Typology	Solar factor ? / DeltaR ?	Croatia (100x100 cm)
No replacement	No replacement		-
Overhang - vertical 50 0.29	Overhang - vertical	0.29	100.00 €
Overhang - horizontal 50 0.29	Overhang - horizontal	0.29	120.00 €

Table 52- Shadings Croatia

	A	B	C	D	E	F	G	H	I	J	K
1	Code	Typology	Thickness [cm]	Thermal Conductivity [W/mK]	Thermal Resistance [m2K/W]	Linear Thermal Trasmittance [W/mK]			ITALY Cost [€/m	SPAIN Cost [€/m]	Croatia [€/m]
2						Internal	External	Overall Internal			
3	TB_0	No replacement									
4	TB_1	Insulation of thermal bridges with panels made of PUR injected in the slabs to go from 1.01 to 0.6 for the Façade-Slabs TB	2	0.09	0.22	0.6			€ 13.78	8.63 €	25.68 €
5	TB_2	Insulation of thermal bridges with panels made of mineralized wood wool and bound with high-strength cement	3	0.09	0.33	0.25			€ 15.48	11.37 €	-
6	TB_3	Insulation of thermal bridges with application on kerbs, lintels, veils, pillars, etc. of polystyrene sheet strips extruded foam, rough surface without skin	3	0.033	0.91	0.35			€ 13.06	12.27 €	17.57 €
7	TB_4	Insulation of thermal bridges with application between windows and facades	5	0.035	1.43	0.05			€ 17.14	5.83 €	20.27 €
8	TB_5	Insulation of thermal bridges on vertical and horizontal structures in phase of the casting, realized with application on the formworks of panels in wood wool mineralized with high temperature magnesite;	3.5	0.094	0.37	?			€ 26.10		-
9	TB_6										-
10	TB_7										-
11	TB_8_Roofs_R5					0.6	0.8	0.8		11	-
12	TB_9_Roofs_R9					0.15	-0.05	0.15		11	-
13	TB_10_Roofs_R11					0.25	0.05	0.25		11	-
14	TB_11_Balconies_B3					1	0.9	0.9		11	-
15	TB_12_Corners_C5					-0.15	0.05	-0.15		11	-
16	TB_13_Corners_C1					0.15	-0.05	0.15		11	-
17	TB_14_Corners_C7					-0.05	0.15	-0.05		11	-
18	TB_15_Intermediate_Floors_IF1					0.1	0	0		11	-
19	TB_16_Intermediate Floor_IF8					0.6	0.45	0.45		11	-
20	TB_17_Internal Walls_IW1					0.1	0	0		11	-
21	TB_18_Slab-on-ground floors_GF 5					0.75	0.6	0.75		11	-
22	TB_19_Slab-on-groud floors_GF7					0.1	-0.05	0.1		11	-
23	TB_20_Slab-on-ground floors_GF 13					0.8	0.6	0.8		11	-
24	TB_21_Slab-on-groud floors_GF15					0.1	0.1	0.1		11	-
25	TB_22_Pillars_P1					1.3	1.3	1.3		14	-
26	TB_22_Pillars_P3					1.15	1.15	1.15		14	-
27	TB23_Windows and openings_W1					0	0	0		7	-
28	TB_24_Windows and openings_W6					0.1	0.1	0.1		7	-
29	TB25_Windows and openings_W11					0	0	0		7	-
30	TB_26_Windows and					0.1	0.1	0.1		7	-
31	TB27_Windows and openings_W15					0	0	0		7	-
32	TB_28_Windows and					0.2	0.2	0.2		7	-
33											
34											
35		Legend									

Table 53- Thermal Bridges - Croatia

	Description	Energy vector	Efficiency	COP	SEER	combined DHW?	SFH-Single dwelling (costs calculated per single apartment)	MFH	Croatia / Cost [€] - only for equipment procurement & installation & auxiliaries
HC_1	Wall-mounted gas boiler <= 25 kW - without DHW	Natural gas	0,96	-	-	No	x		-
HC_2	Wall-mounted gas boiler <= 25 kW	Natural gas	0,96	-	-	Yes	x		-
HC_3	Floor-standing gas boiler > 25 kW [INOX]	Natural gas	0,96	-	-	Yes		x	-
HC_4	Wall-mounted condensing gas boiler <= 25 kW - without DHW	Natural gas	1,05	-	-	No	x		1.702,70 €
HC_5	Wall-mounted condensing gas boiler <= 25 kW	Natural gas	1,05	-	-	Yes	x		1.837,84 €
HC_6	Floor-standing condensing gas boiler <= 25 kW- without DHW	Natural gas	1,05	-	-	No	x		2.405,41 €
HC_7	Floor-standing condensing gas boiler <= 25 kW	Natural gas	1,05	-	-	Yes	x		2.043,24 €
HC_8	Floor-standing	Natural gas	1,05	-	-	No		x	5.959,46 €

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	condensing gas boiler: 100-150 kW								
HC_9	Floor-standing condensing gas boiler: 200-250 kW	Natural gas	1,05	-	-	No		x	8.172,97 €
HC_10	Installation of an electric air-air HP - multisplit <= 15 kW	Electricity	-	4,5	4	No	x		7.162,16 €
HC_11	Installation of an electric air-air HP - multisplit <= 15 kW - only cooling	Electricity	-	-	4	No	x		-
HC_12	Installation of an electric air-water HP <= 15kW - without DHW	Electricity	-	4,5	4	No	x		-
HC_13	Installation of an electric air-water HP <= 25kW	Electricity	-	4,5	4	No	x		39.189,19 €
HC_14	Installation of an electric air-water HP - 100-150kW	Electricity	-	4	3	No		x	218.918,92 €
HC_15	Installation of an electric air-water HP - 200-250kW	Electricity	-	4	3	No		x	431.081,08 €
HC_16	GSHP - Ground Source Heat Pump - 100-150kW	Electricity	-	4,29		No		x	327.702,70 €
HC_17	GSHP - Ground Source Heat Pump - 200-250kW	Electricity	-	4,33		No		x	612.387,39 €
HC_18	Biomass boiler	Woodchips or	0,876		-		x		-

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		pellets							
HC_19	Biomass boiler	Woodchips or pellets		-	-			x	-
HC_20	MicroCHP - Gas turbine	Gas	0,8						-
HC_21	MicroCHP - Internal combustion engine	Natural gas/Diesel							-
HC_22	District heating								-
HC_23	Absorption chiller + Solar thermal	RES							-
HC_24	Microtrigeneration with internal combustion engine + Absorption chiller	Natural gas/Diesel							-

Table 54- Heating and Cooling Systems Croatia

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

Description	Energy vector	Efficiency	COP	SFH-Single dwelling (costs calculated per single apartment)	MFH	Croatia [Cost [€/UFR] - only for equipment procurement & installation
Combined with Heating				x	x	
Electric boiler - SFH	Electricity	0.99		x		
Electric boilers [20 apartments]	Electricity	0.99			x	
Gas boiler with high efficiency	Natural gas			x		
Gas boiler with high efficiency [20 apartments]	Natural gas				x	
Solar thermal				x	x	1,260.00 €
air-to-water Electric Heat pump - SFH	Electricity	-	4.5	x		
air-to-water Electric Heat pump - MFH [20 apartments]	Electricity	-	4.5		x	

Table 55- DHW Croatia

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Code	Ventilation	equivalent air flow (n air change/h - m3/h)	Croatia Cost [€] - 100 m2 of room space, single floor
V_1	Controlled VMC	0.42	5,675.68 €
V_2	Controlled with thermal exchange (Heat Recovery System)	0.6	6,756.76 €
V_3	Free cooling- Night ventilation	10	180.00 €
Code	**Air tightness**	**n50**	**[PARTNER_NAME] Cost [€/m]**
A_1	Soudal window system	3	
A_2	Passive house solution	0.5	

Table 56- Ventilation Croatia

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Code	RES electricity	Technical Characteristics			Partner Cost [€/kW]: materials + installation
RES_E_1	Photovoltaic (costs per kWp - from 1 kW up to 7 kWp)	1-7 kWp			
RES_E_2	Photovoltaic (costs per kWp - from 7 kW up to 20 kWp)	7-20 kWp			
RES_E_3	Photovoltaic (costs per kWp - from 21 kW up to 50 kWp)	21-50 kWp			
Code	**RES thermal**	**Technical Characteristics**	**SFH or MFH**	**Notes**	
RES_T_1	Biomass (woodchips or pellets generators) (cost in kWt)	efficiency 0,9	SFH		
RES_T_2	Solar thermal (cost per m2)	% DHW covered (e.g. 50% Spain)			
RES_T_3	Geothermal (HP - cost per kWt)_Ground-Water System	COP / EER 4,5 /5	SFH	Power Needed 8 kW soil efficiency 40 W/mK	
RES_T_4	Geothermal (HP - cost per kWt)_Ground-Water System	COP / EER 4,5 /5	MFH	Power Needed 31 kW	
RES_T_5	Geothermal (HP - cost per kWt)_Water-Water System	COP / EER 4 /5	SFH	Power Needed 8 kW soil efficiency 40 W/mK	
RES_T_6	Geothermal (HP - cost per kWt)_Water-Water System	COP / EER 4 /5	MFH	Power Needed 31 kW	

Table 57- Croatia RES

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9.2.1 Energy prices

Energy source	Unit	Energy value (kWh/unit)	Unit price (€/unit)	Unit price (€/kWh)	System efficency	Corrected price (€/kWh)
Electric energy	**kWh**	1.00	0.1318	0.1318	100%	0.1318
Natural gas	**m^3**	9.25	0.0052	0.0481	98%	0.0491
LPG PB	**kg**	12.80	0.9054	0.0707	98%	0.0722
LPG P	**kg**	13.80	0.9459	0.0685	98%	0.0699
Fuel oil - extra light	**lit**	10.20	0.6757	0.0662	92%	0.0720
Diesel fuel	**lit**	10.22	0.6919	0.0677	92%	0.0736
Dry wood (20% moisture)	**kg**	3.98	0.1606	0.0403	75%	0.0538
Pellets	**kg**	5.40	0.2423	0.0449	95%	0.0472
Brickets	**kg**	5.11	0.2419	0.0473	75%	0.0631
Wood chips (35% moisture)	**kg**	3.00	0.0445	0.0148	95%	0.0156
Coal brickets	**kg**	5.30	0.3635	0.0686	84%	0.0817

Table 58- Energy Prices Croatia

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9.3 Greece

Code	Description	Typology	Insulation material	Thickness [cm]	Other (coating)	Therm conductivity [W/mK]	R [m2K/W]	emissivity	Solar Reflectance Index (external)	GREECE Cost [€/m2]: materials + installation
EW_0	No insulation	No insulation								
EW_1	ETICS with 4 of EPS	ETICS	EPS	4		0,036	1,1			€ 43,00
EW_2	ETICS with 8 of EPS	ETICS	EPS	8		0,036	2,2			€ 47,00
EW_3	ETICS with 12 of EPS	ETICS	EPS	12		0,036	3,3			€ 52,00
EW_4	ETICS with 4 of RW	ETICS	RW	4		0,040	1,0			€ 45,00
EW_5	ETICS with 8 of RW	ETICS	RW	8		0,040	2,0			€ 55,00
EW_6	ETICS with 12 of RW	ETICS	RW	12		0,040	3,0			€ 65,00
EW_7	ETICS with 4 of GW	ETICS	GW	4		0,034	1,2			€ 47,00
EW_8	ETICS with 8 of GW	ETICS	GW	8		0,034	2,4			€ 52,00
EW_9	ETICS with 12 of GW	ETICS	GW	12		0,034	3,5			€ 60,00
EW_10	ETICS with 4 of EPS and high SRI coating	ETICS	EPS	4	high SRI coating	0,036	1,1	0,51	0,87	€ 55,00
EW_11	ETICS with 8 of EPS and high SRI coating	ETICS	EPS	8	high SRI coating	0,036	2,2	0,51	0,87	€ 59,00
EW_12	ETICS with 12 of EPS and high SRI coating	ETICS	EPS	12	high SRI coating	0,036	3,3	0,51	0,87	€ 64,00
EW_13	ETICS with 4 of RW and high SRI coating	ETICS	RW	4	high SRI coating	0,040	1,0	0,51	0,87	€ 58,00
EW_14	ETICS with 8 of RW and high SRI coating	ETICS	RW	8	high SRI coating	0,040	2,0	0,51	0,87	€ 68,00
EW_15	ETICS with 12 of RW and high SRI coating	ETICS	RW	12	high SRI coating	0,040	3,0	0,51	0,87	€ 78,00
EW_16	ETICS with 4 of GW and	ETICS	GW	4	high SRI	0,034	1,2	0,51	0,87	€ 60,00

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	high SRI coating				coating					
EW_17	ETICS with 8 of GW and high SRI coating	ETICS	GW	8	high SRI coating	0,034	2,4	0,51	0,87	€ 65,00
EW_18	ETICS with 12 of GW and high SRI coating	ETICS	GW	12	high SRI coating	0,034	3,5	0,51	0,87	€ 73,00
EW_19	Ventilated Facade with 4 of EPS	Ventilated Facade	EPS	4		0,036	1,1			
EW_20	Ventilated Facade with 8 of EPS	Ventilated Facade	EPS	8		0,036	2,2			
EW_21	Ventilated Facade with 4 of RW	Ventilated Facade	RW	4		0,040	1,0			
EW_22	Ventilated Facade with 8 of RW	Ventilated Facade	RW	8		0,040	2,0			
EW_23	Internal/Air chamber insultation with 3 of XPS	Internal/Air chamber insultation	XPS	3		0,033	0,9			€ 11,00
EW_24	Internal/Air chamber insultation with 5 of XPS	Internal/Air chamber insultation	XPS	5		0,033	1,5			€ 13,00
EW_25	Internal/Air chamber insultation with 3 of RW	Internal/Air chamber insultation	RW	3		0,034	0,9			€ 14,00
EW_26	Internal/Air chamber insultation with 5 of RW	Internal/Air chamber insultation	RW	5		0,034	1,5			€ 16,00
EW_27	Internal/Air chamber insultation with 3 of Expanded Perlite	Internal/Air chamber insultation	Expanded Perlite	3		0,043	0,7			€ 11,00
EW_28	Internal/Air chamber insultation with 5 of Expanded Perlite	Internal/Air chamber insultation	Expanded Perlite	5		0,043	1,2			€ 13,00
EW_29	Internal insultation with 2 cm of AEROGEL	Internal insultation	AEROGEL	2		0,014	1,4			
EW_30	Internal insultation with	Internal	AEROGEL	2	low	0,014	1,4			

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	2 cm of AEROGEL and low emission coating	insultation			emission coating					

Table 59- External walls Greece

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

Code	Description	Typology	Insulation material	Thickness[cm]	Thermal conductivity [W/mK]	Thermal resistance [m2K/W]	Other	Emissivity	Solar Reflectance Index (external)	GREECE Cost (materials+Installation) [€/m2]
TR_0	No insulation	No insulation								
TR_1	External insulation with 3 of XPS	External insulation	XPS	3	0,032	0,9				€ 9,04
TR_2	External insulation with 5 of XPS	External insulation	XPS	5	0,032	1,6				€ 10,44
TR_3	External insulation with 8 of XPS	External insulation	XPS	8	0,032	2,5				€ 14,44
TR_4	External insulation with 12 of XPS	External insulation	XPS	12	0,032	3,8				€ 18,44
TR_6	External insulation with 3 of PU Foam	External insulation	PU Foam	3	0,028	1,1				€ 18,00
TR_7	External insulation with 5 of PU Foam	External insulation	PU Foam	5	0,028	1,8				€ 22,00
TR_8	External insulation with 8 of PU Foam	External insulation	PU Foam	8	0,028	2,9				€ 28,00
TR_9	External insulation with 0,5+1,5+0,5 of PU Foam Sintered with 2 layers of WW	External insulation	PU Foam Sintered with 2 layers of WW	0,5+1,5+0,5	0,661	0,04				-
TR_10	External insulation with	External insulation	PU Foam Sintered	0,5+2,5+0,5	1,375	0,03				-

	0,5+2,5+0,5 of PU Foam Sintered with 2 layers of WW		with 2 layers of WW							
TR_11	External insulation with 0,5+4+0,5 of PU Foam Sintered with 2 layers of WW	External insulation	PU Foam Sintered with 2 layers of WW	0,5+4+0,5	1,911	0,03				-
TR_12	External insulation with 0,5+6,5+0,5 of PU Foam Sintered with 2 layers of WW	External insulation	PU Foam Sintered with 2 layers of WW	0,5+6,5+0,5	2,446	0,03				-
TR_13	External Insulation with 5 of Rockwool (RW)	External Insulation	Rockwool (RW)	5	0,035	1,4				€ 14,00
TR_14	External Insulation with 8 of Rockwool (RW)	External Insulation	Rockwool (RW)	8	0,035	2,3				€ 18,00
TR_15	Ventilated roof (5 cm air gap) with external insultation with 5 of XPS Panels	Ventilated roof (5 cm air gap) with external insultation	XPS Panels	5	0,033	1,5				€ 32,00
TR_16	Ventilated roof (5 cm air gap) with external insultation with 8 of XPS Panels	Ventilated roof (5 cm air gap) with external insultation	XPS Panels	8	0,033	2,4				€ 38,00
TR_17	Ventilated roof (5 cm air gap) with external	Ventilated roof (5 cm air gap) with external	XPS Panels	12	0,033	3,6				€ 44,00

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	insultation with 12 of XPS Panels	insultation								
TR_18	Internal insulation with 2 of RW	Internal insulation	RW	2	0,035	0,6				€ 14,00
TR_19	Internal insulation with 4 of RW and low emission coating	Internal insulation	RW	4	0,035	1,1	low emission coating	0,51		€ 27,00
TR_20	Internal insulation with 4 of RW and low emission coating	Internal insulation	RW	4	0,035	1,1	low emission coating	0,51		€ 27,00
TR_21	Internal insulation with 2 of AEROGEL	Internal insulation	AEROGEL	2	0,014	1,4				-
TR_22	Internal insulation with 2 of AEROGEL and low emission coating	Internal insulation	AEROGEL	2	0,014	1,4	low emission coating	0,51		-
FR_1	External insutation with 3 of XPS	External insutation	XPS	3	0,034	0,9				€ 9,04
FR_2	External insulation with 5 of XPS	External insulation	XPS	5	0,034	1,5				€ 10,44
FR_3	External insulation with 8 of XPS	External insulation	XPS	8	0,034	2,4				€ 14,44
FR_4	External insulation with 5 of GW	External insulation	GW	5	0,037	1,4				-
FR_5	External insulation with 8	External insulation	GW	8	0,037	2,2				-

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	of GW									
FR_6	External insulation with 12 of GW	External insulation	GW	12	0,037	3,2				-
FR_7	Internal insulation with 2 of Perlite and low emission coating	Internal insulation	Perlite	2	0,043	0,5	low emission coating	0,51		€ 32,00
FR_8	Internal insulation with 4 of Perlite	Internal insulation	Perlite	4	0,043	0,9				€ 11,00
FR_9	Internal insulation with 4 of Perlite and low emission coating	Internal insulation	Perlite	4	0,043	0,9	low emission coating	0,51		€ 39,00
FR_10	Internal insulation with 2 of GW and low emission coating	Internal insulation	GW	2	0,037	0,5	low emission coating	0,51		€ 32,00
FR_11	Internal insultation with 4 of GW	Internal insultation	GW	4	0,037	1,1				€ 11,00
FR_12	Internal insultation with 4 of GW and low emission coating	Internal insultation	GW	4	0,037	1,1	low emission coating	0,51		€ 40,00
FR_13	Internal insultation with 2 of AEROGEL	Internal insultation	AEROGEL	2	0,014	1,4				-
FR_14	Internal insultation with 2 of AEROGEL and low emission coating	Internal insultation	AEROGEL	2	0,014	1,4	low emission coating	0,51		-

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FR_15	External insultation with 5 cm of XPS and high SRI coating	External insultation	XPS	5	0,032	1,6	high SRI coating		0,87	-
FR_16	External insultation with 8 cm of XPS and high SRI coating	External insultation	XPS	8	0,032	2,5	high SRI coating		0,87	-
FR_17	External insultation with 12 cm of XPS and high SRI coating	External insultation	XPS	12	0,032	3,8	high SRI coating		0,87	-
FR_21	External insultation with 5 cm of GW and high SRI coating	External insultation	GW	5	0,037	1,4	high SRI coating		0,87	-
FR_22	External insultation with 8 cm of GW and high SRI coating	External insultation	GW	8	0,037	2,2	high SRI coating		0,87	-
FR_23	External insultation with 12 cm of GW and high SRI coating	External insultation	GW	12	0,037	3,2	high SRI coating		0,87	-

Table 60- Roof and ceiling Greece

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

Code	Description	Typology	Insulation material	Thickness[cm]	Thermal conductivity [W/mK]	Thermal Resistance [m2K/W]	GREECE Costs [€/m2]
B_0	No insulation	No insulation					
B_1	Insulation with 5 of light-weighted cement based with EPS	Insulation	light-weighted cement based with EPS	5	0,100	0,5	€ 37,00
B_2	Insulation with 5 of light-weighted cement based with Expanded Perlite	Insulation	light-weighted cement based with Expanded Perlite	5	0,088	0,6	-
B_3	Insulation with 5 of light-weighted cement based with Vermiculite	Insulation	light-weighted cement based with Vermiculite	5	0,080	0,6	-
B_4	Insulation with 5 of light-weighted cement based with Expanded Clay	Insulation	light-weighted cement based with Expanded Clay	5	0,090	0,6	-
B_5	#RIF!	Insulation	light-weighted cement based with Expanded Glass	5	0,300	0,2	€ 26,00
B_6	Insulation with 10 of light-weighted cement based with EPS	Insulation	light-weighted cement based with EPS	10	0,100	1,0	€ 40,00
B_7	Insulation with 10 of light-weighted cement based with Expanded Perlite	Insulation	light-weighted cement based with Expanded Perlite	10	0,088	1,1	€ 42,00
B_8	Insulation with 10 of light-weighted cement based with Vermiculite	Insulation	light-weighted cement based with Vermiculite	10	0,080	1,3	-
B_9	Insulation with 10 of light-weighted cement based with Expanded Clay	Insulation	light-weighted cement based with Expanded Clay	10	0,090	1,1	-
B_10	#RIF!	Insulation	light-weighted cement based with Expanded Glass	10	0,300	0,3	-
B_11	Insulation with 15 of light-weighted cement based with EPS	Insulation	light-weighted cement based with EPS	15	0,100	1,5	-
B_12	Insulation with 15 of light-weighted cement based with	Insulation	light-weighted cement based with Expanded	15	0,088	1,7	-

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	Expanded Perlite		Perlite				
B_13	Insulation with 15 of light-weighted cement based with Vermiculite	Insulation	light-weighted cement based with Vermiculite	15	0,080	1,9	-
B_14	Insulation with 15 of light-weighted cement based with Expanded Clay	Insulation	light-weighted cement based with Expanded Clay	15	0,090	1,7	-
B_15	#RIF!	Insulation	light-weighted cement based with Expanded Glass	15	0,300	0,5	-
B_16	#RIF!	Insulation	XPS or PU Panels	2	0,028	0,71	€ 15,75
B_17	#RIF!	Insulation	XPS or PU Panels	4	0,028	1,43	€ 17,70
B_18	#RIF!	Insulation	XPS or PU Panels	6	0,028	2,14	-

Table 61- Basement_Greece

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

Code	Description	Typology	Insulation material	Cavity Thickness	Frame kind	Uw [W/m2K]	g value [-]	Uf (W/M2k)	GREECE Cost [€/m2]
W_0	No replacement	No replacement							
W_1	Double windows with 2 glasses with 1.6 cm of air interspace	Double windows with 2 glasses	air interspace	1.6 cm	ALUMINIUM	2,7	0,77	3,5	0
W_2	Double windows with 2 glasses window with low-ε with 1.6 cm of air interspace	Double windows with 2 glasses window with low-ε	air interspace	1.6 cm	ALUMINIUM	1,4	0,58	3,5	0
W_3	2 glasses window with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)	2 glasses window	argon interspace	1.6 cm	ALUMINIUM	2,6	0,77	3,5	250
W_4	2 glasses window with low-ε with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)	2 glasses window with low-ε	argon interspace	1.6 cm	ALUMINIUM	1,1	0,59	3,5	350
W_5	3 glasses window with 1.6 cm of argon interspace and ALUMINIUM	3 glasses window	argon interspace	1.6 cm	ALUMINIUM	0,6	0,53	3,5	300
W_6	3 glasses window medium-ε with 1.6 cm of argon interspace and ALUMINIUM	3 glasses window medium-ε	argon interspace	1.6 cm	ALUMINIUM	0,6	0,54	3,5	450
W_7	3 glasses window with low-ε with 1.6 cm of argon interspace and ALUMINIUM	3 glasses window with low-ε	argon interspace	1.6 cm	ALUMINIUM	0,6	0,26	3,5	500
W_8	Double windows with 2 glasses with 1.6 cm of air interspace	Double windows with 2 glasses	air interspace	1.6 cm	WOOD	2,7	0,77	1,43	150

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W_9	Double windows with 2 glasses window with low-ε with 1.6 cm of air interspace	Double windows with 2 glasses window with low-ε	air interspace	1.6 cm	WOOD	1,4	0,58	1,43	250
W_10	2 glasses window with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)	2 glasses window	argon interspace	1.6 cm	WOOD	2,6	0,77	1,43	250
W_11	2 glasses window with low-ε with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)	2 glasses window with low-ε	argon interspace	1.6 cm	WOOD	1,1	0,59	1,43	350
W_12	3 glasses window with 1.6 cm of argon interspace and WOOD	3 glasses window	argon interspace	1.6 cm	WOOD	0,6	0,53	1,43	400
W_13	3 glasses window with 1.6 cm of argon interspace and WOOD	3 glasses window	argon interspace	1.6 cm	WOOD	0,6	0,54	1,43	450
W_14	3 glasses window with low-ε with 1.6 cm of argon interspace and WOOD	3 glasses window with low-ε	argon interspace	1.6 cm	WOOD	0,6	0,26	1,43	500
W_15	Double windows with 2 glasses with 1.6 cm of air interspace	Double windows with 2 glasses	air interspace	1.6 cm	PVC	2,7	0,77	1,3	0
W_16	Double windows with 2 glasses window with low-ε with 1.6 cm of air interspace	Double windows with 2 glasses window with low-ε	air interspace	1.6 cm	PVC	1,4	0,58	1,3	0
W_17	2 glasses window with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)	2 glasses window	argon interspace	1.6 cm	PVC	2,6	0,77	1,3	250
W_18	2 glasses window with low-ε with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames	2 glasses window with low-ε	argon interspace	1.6 cm	PVC	1,1	0,59	1,3	350

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	(Wood, aluminum, PVC)								
W_19	3 glasses window with 1.6 cm of argon interspace and PVC	3 glasses window	argon interspace	1.6 cm	PVC	0,6	0,53	1,3	350
W_20	3 glasses window with 1.6 cm of argon interspace and PVC	3 glasses window	argon interspace	1.6 cm	PVC	0,6	0,54	1,3	350
W_21	3 glasses window with low-ε with 1.6 cm of argon interspace and PVC	3 glasses window with low-ε	argon interspace	1.6 cm	PVC	0,6	0,26	1,3	400
W_22	3 glasses window with 1.8 cm of air interspace	3 glasses window	air interspace	1.8 cm	ALUMINIUM				
W_23	3 glasses window with 1.8 cm of air interspace	3 glasses window	air interspace	1.8 cm	ALUMINIUM				
W_24	3 glasses window with low-ε with 1.8 cm of air interspace	3 glasses window with low-ε	air interspace	1.8 cm	ALUMINIUM				
W_25	3 glasses window with 1.8 cm of air interspace	3 glasses window	air interspace	1.8 cm	WOOD				
W_26	3 glasses window with 1.8 cm of air interspace	3 glasses window	air interspace	1.8 cm	WOOD				
W_27	3 glasses window with low-ε with 1.8 cm of air interspace	3 glasses window with low-ε	air interspace	1.8 cm	WOOD				
W_28	3 glasses window with 1.8 cm of air interspace	3 glasses window	air interspace	1.8 cm	PVC				
W_29	3 glasses window with 1.8 cm of air interspace	3 glasses window	air interspace	1.8 cm	PVC				
W_30	3 glasses window with low-ε with 1.8 cm of air interspace	3 glasses window with low-ε	air interspace	1.8 cm	PVC				

Table 62- Windows- Greece

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

Description	Typology	Solar factor ? / DeltaR ?	GREECE Cost [€/m2]
No replacement	No replacement		-
Overhang - vertical 50 0,29	Overhang - vertical	0.29	70.00 €
Overhang - horizontal 50 0,29	Overhang - horizontal	0.29	70.00 €

Table 63- Shadings - Greece

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

1	Code	Typology	Thickness [cm]	Thermal Conductivity [W/mK]	Thermal Resistance [m2K/W]	Linear Thermal Trasmittance [W/mK]			ITALY Cost [€/m	SPAIN Cost [€/m]	GREECE [€/m]
2						Internal	External	Overall Internal			
3	TB_0	No replacement									
4	TB_1	Insulation of thermal bridges with panels made of PUR injected in the slabs to go from 1.01 to 0.6 for the Façade-Slabs TB	2	0.09	0.22	0.6			€ 13.78	8.63 €	14.00 €
5	TB_2	Insulation of thermal bridges with panels made of mineralized wood wool and bound with high-strength cement	3	0.09	0.33	0.25			€ 15.48	11.37 €	15.00 €
6	TB_3	Insulation of thermal bridges with application on kerbs, lintels, veils, pillars, etc. of polystyrene sheet strips extruded foam, rough surface without skin	3	0.033	0.91	0.35			€ 13.06	12.27 €	12.00 €
7	TB_4	Insulation of thermal bridges with application between windows and facades	5	0.035	1.43	0.05			€ 17.14	5.83 €	14.00 €
8	TB_5	Insulation of thermal bridges on vertical and horizontal structures in phase of the casting, realized with application on the formworks of panels in wood wool mineralized with high temperature magnesite;	3.5	0.094	0.37	?			€ 26.10		
9	TB_6										
10	TB_7										
11	TB_8_Roofs_R5					0.6	0.8	0.8		11	
12	TB_9_Roofs_R9					0.15	-0.05	0.15		11	
13	TB_10_Roofs_R11					0.25	0.05	0.25		11	
14	TB_11_Balconies_B3					1	0.9	0.9		11	
15	TB_12_Corners_C5					-0.15	0.05	-0.15		11	
16	TB_13_Corners_C1					0.15	-0.05	0.15		11	
17	TB_14_Corners_C7					-0.05	0.15	-0.05		11	
18	TB_15_Intermediate_Floors_IF1					0.1	0	0		11	
19	TB_16_Intermediate Floor_IF8					0.6	0.45	0.45		11	
20	TB_17_Internal Walls_IW1					0.1	0	0		11	
21	TB_18_Slab-on-ground floors_GF 5					0.75	0.6	0.75		11	
22	TB_19_Slab-on-groud floors_GF7					0.1	-0.05	0.1		11	
23	TB_20_Slab-on-ground floors_GF 13					0.8	0.6	0.8		11	
24	TB_21_Slab-on-groud floors_GF15					0.1	0.1	0.1		11	
25	TB_22_Pillars_P1					1.3	1.3	1.3		14	
26	TB_22_Pillars_P3					1.15	1.15	1.15		14	
27	TB23_Windows and openings_W1					0	0	0		7	
28	TB_24_Windows and openings_W6					0.1	0.1	0.1		7	
29	TB25_Windows and openings_W11					0	0	0		7	
30	TB_26_Windows and					0.1	0.1	0.1		7	

Table 64- Thermal Bridges

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

	Description	Energy vector	Efficiency	COP	SEER	combined DHW?	SFH-Single dwelling (costs calculated per single apartment)	MFH	GREECE Cost [€] - only for equipment procurement & installation & auxiliaries
HC_1	Wall-mounted gas boiler <= 25 kW - without DHW	Natural gas	0,96	-	-	No	x		**-**
HC_2	Wall-mounted gas boiler <= 25 kW	Natural gas	0,96	-	-	Yes	x		**-**
HC_3	Floor-standing gas boiler > 25 kW [INOX]	Natural gas	0,96	-	-	Yes		x	**3100**
HC_4	Wall-mounted condensing gas boiler <= 25 kW - without DHW	Natural gas	1,05	-	-	No	x		**2400**
HC_5	Wall-mounted condensing gas boiler <= 25 kW	Natural gas	1,05	-	-	Yes	x		**2600**
HC_6	Floor-standing condensing gas boiler <= 25 kW- without DHW	Natural gas	1,05	-	-	No	x		**3000**
HC_7	Floor-standing condensing gas boiler <= 25 kW	Natural gas	1,05	-	-	Yes	x		**3200**
HC_8	Floor-standing condensing gas boiler: 100-150 kW	Natural gas	1,05	-	-	No		x	**10.500**
HC_9	Floor-standing condensing gas	Natural gas	1,05	-	-	No		x	**17.000**

	boiler: 200-250 kW								
HC_10	Installation of an electric air-air HP - multisplit <= 15 kW	Electricity	-	4,5	4	No	x		**5.000**
HC_11	Installation of an electric air-air HP - multisplit <= 15 kW - only cooling	Electricity	-	-	4	No	x		
HC_12	Installation of an electric air-water HP <= 15kW - without DHW	Electricity	-	4,5	4	No	x		
HC_13	Installation of an electric air-water HP <= 25kW	Electricity	-	4,5	4	No	x		**5.000**
HC_14	Installation of an electric air-water HP - 100-150kW	Electricity	-	4	3	No		x	**40.000**
HC_15	Installation of an electric air-water HP - 200-250kW	Electricity	-	4	3	No		x	**60.000**
HC_16	GSHP - Ground Source Heat Pump - 100-150kW	Electricity	-	4,29		No		x	**58.000**
HC_17	GSHP - Ground Source Heat Pump - 200-250kW	Electricity	-	4,33		No		x	**70.000**
HC_18	Biomass boiler	Woodchips or pellets	0,876		-		x		**230/kw**
HC_19	Biomass boiler	Woodchips or pellets		-	-			x	**230/kw**
HC_20	MicroCHP - Gas turbine	Gas	0,8						

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HC_21	MicroCHP - Internal combustion engine	Natural gas/Diesel							
HC_22	District heating								
HC_23	Absorption chiller + Solar thermal	RES							
HC_24	Microtrigeneration with internal combustion engine + Absorption chiller	Natural gas/Diesel							

Table 65- HVAC-Greece

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

Code	Description	Energy vector	Efficiency	COP	GREECE Cost [€/UFR] - only for equipment procurement & installation
DHW_0	Combined with Heating				
DHW_1	Electric boiler - SFH	Electricity	0.99		400.00 €
DHW_2	Electric boilers [20 apartments]	Electricity	0.99		-
DHW_3	Gas boiler with high efficiency	Natural gas			2,000.00 €
DHW_4	Gas boiler with high efficiency [20 apartments]	Natural gas			-
DHW_5	Solar thermal				solar collector 1300
DHW_6	air-to-water Electric Heat pump - SFH	Electricity	-	4.5	3,500.00 €
DHW_7	air-to-water Electric Heat pump - MFH [20 apartments]	Electricity	-	4.5	35,000.00 €

Table 66- DHW-Greece

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

Code	Ventilation	equivalent air flow (n air change/h - m3/h)	GREECE Cost [€]
V_1	Controlled VMC	0.42	390.00 €
V_2	Controlled with thermal exchange (Heat Recovery System)	0.6	5,217.11 €
V_3	Free cooling- Night ventilation	10	
Code	**Air tightness**	**n50**	**GREECE Cost [€/m]**
A_1	Soudal window system	3	18.00 €
A_2	Passive house solution	0.5	40.00 €

Table 67- Ventilation Greece

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

Code	RES electricity	Technical Characteristics	GREECE [€/kW]: materials + installation
RES_E_1	Photovoltaic (costs per kWp - from 1 kW up to 7 kWp)	1-7 kWp	3,950.00 €
RES_E_2	Photovoltaic (costs per kWp - from 7 kW up to 20 kWp)	7-20 kWp	10,100.00 €
RES_E_3	Photovoltaic (costs per kWp - from 21 kW up to 50 kWp)	21-50 kWp	21,300.00 €
Code	**RES thermal**	**Technical Characteristics**	
RES_T_1	Biomass (woodchips or pellets generators) (cost in kWt)	efficiency 0,9	230.00 €
RES_T_2	Solar thermal (cost per m2)	% DHW covered (e.g. 50% Spain)	800.00 €
RES_T_3	Geothermal (HP - cost per kWt)_Ground-Water System	COP / EER 4,5 /5	28,000.00 €
RES_T_4	Geothermal (HP - cost per kWt)_Ground-Water System	COP / EER 4,5 /5	65,000.00 €
RES_T_5	Geothermal (HP - cost per kWt)_Water-Water System	COP / EER 4 /5	-
RES_T_6	Geothermal (HP - cost per kWt)_Water-Water System	COP / EER 4 /5	-

Table 68- RES Grrece

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

9.3.1 Energy prices

Electricity price depends on type of building (residential, commercial etc). For residential buildings until 2000KWh consumption the price is 0.09460 €/kWh
Thermal oil price at this time is 1.066 €/kWh
Gas price at this time is 0.06205 €/kWh

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9.4 Cyprus

Code	Description	Typology	Insulation material	Thickness [cm]	Other (coating)	Therm conductivity [W/mK]	R [m2K/W]	emissivity	Solar Reflectance Index (external)	ITALY Cost [€/m2]: materials + installation	SPAIN Cost [€/m2]: materials + installation	CYPRUS Cost [€/m2]: materials + installation
EW_0	No insulation	No insulation										
EW_1	ETICS with 4 of EPS	ETICS	EPS	4		0.036	1.1			€ 42.06	€ 54.24	€ 36.34
EW_2	ETICS with 8 of EPS	ETICS	EPS	8		0.036	2.2			€ 46.02	€ 60.98	€ 40.18
EW_3	ETICS with 12 of EPS	ETICS	EPS	12		0.036	3.3			€ 49.98	€ 67.70	€ 44.02
EW_4	ETICS with 4 of RW	ETICS	RW	4		0.040	1.0			€ 47.27	€ 52.10	€ 44.00
EW_5	ETICS with 8 of RW	ETICS	RW	8		0.040	2.0			€ 38.03	€ 70.99	€ 50.00
EW_6	ETICS with 12 of RW	ETICS	RW	12		0.040	3.0			€ 28.79	€ 73.01	€ 56.00
EW_7	ETICS with 4 of GW	ETICS	GW	4		0.034	1.2			€ 46.52	€ 58.21	€ 42.40
EW_8	ETICS with 8 of GW	ETICS	GW	8		0.034	2.4			€ 52.72	€ 60.17	€ 48.80
EW_9	ETICS with 12 of GW	ETICS	GW	12		0.034	3.5			€ 58.92	€ 61.15	€ 55.20
EW_10	ETICS with 4 of EPS and high SRI coating	ETICS	EPS	4	high SRI coating	0.036	1.1	0.51	0.87	€ 72.45	€ 66.80	€ 61.34
EW_11	ETICS with 8 of	ETICS	EPS	8	high SRI	0.036	2.2	0.51	0.87	€ 76.41	€ 73.54	€ 65.18

	EPS and high SRI coating				coating							
EW_12	ETICS with 12 of EPS and high SRI coating	ETICS	EPS	12	high SRI coating	0.036	3.3	0.51	0.87	€ 80.37	€ 80.26	€ 69.02
EW_13	ETICS with 4 of RW and high SRI coating	ETICS	RW	4	high SRI coating	0.040	1.0	0.51	0.87	€ 77.66	€ 64.66	€ 69.00
EW_14	ETICS with 8 of RW and high SRI coating	ETICS	RW	8	high SRI coating	0.040	2.0	0.51	0.87	€ 68.42	€ 83.55	€ 75.00
EW_15	ETICS with 12 of RW and high SRI coating	ETICS	RW	12	high SRI coating	0.040	3.0	0.51	0.87	€ 59.18	€ 85.57	€ 81.00
EW_16	ETICS with 4 of GW and high SRI coating	ETICS	GW	4	high SRI coating	0.034	1.2	0.51	0.87	€ 76.91	€ 70.77	€ 67.40
EW_17	ETICS with 8 of GW and high SRI coating	ETICS	GW	8	high SRI coating	0.034	2.4	0.51	0.87	€ 83.11	€ 72.73	€ 73.80
EW_18	ETICS with 12 of GW and high SRI coating	ETICS	GW	12	high SRI coating	0.034	3.5	0.51	0.87	€ 89.31	€ 73.71	€ 80.20
EW_19	Ventilated Facade with 4 of EPS	Ventilated Facade	EPS	4		0.036	1.1			€ 212.79	€ 216.26	?
EW_20	Ventilated Facade with 8 of EPS	Ventilated Facade	EPS	8		0.036	2.2			€ 216.75	€ 219.30	?
EW_21	Ventilated Facade with 4 of RW	Ventilated Facade	RW	4		0.040	1.0			€ 218.00	€ 226.24	?
EW_22	Ventilated Facade with 8 of RW	Ventilated Facade	RW	8		0.040	2.0			€ 208.76	€ 218.69	?

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

EW_23	Internal/Air chamber insultation with 3 of XPS	Internal/Air chamber insultation	XPS	3		0.033	0.9			€ 8.80	€ 9.62	?
EW_24	Internal/Air chamber insultation with 5 of XPS	Internal/Air chamber insultation	XPS	5		0.033	1.5			€ 12.46	€ 14.32	?
EW_25	Internal/Air chamber insultation with 3 of RW	Internal/Air chamber insultation	RW	3		0.034	0.9			€ 6.27		?
EW_26	Internal/Air chamber insultation with 5 of RW	Internal/Air chamber insultation	RW	5		0.034	1.5			€ 8.37		?
EW_27	Internal/Air chamber insultation with 3 of Expanded Perlite	Internal/Air chamber insultation	Expanded Perlite	3		0.043	0.7			€ 9.36	€ 9.29	?
EW_28	Internal/Air chamber insultation with 5 of Expanded Perlite	Internal/Air chamber insultation	Expanded Perlite	5		0.043	1.2			€ 11.32		?
EW_29	Internal insultation with 2 cm of AEROGEL	Internal insultation	AEROGEL	2		0.014	1.4			€ 83.00		?
EW_30	Internal insultation with 2 cm of	Internal insultation	AEROGEL	2	low emission	0.014	1.4			€ 83.00		?

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

	AEROGEL and low emission coating				coating							

Table 69- External Walls_Cyprus

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

Description	Typology	Thickness[cm]	Thermal conductivity [W/mK]	Thermal resistance [m2K/W]	Other	Emissivity	Solar Reflectance Index (external)	ITALY Cost (materials+Installation) [€/m2]	SPAIN Cost (materials+Installation) [€/m2]	CYPRUS Cost (materials+Installation) [€/m2]
No insulation	No insulation									
External insulation with 3 of XPS	External insulation	3	0.032	0.9				€ 9.39	€ 8.15	€ 38.90
External insulation with 5 of XPS	External insulation	5	0.032	1.6				€ 13.05	€ 10.94	€ 40.00
External insulation with 8 of XPS	External insulation	8	0.032	2.5				€ 18.54	€ 16.32	€ 43.30
External insulation with 12 of XPS	External insulation	12	0.032	3.8				€ 25.86	€ 22.85	€ 45.50
External insulation with 3 of PU Foam	External insulation	3	0.028	1.1				€ 8.96	€ 10.61	
External insulation with 5 of PU Foam	External insulation	5	0.028	1.8				€ 11.74	€ 12.85	

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External insulation with 8 of PU Foam	External insulatio n	8	0.028	2.9				€ 15.91	€ 17.17		
External insulation with 0,5+1,5+0,5 of PU Foam Sintered with 2 layers of WW	External insulatio n	0,5+1,5+0,5	0.661	0.04				€ 14.06	-		
External insulation with 0,5+2,5+0,5 of PU Foam Sintered with 2 layers of WW	External insulatio n	0,5+2,5+0,5	1.375	0.03				€ 16.63	-		
External insulation with 0,5+4+0,5 of PU Foam Sintered with 2 layers of WW	External insulatio n	0,5+4+0,5	1.911	0.03				€ 20.09	-		
External insulation with 0,5+6,5+0,5	External insulatio n	0,5+6,5+0,5	2.446	0.03				€ 26.11	-		

of PU Foam Sintered with 2 layers of WW										
External Insulation with 5 of Rockwool (RW)	External Insulati on	5	0.035	1.4				€ 12.48	€ 15.50	€ 20.00
External Insulation with 8 of Rockwool (RW)	External Insulati on	8	0.035	2.3				€ 17.52	€ 22.91	€ 25.00
Ventilated roof (5 cm air gap) with external insultation with 5 of XPS Panels	Ventilat ed roof (5 cm air gap) with external insultati on	5	0.033	1.5				€ 33.48	€ 10.25	?
Ventilated roof (5 cm air gap) with external insultation with 8 of XPS Panels	Ventilat ed roof (5 cm air gap) with external insultati on	8	0.033	2.4				€ 39.54	€ 14.45	?
Ventilated roof (5 cm air gap) with	Ventilat ed roof (5 cm air gap)	12	0.033	3.6				€ 47.62	€ 17.25	?

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external insultation with 12 of XPS Panels	with external insultation									
Internal insulation with 2 of RW	Internal insulation	2	0.035	0.6				€ 10.80	-	€ 42.00
Internal insulation with 4 of RW and low emission coating	Internal insulation	4	0.035	1.1	low emission coating	0.51		€ 41.19	€ 13.40	€ 45.00
Internal insulation with 4 of RW and low emission coating	Internal insulation	4	0.035	1.1	low emission coating	0.51		€ 41.19	€ 13.40	€ 45.00
Internal insulation with 2 of AEROGEL	Internal insulation	2	0.014	1.4				€ 83.00	-	?
Internal insulation with 2 of AEROGEL and low emission coating	Internal insulation	2	0.014	1.4	low emission coating	0.51		€ 83.00	-	?
External insutation	External insutati	3	0.034	0.9				€ 8.89	€ 7.45	€ 39.50

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with 3 of XPS	on									
External insulation with 5 of XPS	External insulatio n	5	0.034	1.5				€ 12.47	€ 10.25	€ 42.00
External insulation with 8 of XPS	External insulatio n	8	0.034	2.4				€ 17.84	€ 14.45	€ 45.00
External insulation with 5 of GW	External insulatio n	5	0.037	1.4				€ 13.30	-	€ 20.00
External insulation with 8 of GW	External insulatio n	8	0.037	2.2				€ 19.42	-	€ 25.00
External insulation with 12 of GW	External insulatio n	12	0.037	3.2				€ 27.58	-	€ 28.00
Internal insulation with 2 of Perlite and low emission coating	Internal insulatio n	2	0.043	0.5	low emissi on coatin g	0.51		€ 38.37	€ 9.29	
Internal insulation with 4 of Perlite	Internal insulatio n	4	0.043	0.9				€ 11.90	€ 9.29	
Internal insulation	Internal insulatio	4	0.043	0.9	low emissi	0.51		€ 42.29	€ 9.29	

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

with 4 of Perlite and low emission coating	n				on coatin g					
Internal insulation with 2 of GW and low emission coating	Internal insulatio n	2	0.037	0.5	low emissi on coatin g	0.51		€ 43.69	-	
Internal insultation with 4 of GW	Internal insultati on	4	0.037	1.1				€ 13.30	-	
Internal insultation with 4 of GW and low emission coating	Internal insultati on	4	0.037	1.1	low emissi on coatin g	0.51		€ 43.69	-	
Internal insultation with 2 of AEROGEL	Internal insultati on	2	0.014	1.4				€ 83.00	-	?
Internal insultation with 2 of AEROGEL and low emission coating	Internal insultati on	2	0.014	1.4	low emissi on coatin g	0.51		€ 83.00	-	?
External	External	5	0.032	1.6	high		0.87	€ 43.44	-	

insultation with 5 cm of XPS and high SRI coating	insultati on				SRI coatin g					
External insultation with 8 cm of XPS and high SRI coating	External insultati on	8	0.032	2.5	high SRI coatin g		0.87	€ 48.93	-	
External insultation with 12 cm of XPS and high SRI coating	External insultati on	12	0.032	3.8	high SRI coatin g		0.87	€ 56.25	-	
External insultation with 5 cm of GW and high SRI coating	External insultati on	5	0.037	1.4	high SRI coatin g		0.87	€ 43.69	-	
External insultation with 8 cm of GW and high SRI coating	External insultati on	8	0.037	2.2	high SRI coatin g		0.87	€ 111.79	-	
External insultation with 12 cm of GW and high SRI coating	External insultati on	12	0.037	3.2	high SRI coatin g		0.87	€ 138.92	-	

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

Table 70- Roof and Ceilnig- Cyprus

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

Code	Description	Typology	Insulation material	Thickness[cm]	Thermal conductivity [W/mK]	Thermal Resistance [m2K/W]	Costs [€/m2]
B_0	No insulation	No insulation					
B_1	Insulation with 5 of light-weighted cement based with EPS	Insulation	light-weighted cement based with EPS	5	0.100	0.5	
B_2	Insulation with 5 of light-weighted cement based with Expanded Perlite	Insulation	light-weighted cement based with Expanded Perlite	5	0.088	0.6	
B_3	Insulation with 5 of light-weighted cement based with Vermiculite	Insulation	light-weighted cement based with Vermiculite	5	0.080	0.6	
B_4	Insulation with 5 of light-weighted cement based with Expanded Clay	Insulation	light-weighted cement based with Expanded Clay	5	0.090	0.6	
B_5	Insulation with 5 of light-weighted cement based with Expanded Glass and 25.125	Insulation	light-weighted cement based with Expanded Glass	5	0.300	0.2	
B_6	Insulation with 10 of light-weighted cement based with EPS	Insulation	light-weighted cement based with EPS	10	0.100	1.0	
B_7	Insulation with 10 of light-weighted cement based with Expanded Perlite	Insulation	light-weighted cement based with Expanded Perlite	10	0.088	1.1	
B_8	Insulation with 10 of light-weighted cement based with Vermiculite	Insulation	light-weighted cement based with Vermiculite	10	0.080	1.3	
B_9	Insulation with 10 of light-weighted cement based with Expanded Clay	Insulation	light-weighted cement based with Expanded Clay	10	0.090	1.1	
B_10	Insulation with 10 of light-weighted cement based with Expanded Glass and 48.24	Insulation	light-weighted cement based with Expanded Glass	10	0.300	0.3	

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B_11	Insulation with 15 of light-weighted cement based with EPS	Insulation	light-weighted cement based with EPS	15	0.100	1.5	
B_12	Insulation with 15 of light-weighted cement based with Expanded Perlite	Insulation	light-weighted cement based with Expanded Perlite	15	0.088	1.7	
B_13	Insulation with 15 of light-weighted cement based with Vermiculite	Insulation	light-weighted cement based with Vermiculite	15	0.080	1.9	
B_14	Insulation with 15 of light-weighted cement based with Expanded Clay	Insulation	light-weighted cement based with Expanded Clay	15	0.090	1.7	
B_15	Insulation with 15 of light-weighted cement based with Expanded Glass and 69.345	Insulation	light-weighted cement based with Expanded Glass	15	0.300	0.5	
B_16	Insulation with 2 of XPS or PU Panels	Insulation	XPS or PU Panels	2	0.028	0.71	
B_17	Insulation with 4 of XPS or PU Panels	Insulation	XPS or PU Panels	4	0.028	1.43	
B_18	Insulation with 6 of XPS or PU Panels	Insulation	XPS or PU Panels	6	0.028	2.14	

Table 71- Basement Cyprus

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

Code	Description	Typology	Insulation material	Cavity Thickness	Frame kind	Uw [W/m2K]	g value [-]	Uf (W/M2k)	CYPRUS Cost [€/m2]
W_0	No replacement	No replacement							
W_1	Double windows with 2 glasses with 1.6 cm of air interspace	Double windows with 2 glasses	air interspace	1.6 cm	ALUMINIUM	2.7	0.77	3.5	
W_2	Double windows with 2 glasses window with low-ε with 1.6 cm of air interspace	Double windows with 2 glasses window with low-ε	air interspace	1.6 cm	ALUMINIUM	1.4	0.58	3.5	
W_3	2 glasses window with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)	2 glasses window	argon interspace	1.6 cm	ALUMINIUM	2.6	0.77	3.5	250
W_4	2 glasses window with low-ε with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)	2 glasses window with low-ε	argon interspace	1.6 cm	ALUMINIUM	1.1	0.59	3.5	
W_5	3 glasses window with 1.6 cm of argon interspace and ALUMINIUM	3 glasses window	argon interspace	1.6 cm	ALUMINIUM	0.6	0.53	3.5	-

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W_6	3 glasses window medium-ε with 1.6 cm of argon interspace and ALUMINIUM	3 glasses window medium-ε	argon interspace	1.6 cm	ALUMINIUM	0.6	0.54	3.5	-
W_7	3 glasses window with low-ε with 1.6 cm of argon interspace and ALUMINIUM	3 glasses window with low-ε	argon interspace	1.6 cm	ALUMINIUM	0.6	0.26	3.5	-
W_8	Double windows with 2 glasses with 1.6 cm of air interspace	Double windows with 2 glasses	air interspace	1.6 cm	WOOD	2.7	0.77	1.43	
W_9	Double windows with 2 glasses window with low-ε with 1.6 cm of air interspace	Double windows with 2 glasses window with low-ε	air interspace	1.6 cm	WOOD	1.4	0.58	1.43	
W_10	2 glasses window with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)	2 glasses window	argon interspace	1.6 cm	WOOD	2.6	0.77	1.43	
W_11	2 glasses window with low-ε with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)	2 glasses window with low-ε	argon interspace	1.6 cm	WOOD	1.1	0.59	1.43	
W_12	3 glasses window with 1.6 cm of argon interspace and WOOD	3 glasses window	argon interspace	1.6 cm	WOOD	0.6	0.53	1.43	-

W_13	3 glasses window with 1.6 cm of argon interspace and WOOD	3 glasses window	argon interspace	1.6 cm	WOOD	0.6	0.54	1.43	-
W_14	3 glasses window with low-ε with 1.6 cm of argon interspace and WOOD	3 glasses window with low-ε	argon interspace	1.6 cm	WOOD	0.6	0.26	1.43	-
W_15	Double windows with 2 glasses with 1.6 cm of air interspace	Double windows with 2 glasses	air interspace	1.6 cm	PVC	2.7	0.77	1.3	
W_16	Double windows with 2 glasses window with low-ε with 1.6 cm of air interspace	Double windows with 2 glasses window with low-ε	air interspace	1.6 cm	PVC	1.4	0.58	1.3	
W_17	2 glasses window with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)	2 glasses window	argon interspace	1.6 cm	PVC	2.6	0.77	1.3	
W_18	2 glasses window with low-ε with 1.6 cm of argon interspace and Average value for costs, when considering the three kinds of frames (Wood, aluminum, PVC)	2 glasses window with low-ε	argon interspace	1.6 cm	PVC	1.1	0.59	1.3	
W_19	3 glasses window with 1.6 cm of argon interspace and PVC	3 glasses window	argon interspace	1.6 cm	PVC	0.6	0.53	1.3	-
W_20	3 glasses window with 1.6 cm of argon interspace and PVC	3 glasses window	argon interspace	1.6 cm	PVC	0.6	0.54	1.3	-

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W_21	3 glasses window with low-ε with 1.6 cm of argon interspace and PVC	3 glasses window with low-ε	argon interspace	1.6 cm	PVC	0.6	0.26	1.3	-
W_22	3 glasses window with 1.8 cm of air interspace	3 glasses window	air interspace	1.8 cm	ALUMINIUM				
W_23	3 glasses window with 1.8 cm of air interspace	3 glasses window	air interspace	1.8 cm	ALUMINIUM				
W_24	3 glasses window with low-ε with 1.8 cm of air interspace	3 glasses window with low-ε	air interspace	1.8 cm	ALUMINIUM				
W_25	3 glasses window with 1.8 cm of air interspace	3 glasses window	air interspace	1.8 cm	WOOD				
W_26	3 glasses window with 1.8 cm of air interspace	3 glasses window	air interspace	1.8 cm	WOOD				
W_27	3 glasses window with low-ε with 1.8 cm of air interspace	3 glasses window with low-ε	air interspace	1.8 cm	WOOD				
W_28	3 glasses window with 1.8 cm of air interspace	3 glasses window	air interspace	1.8 cm	PVC				
W_29	3 glasses window with 1.8 cm of air interspace	3 glasses window	air interspace	1.8 cm	PVC				
W_30	3 glasses window with low-ε with 1.8 cm of air interspace	3 glasses window with low-ε	air interspace	1.8 cm	PVC				

Table 72- Windows- Cyprus

Typology	Solar factor ? / DeltaR ?	ITALY Cost [€/m2]	SPAIN Cost [€/m2]	[CYPRUS] [€/m2]
No replacement				-
Overhang - vertical	0.29	50	90.00 €	150.00 €
Overhang - horizontal	0.29	50	90.00 €	150.00 €

Table 73- Shadings_Cyprus

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

Code	Typology	Thickness [cm]	Thermal Conductivity [W/mK]	Thermal Resistance [m2K/W]	Linear Thermal Trasmittance [W/mK]			ITALY Cost [€/m	SPAIN Cost [€/m]	CYPRUS [€/m]
					Internal	External	Overall Internal			
TB_0	No replacement									
TB_1	Insulation of thermal bridges with panels made of PUR injected in the slabs to go from 1.01 to 0.6 for the Façade-Slabs TB	2	0.09	0.22	0.6			€ 13.78	8.63 €	11.5
TB_2	Insulation of thermal bridges with panels made of mineralized wood wool and bound with high-strength cement	3	0.09	0.33	0.25			€ 15.48	11.37 €	13.5
TB_3	Insulation of thermal bridges with application on kerbs, lintels, veils, pillars, etc. of polystyrene sheet strips extruded foam, rough surface without skin	3	0.033	0.91	0.35			€ 13.06	12.27 €	14
TB_4	Insulation of thermal bridges with application between windows and facades	5	0.035	1.43	0.05			€ 17.14	5.83 €	7
TB_5	Insulation of thermal bridges on vertical and horizontal structures in phase of the casting, realized with application on the formworks of panels in wood wool mineralized with high temperature magnesite;	3.5	0.094	0.37	?			€ 26.10		?
TB_6										
TB_7										
TB_8_Roofs_R5					0.6	0.8	0.8		11	
TB_9_Roofs_R9					0.15	-0.05	0.15		11	
TB_10_Roofs_R11					0.25	0.05	0.25		11	
TB_11_Balconies_B3					1	0.9	0.9		11	
TB_12_Corners_C5					-0.15	0.05	-0.15		11	
TB_13_Corners_C1					0.15	-0.05	0.15		11	
TB_14_Corners_C7					-0.05	0.15	-0.05		11	
TB_15_Intermediate_Floors_IF1					0.1	0	0		11	
TB_16_Intermediate Floor_IF8					0.6	0.45	0.45		11	
TB_17_Internal Walls_IW1					0.1	0	0		11	
TB_18_Slab-on-ground floors_GF 5					0.75	0.6	0.75		11	
TB_19_Slab-on-groud floors_GF7					0.1	-0.05	0.1		11	
TB_20_Slab-on-ground floors_GF 13					0.8	0.6	0.8		11	
TB_21_Slab-on-groud floors_GF15					0.1	0.1	0.1		11	
TB_22_Pillars_P1					1.3	1.3	1.3		14	
TB_22_Pillars_P3					1.15	1.15	1.15		14	
TB23_Windows and openings_W1					0	0	0		7	
TB_24_Windows and openings_W6					0.1	0.1	0.1		7	
TB25_Windows and openings_W11					0	0	0		7	
TB_26_Windows and					0.1	0.1	0.1		7	
TB27_Windows and openings_W15					0	0	0		7	
TB_28_Windows and					0.2	0.2	0.2		7	

Table 74- Thermal Briges Cyprus

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

	Description	Energy vector	Efficiency	COP	SEER	combined DHW?	CYPRUS /Cost [€] - only for equipment procurement & installation & auxiliaries
HC_1	Wall-mounted gas boiler <= 25 kW - without DHW	Natural gas	0.96	-	-	No	3,500.00 €
HC_2	Wall-mounted gas boiler <= 25 kW	Natural gas	0.96	-	-	Yes	
HC_3	Floor-standing gas boiler > 25 kW [INOX]	Natural gas	0.96	-	-	Yes	
HC_4	Wall-mounted condensing gas boiler <= 25 kW - without DHW	Natural gas	1.05	-	-	No	
HC_5	Wall-mounted condensing gas boiler <= 25 kW	Natural gas	1.05	-	-	Yes	
HC_6	Floor-standing condensing gas boiler <= 25 kW- without DHW	Natural gas	1.05	-	-	No	
HC_7	Floor-standing condensing gas boiler <= 25 kW	Natural gas	1.05	-	-	Yes	
HC_8	Floor-standing condensing gas boiler: 100-150 kW	Natural gas	1.05	-	-	No	
HC_9	Floor-standing condensing gas boiler: 200-250 kW	Natural gas	1.05	-	-	No	
HC_10	Installation of an electric air-air HP - multisplit <=	Electricity	-	4.5	4	No	

	15 kW						
HC_11	Installation of an electric air-air HP - multisplit <= 15 kW - only cooling	Electricity	-	-	4	No	
HC_12	Installation of an electric air-water HP <= 15kW - without DHW	Electricity	-	4.5	4	No	
HC_13	Installation of an electric air-water HP <= 25kW	Electricity	-	4.5	4	No	
HC_14	Installation of an electric air-water HP - 100-150kW	Electricity	-	4	3	No	
HC_15	Installation of an electric air-water HP - 200-250kW	Electricity	-	4	3	No	
HC_16	GSHP - Ground Source Heat Pump - 100-150kW	Electricity	-	4.29		No	
HC_17	GSHP - Ground Source Heat Pump - 200-250kW	Electricity	-	4.33		No	
HC_18	Biomass boiler	Woodchips or pellets	0.876		-		
HC_19	Biomass boiler	Woodchips or pellets		-	-		
HC_20	MicroCHP - Gas turbine		0.8				
HC_21	MicroCHP - Internal combustion engine	Natural gas/Diesel					
HC_22	District heating						
HC_23	Absorption chiller + Solar thermal	RES					
HC_24	Microtrigeneration with internal combustion engine + Absorption chiller	Natural gas/Diesel					

Table 75- HVAC Systems

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

	Description	Energy vector	Efficiency	COP	CYPRUS Cost [€/UFR] - only for equipment procurement & installation
DHW_0	Combined with Heating				
DHW_1	Electric boiler - SFH	Electricity	0.99		
DHW_2	Electric boilers [20 apartments]	Electricity	0.99		
DHW_3	Gas boiler with high efficiency	Natural gas			3,500.00 €
DHW_4	Gas boiler with high efficiency [20 apartments]	Natural gas			
DHW_5	Solar thermal				428.00 €
DHW_6	air-to-water Electric Heat pump - SFH	Electricity	-	4.5	6,500.00 €
DHW_7	air-to-water Electric Heat pump - MFH [20 apartments]	Electricity	-	4.5	

Table 76- DHW- Cyprus

Code	Ventilation	equivalent air flow (n air change/h - m3/h)	CYPRUS Cost [€]
V_1	Controlled VMC	0.42	?
V_2	Controlled with thermal exchange (Heat Recovery System)	0.6	?
V_3	Free cooling- Night ventilation	10	?
			?
A_1	Soudal window system	3	?
A_2	Passive house solution	0.5	?

Table 77- Ventilation Cyprus

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

Code	RES electricity	Technical Characteristics			CYPRUS Cost [€/kW]: materials + installation
RES_E_1	Photovoltaic (costs per kWp - from 1 kW up to 7 kWp)	1-7 kWp			1,661
RES_E_2	Photovoltaic (costs per kWp - from 7 kW up to 20 kWp)	7-20 kWp			-
RES_E_3	Photovoltaic (costs per kWp - from 21 kW up to 50 kWp)	21-50 kWp			-
Code	**RES thermal**	**Technical Characteristics**	**SFH or MFH**	**Notes**	
RES_T_1	Biomass (woodchips or pellets generators) (cost in kWt)	efficiency 0,9	SFH		
RES_T_2	Solar thermal (cost per m2)	% DHW covered (e.g. 50% Spain)			428
RES_T_3	Geothermal (HP - cost per kWt)_Ground-Water System	COP / EER 4,5 /5	SFH	Power Needed 8 kW soil efficiency 40 W/mK	20,000
RES_T_4	Geothermal (HP - cost per kWt)_Ground-Water System	COP / EER 4,5 /5	MFH	Power Needed 31 kW	
RES_T_5	Geothermal (HP - cost per kWt)_Water-Water System	COP / EER 4 /5	SFH	Power Needed 8 kW soil efficiency 40 W/mK	
RES_T_6	Geothermal (HP - cost per kWt)_Water-Water System	COP / EER 4 /5	MFH	Power Needed 31 kW	

Table 78- Cypru

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9.4.1 Energy prices

Electricity Supply from Grid			
Charge Type	Domestic		Industrial
	Tariff No.01 Common	Tariff No.56 Elect. Storage Heaters (3Φ)	Tariff No.10 Low Voltage
Fixed (€)	5.64	0	39.36
Price per kWh (€/kWh)	0.14625	0.15	0.146
Fuel Oil			
Current Price per Mega Tonne (€/MT)	496.81		

Table 79- Energy Prices Cyprus

For the domestic Net-Metering (Photovoltaics up to 10kW) there is a fixed charge of around €10/kW of installed rated power and
for any surplus consumption (i.e. consumption was more than the PV produced energy), Tariff No.1 charges apply.
NOTE: All prices shown above do not include country VAT which is 19%.

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9.5 Slovenia

Code	Description	Typology	Insulation material	Thickness [cm]	Other (coating)	Therm conductivity [W/mK]	R [m2K/W]	emissivity	Solar Reflectance Index (external)	ZRMK_SLOVENIA Cost [€/m2]: materials + installation WITH VAT
EW_0	No insulation	No insulation								
EW_1	ETICS with 4 of EPS	ETICS	EPS	4		0,036	1,1			€ 40,63
EW_2	ETICS with 8 of EPS	ETICS	EPS	8		0,036	2,2			€ 44,14
EW_3	ETICS with 12 of EPS	ETICS	EPS	12		0,036	3,3			€ 48,82
EW_3a	ETICS with 14 of EPS	ETICS	EPS	14		0,036	3,9			€ 51,17
EW_4	ETICS with 4 of RW	ETICS	RW	4		0,040	1,0			€ 45,69
EW_5	ETICS with 8 of RW	ETICS	RW	8		0,040	2,0			€ 48,30
EW_6	ETICS with 12 of RW	ETICS	RW	12		0,040	3,0			€ 55,06
EW_6a	ETICS with 14 of RW	ETICS	RW	14		0,040	3,5			€ 58,44
EW_7	ETICS with 4 of GW	ETICS	GW	4		0,034	1,2			€ 41,86
EW_8	ETICS with 8 of GW	ETICS	GW	8		0,034	2,4			€ 43,86
EW_9	ETICS with 12 of GW	ETICS	GW	12		0,034	3,5			€ 47,45
EW_9a	ETICS with 14 of GW	ETICS	GW	14		0,034	4,1			€ 49,85
EW_10	ETICS with 4 of EPS and high SRI coating	ETICS	EPS	4	high SRI coating	0,036	1,1	0,51	0,87	€ 60,94
EW_11	ETICS with 8 of EPS and high SRI coating	ETICS	EPS	8	high SRI coating	0,036	2,2	0,51	0,87	€ 66,21
EW_12	ETICS with 12 of EPS and high SRI coating	ETICS	EPS	12	high SRI coating	0,036	3,3	0,51	0,87	€ 73,24
EW_13	ETICS with 4 of RW and high SRI coating	ETICS	RW	4	high SRI coating	0,040	1,0	0,51	0,87	€ 68,53
EW_14	ETICS with 8 of RW	ETICS	RW	8	high SRI	0,040	2,0	0,51	0,87	€ 72,45

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	and high SRI coating				coating					
EW_15	ETICS with 12 of RW and high SRI coating	ETICS	RW	12	high SRI coating	0,040	3,0	0,51	0,87	€ 82,59
EW_16	ETICS with 4 of GW and high SRI coating	ETICS	GW	4	high SRI coating	0,034	1,2	0,51	0,87	€ 62,79
EW_17	ETICS with 8 of GW and high SRI coating	ETICS	GW	8	high SRI coating	0,034	2,4	0,51	0,87	€ 65,79
EW_18	ETICS with 12 of GW and high SRI coating	ETICS	GW	12	high SRI coating	0,034	3,5	0,51	0,87	€ 71,17
EW_19	Ventilated Facade with 4 of EPS	Ventilated Facade	EPS	4		0,036	1,1			€ 100,00
EW_20	Ventilated Facade with 8 of EPS	Ventilated Facade	EPS	8		0,036	2,2			€ 102,88
EW_21	Ventilated Facade with 4 of RW	Ventilated Facade	RW	4		0,040	1,0			€ 104,15
EW_22	Ventilated Facade with 8 of RW	Ventilated Facade	RW	8		0,040	2,0			€ 106,29
EW_23	Internal/Air chamber insultation with 3 of XPS	Internal/Air chamber insultation	XPS	3		0,033	0,9			
EW_24	Internal/Air chamber insultation with 5 of XPS	Internal/Air chamber insultation	XPS	5		0,033	1,5			
EW_25	Internal/Air chamber insultation with 3 of RW	Internal/Air chamber insultation	RW	3		0,034	0,9			
EW_26	Internal/Air chamber insultation with 5 of RW	Internal/Air chamber insultation	RW	5		0,034	1,5			
EW_27	Internal/Air chamber insultation with 3 of Expanded Perlite	Internal/Air chamber insultation	Expanded Perlite	3		0,043	0,7			
EW_28	Internal/Air chamber insultation with 5 of	Internal/Air chamber	Expanded Perlite	5		0,043	1,2			

	Expanded Perlite	insultation								
EW_29	Internal insultation with 2 cm of AEROGEL	Internal insultation	AEROGEL	2		0,014	1,4			
EW_30	Internal insultation with 2 cm of AEROGEL and low emission coating	Internal insultation	AEROGEL	2	low emission coating	0,014	1,4			

Table 80- External walls Slovenia

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

Code	Description	Typology	Insulation material	Thickness[cm]	Thermal conductivity [W/mK]	Thermal resistance [m2K/W]	Other	Emissivity	Solar Reflectance Index (external)	[ZRMK_SLOVENIA] Cost (materials+Installation) [€/m2]
TR_0	No insulation	No insulation								
TR_1	External insulation with 3 of XPS	External insulation	XPS	3	0,032	0,9				€ 45,00
TR_2	External insulation with 5 of XPS	External insulation	XPS	5	0,032	1,6				€ 48,73
TR_3	External insulation with 8 of XPS	External insulation	XPS	8	0,032	2,5				€ 50,60
TR_4	External insulation with 12 of XPS	External insulation	XPS	12	0,032	3,8				€ 52,47
TR_6	External insulation with 3 of PU Foam	External insulation	PU Foam	3	0,028	1,1				€ 49,34
TR_7	External insulation with 5 of PU Foam	External insulation	PU Foam	5	0,028	1,8				€ 52,47
TR_8	External insulation with 8 of PU Foam	External insulation	PU Foam	8	0,028	2,9				€ 58,94
TR_9	External insulation with 0,5+1,5+0,5 of PU Foam Sintered with 2 layers of WW	External insulation	PU Foam Sintered with 2 layers of WW	0,5+1,5+0,5	0,661	0,04				
TR_10	External insulation with 0,5+2,5+0,5 of PU Foam Sintered with 2 layers of WW	External insulation	PU Foam Sintered with 2 layers of WW	0,5+2,5+0,5	1,375	0,03				
TR_11	External insulation with 0,5+4+0,5 of PU Foam Sintered with 2 layers of WW	External insulation	PU Foam Sintered with 2 layers of WW	0,5+4+0,5	1,911	0,03				

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TR_12	External insulation with 0,5+6,5+0,5 of PU Foam Sintered with 2 layers of WW	External insulation	PU Foam Sintered with 2 layers of WW	0,5+6,5+0,5	2,446	0,03				
TR_13	External Insulation with 5 of Rockwool (RW)	External Insulation	Rockwool (RW)	5	0,035	1,4				€ 44,62
TR_14	External Insulation with 8 of Rockwool (RW)	External Insulation	Rockwool (RW)	8	0,035	2,3				€ 46,76
TR_14	External Insulation with 12 of Rockwool (RW)	External Insulation	Rockwool (RW)	12	0,035	3,4				€ 52,30
TR_14	External Insulation with 14 of Rockwool (RW)	External Insulation	Rockwool (RW)	14	0,035	4,0				€ 55,07
TR_15	Ventilated roof (5 cm air gap) with external insultation with 5 of XPS Panels	Ventilated roof (5 cm air gap) with external insultation	XPS Panels	5	0,033	1,5				€ 87,72
TR_16	Ventilated roof (5 cm air gap) with external insultation with 8 of XPS Panels	Ventilated roof (5 cm air gap) with external insultation	XPS Panels	8	0,033	2,4				€ 93,32
TR_17	Ventilated roof (5 cm air gap) with external insultation with 12 of XPS Panels	Ventilated roof (5 cm air gap) with external insultation	XPS Panels	12	0,033	3,6				€ 100,79
TR_18	Internal insulation with 2 of RW	Internal insulation	RW	2	0,035	0,6				
TR_19	Internal insulation with 4 of RW and low emission coating	Internal insulation	RW	4	0,035	1,1	low emission coating	0,51		

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TR_20	Internal insulation with 4 of RW and low emission coating	Internal insulation	RW	4	0,035	1,1	low emission coating	0,51		
TR_21	Internal insulation with 2 of AEROGEL	Internal insulation	AEROGEL	2	0,014	1,4				
TR_22	Internal insulation with 2 of AEROGEL and low emission coating	Internal insulation	AEROGEL	2	0,014	1,4	low emission coating	0,51		
FR_1	External insutation with 3 of XPS	External insutation	XPS	3	0,034	0,9				
FR_2	External insulation with 5 of XPS	External insulation	XPS	5	0,034	1,5				
FR_3	External insulation with 8 of XPS	External insulation	XPS	8	0,034	2,4				
FR_4	External insulation with 5 of GW	External insulation	GW	5	0,037	1,4				€ 45,21
FR_5	External insulation with 8 of GW	External insulation	GW	8	0,037	2,2				€ 46,85
FR_6	External insulation with 12 of GW	External insulation	GW	12	0,037	3,2				€ 49,79
FR_7	Internal insulation with 2 of Perlite and low emission coating	Internal insulation	Perlite	2	0,043	0,5	low emission coating	0,51		
FR_8	Internal insulation with 4 of Perlite	Internal insulation	Perlite	4	0,043	0,9				
FR_9	Internal insulation with 4 of Perlite and low emission coating	Internal insulation	Perlite	4	0,043	0,9	low emission coating	0,51		
FR_10	Internal insulation with 2 of GW and low emission coating	Internal insulation	GW	2	0,037	0,5	low emission coating	0,51		
FR_11	Internal insultation with 4 of GW	Internal insultation	GW	4	0,037	1,1				€ 45,21

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FR_12	Internal insultation with 4 of GW and low emission coating	Internal insultation	GW	4	0,037	1,1	low emission coating	0,51		
FR_13	Internal insultation with 2 of AEROGEL	Internal insultation	AEROGEL	2	0,014	1,4				
FR_14	Internal insultation with 2 of AEROGEL and low emission coating	Internal insultation	AEROGEL	2	0,014	1,4	low emission coating	0,51		-
FR_15	External insultation with 5 cm of XPS and high SRI coating	External insultation	XPS	5	0,032	1,6	high SRI coating		0,87	-
FR_16	External insultation with 8 cm of XPS and high SRI coating	External insultation	XPS	8	0,032	2,5	high SRI coating		0,87	-
FR_17	External insultation with 12 cm of XPS and high SRI coating	External insultation	XPS	12	0,032	3,8	high SRI coating		0,87	-
FR_21	External insultation with 5 cm of GW and high SRI coating	External insultation	GW	5	0,037	1,4	high SRI coating		0,87	-
FR_22	External insultation with 8 cm of GW and high SRI coating	External insultation	GW	8	0,037	2,2	high SRI coating		0,87	-
FR_23	External insultation with 12 cm of GW and high SRI coating	External insultation	GW	12	0,037	3,2	high SRI coating		0,87	-

Table 81 Roof and Ceiling Slovenia

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

Code	Description	Typology	Insulation material	Thickness[cm]	Thermal conductivity [W/mK]	Thermal Resistance [m2K/W]	[ZRMK_SLOVENIA] Costs [€/m2]
B_0	No insulation	No insulation					
B_1	Insulation with 5 of light-weighted cement based with EPS	Insulation	light-weighted cement based with EPS	5	0,100	0,5	€ 18,00
B_2	Insulation with 5 of light-weighted cement based with Expanded Perlite	Insulation	light-weighted cement based with Expanded Perlite	5	0,088	0,6	€ 22,00
B_3	Insulation with 5 of light-weighted cement based with Vermiculite	Insulation	light-weighted cement based with Vermiculite	5	0,080	0,6	€ 25,00
B_4	Insulation with 5 of light-weighted cement based with Expanded Clay	Insulation	light-weighted cement based with Expanded Clay	5	0,090	0,6	€ 23,00
B_5	#RIF!	Insulation	light-weighted cement based with Expanded Glass	5	0,300	0,2	€ 28,00
B_6	Insulation with 10 of light-weighted cement based with EPS	Insulation	light-weighted cement based with EPS	10	0,100	1,0	€ 38,00
B_7	Insulation with 10 of light-weighted cement based with Expanded Perlite	Insulation	light-weighted cement based with Expanded Perlite	10	0,088	1,1	€ 43,00
B_8	Insulation with 10 of light-weighted cement based with Vermiculite	Insulation	light-weighted cement based with Vermiculite	10	0,080	1,3	€ 49,00
B_9	Insulation with 10 of light-weighted cement based with Expanded Clay	Insulation	light-weighted cement based with Expanded Clay	10	0,090	1,1	€ 45,00
B_10	#RIF!	Insulation	light-weighted cement based with Expanded Glass	10	0,300	0,3	€ 58,00
B_11	Insulation with 15 of light-weighted cement based with EPS	Insulation	light-weighted cement based with EPS	15	0,100	1,5	€ 58,00

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B_12	Insulation with 15 of light-weighted cement based with Expanded Perlite	Insulation	light-weighted cement based with Expanded Perlite	15	0,088	1,7	€ 63,00
B_13	Insulation with 15 of light-weighted cement based with Vermiculite	Insulation	light-weighted cement based with Vermiculite	15	0,080	1,9	€ 60,00
B_14	Insulation with 15 of light-weighted cement based with Expanded Clay	Insulation	light-weighted cement based with Expanded Clay	15	0,090	1,7	€ 56,00
B_15	#RIF!	Insulation	light-weighted cement based with Expanded Glass	15	0,300	0,5	€ 88,00
B_16	#RIF!	Insulation	XPS or PU Panels	2	0,028	0,71	€ 5,00
B_17	#RIF!	Insulation	XPS or PU Panels	4	0,028	1,43	€ 8,00
B_18	#RIF!	Insulation	XPS or PU Panels	6	0,028	2,14	€ 10,00
B_18	#RIF!	Insulation	XPS or PU Panels	12	0,028	4,29	€ 18,00

Table 82. Basement Slovenia

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Code	Description	Typology	Insulation mate	Cavity Thicknes	Frame kind	Uw [W/m2K]	g value [	Uf (W/M2k)	ITALY Cost [€/m2]: materials + replacement			SPAIN Cost [	[ZRMK_SLOVENIA] Cost [€/m2]		
2	W_0	No replacement	No replacement								NOTE	Evaluate which kind of windows are necessary to consider!				
3	W_1	Double windows with 2 glasses with 1.6 cm of air interspace	Double windows with 2 glasses	air interspace	1.6 cm	ALUMINIUM	2.7	0.77	3.5	0			62.11 €			
4	W_2	Double windows with 2 glasses window with low-ε with 1.6 cm of air interspace	Double windows with 2 glasses windo	air interspace	1.6 cm	ALUMINIUM	1.4	0.58	3.5	0			149.67 €			
5	W_3	2 glasses window with 1.6 cm of argon interspace and Average value for costs, when consideri	2 glasses window	argon interspace	1.6 cm	ALUMINIUM	2.6	0.77	3.5	350			69.08 €			
6	W_4	2 glasses window with low-ε with 1.6 cm of argon interspace and Average value for costs, wh	2 glasses window with low-ε	argon interspace	1.6 cm	ALUMINIUM	1.1	0.59	3.5	450			156.64 €			
7	W_4a	2 glasses window with low-ε with 1.6 cm of argon interspace and Average value for costs, wh	2 glasses window with low-ε	argon interspace	1.6 cm	ALUMINIUM	1.1	0.62	1.6	450			156.64 €	722		
8	W_5	3 glasses window with 1.6 cm of argon interspace and ALUMINIUM	3 glasses window	argon interspace	1.6 cm	ALUMINIUM	0.6	0.53	3.5	450			119.57	-		
9	W_5a	3 glasses window with 1.8 cm of argon interspace and ALUMINIUM	3 glasses window	argon interspace	1.8 cm	ALUMINIUM	0.98	0.52	1.6	450			119.57 €	743	g-value is too low for our market	
10	W_6	3 glasses window medium-ε with 1.6 cm of argon interspace and ALUMINIUM	3 glasses window medium-ε	argon interspace	1.6 cm	ALUMINIUM	0.6	0.54	3.5	500				-	U-value is not in accordance with our legislation	
11	W_7	3 glasses window with low-ε with 1.6 cm of argon interspace and ALUMINIUM	3 glasses window with low-ε	argon interspace	1.6 cm	ALUMINIUM	0.6	0.26	3.5	530			315.45 €	-	U-value is not in accordance with our legislation	
12	W_8	Double windows with 2 glasses with 1.6 cm of air interspace	Double windows with 2 glasses	air interspace	1.6 cm	WOOD	2.7	0.77	1.43	0			82.34 €		U-value is not in accordance with our legislation	
13	W_9	Double windows with 2 glasses window with low-ε with 1.6 cm of air interspace	Double windows with 2 glasses window	air interspace	1.6 cm	WOOD	1.4	0.58	1.43	0			169.90 €			
14	W_10	2 glasses window with 1.6 cm of argon interspace and Average value for costs, when consideri	2 glasses window	argon interspace	1.6 cm	WOOD	2.6	0.77	1.43	350			89.31 €			
15	W_11	2 glasses window with low-ε with 1.6 cm of argon interspace and Average value for costs, wh	2 glasses window with low-ε	argon interspace	1.6 cm	WOOD	1.1	0.59	1.43	450			176.874			
16	W_11a	2 glasses window with low-ε with 1.6 cm of argon interspace and Average value for costs, wh	2 glasses window with low-ε	argon interspace	1.6 cm	WOOD	1.2	0.62	1.25	450			176.87 €	290	g-value is too low for our market	
17	W_12	3 glasses window with 1.6 cm of argon interspace and WOOD	3 glasses window	argon interspace	1.6 cm	WOOD	0.6	0.53	1.43	450			139.80 €	-	U-value is not in accordance with our legislation	
18	W_12a	3 glasses window with 1.8 cm of argon interspace and WOOD	3 glasses window	argon interspace	1.8 cm	WOOD	0.6	0.52	1.1	450			139.80 €	385	U-value is not in accordance with our legislation	
19	W_13	3 glasses window with 1.6 cm of argon interspace and WOOD	3 glasses window	argon interspace	1.6 cm	WOOD	0.6	0.54	1.43	500				-	U-value is not in accordance with our legislation	
20	W_14	3 glasses window with low-ε with 1.6 cm of argon interspace and WOOD	3 glasses window with low-ε	argon interspace	1.6 cm	WOOD	0.6	0.26	1.43	530			335.68 €	-		
21	W_15	Double windows with 2 glasses with 1.6 cm of air interspace	Double windows with 2 glasses	air interspace	1.6 cm	PVC	2.7	0.77	1.3	0			59.43 €			
22	W_16	Double windows with 2 glasses window with low-ε with 1.6 cm of air interspace	Double windows with 2 glasses window	air interspace	1.6 cm	PVC	1.4	0.58	1.3	0			146.99 €			
23	W_17	2 glasses window with 1.6 cm of argon interspace and Average value for costs, when consideri	2 glasses window	argon interspace	1.6 cm	PVC	2.6	0.77	1.3	350			66.40 €		g-value is too low for our market	
24	W_18	2 glasses window with low-ε with 1.6 cm of argon interspace and Average value for costs, wh	2 glasses window with low-ε	argon interspace	1.6 cm	PVC	1.1	0.59	1.3	450			153.96 €			
25	W_18a	2 glasses window with low-ε with 1.6 cm of argon interspace and Average value for costs, wh	2 glasses window with low-ε	argon interspace	1.6 cm	PVC	1.2	0.62	0.92	450			153.96 €	211		
26	W_19	3 glasses window with 1.6 cm of argon interspace and PVC	3 glasses window	argon interspace	1.6 cm	PVC	0.6	0.53	1.3	450			116.89 €	-		
27	W_19a	3 glasses window with 1.8 cm of argon interspace and PVC	3 glasses window	argon interspace	1.8 cm	PVC	0.81	0.52	0.92	450			116.89 €	232		
28	W_20	3 glasses window with 1.6 cm of argon interspace and PVC	3 glasses window	argon interspace	1.6 cm	PVC	0.6	0.54	1.3	500				-		
29	W_21	3 glasses window with low-ε with 1.6 cm of argon interspace and PVC	3 glasses window with low-ε	argon interspace	1.6 cm	PVC	0.6	0.26	1.3	530			312.77 €	-		
30	W_22	3 glasses window with 1.8 cm of air interspace	3 glasses window	air interspace	1.8 cm	ALUMINIUM							-			
31	W_23	3 glasses window with 1.8 cm of air interspace	3 glasses window	air interspace	1.8 cm	ALUMINIUM							-			
32	W_24	3 glasses window with low-ε with 1.8 cm of air interspace	3 glasses window with low-ε	air interspace	1.8 cm	ALUMINIUM							-			
33	W_25	3 glasses window with 1.8 cm of air interspace	3 glasses window	air interspace	1.8 cm	WOOD							-			
34	W_26	3 glasses window with 1.8 cm of air interspace	3 glasses window	air interspace	1.8 cm	WOOD							-			
35	W_27	3 glasses window with low-ε with 1.8 cm of air interspace	3 glasses window with low-ε	air interspace	1.8 cm	WOOD							-			
36	W_28	3 glasses window with 1.8 cm of air interspace	3 glasses window	air interspace	1.8 cm	PVC							-			
37	W_29	3 glasses window with 1.8 cm of air interspace	3 glasses window	air interspace	1.8 cm	PVC							-			
38	W_30	3 glasses window with low-ε with 1.8 cm of air interspace	3 glasses window with low-ε	air interspace	1.8 cm	PVC							-			

Table 83. Windows Slovenia

Description	**Typology**	**Solar factor ? / DeltaR ?**	**[SLOVENIA ZRMK] [€/m2]**
No replacement	No replacement		-
Overhang - vertical 50 0.29	Overhang - vertical	0.29	80.00 €
Overhang - horizontal 50 0.29	Overhang - horizontal	0.29	80.00 €

Table 84- Shadings Slovenia

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

Code	Typology	Thickness [cm]	Thermal Conductivity [W/mK]	Thermal Resistance [m2K/W]	Linear Thermal Trasmittance [W/mK]			ITALY Cost [€/m	SPAIN Cost [€/m]	[PARTNER_NAME] [€/m]
					Internal	External	Overall Internal			
TB_0	No replacement									
TB_1	Insulation of thermal bridges with panels made of PUR injected in the slabs to go from 1.01 to 0.6 for the Façade-Slabs TB	2	0.09	0.22	0.6			€ 13.78	8.63 €	18 €
TB_2	Insulation of thermal bridges with panels made of mineralized wood wool and bound with high-strength cement	3	0.09	0.33	0.25			€ 15.48	11.37 €	21 €
TB_3	Insulation of thermal bridges with application on kerbs, lintels, veils, pillars, etc. of polystyrene sheet strips extruded foam, rough surface without skin	3	0.033	0.91	0.35			€ 13.06	12.27 €	15 €
TB_4	Insulation of thermal bridges with application between windows and facades	5	0.035	1.43	0.05			€ 17.14	5.83 €	23 €
TB_5	Insulation of thermal bridges on vertical and horizontal structures in phase of the casting, realized with application on the formworks of panels in wood wool mineralized with high temperature magnesite;	3.5	0.094	0.37	?			€ 26.10		27 €
TB_6										
TB_7										
TB_8_Roofs_R5					0.6	0.8	0.8		11	
TB_9_Roofs_R9					0.15	-0.05	0.15		11	
TB_10_Roofs_R11					0.25	0.05	0.25		11	
TB_11_Balconies_B3					1	0.9	0.9		11	
TB_12_Corners_C5					-0.15	0.05	-0.15		11	
TB_13_Corners_C1					0.15	-0.05	0.15		11	
TB_14_Corners_C7					-0.05	0.15	-0.05		11	
TB_15_Intermediate_Floors_IF1					0.1	0	0		11	
TB_16_Intermediate Floor_IF8					0.6	0.45	0.45		11	
TB_17_Internal Walls_IW1					0.1	0	0		11	
TB_18_Slab-on-ground floors_GF 5					0.75	0.6	0.75		11	
TB_19_Slab-on-groud floors_GF7					0.1	-0.05	0.1		11	
TB_20_Slab-on-ground floors_GF 13					0.8	0.6	0.8		11	
TB_21_Slab-on-groud floors_GF15					0.1	0.1	0.1		11	
TB_22_Pillars_P1					1.3	1.3	1.3		14	
TB_22_Pillars_P3					1.15	1.15	1.15		14	
TB23_Windows and openings_W1					0	0	0		7	
TB_24_Windows and openings_W6					0.1	0.1	0.1		7	
TB25_Windows and openings_W11					0	0	0		7	
TB_26_Windows and					0.1	0.1	0.1		7	

Table 85- Thermal Bridges-Slovenia

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

	Description	Energy vector	Efficiency	COP	SEER	combined DHW?	Cost [€] - for equipment + auxiliaries	SFH-Single dwelling (costs calculated per single apartment)	MFH	ZRMK Slovenia /Cost [€]
HC_1	Wall-mounted gas boiler <= 25 kW - without DHW	Natural gas	0,96	-	-	No		x		NA
HC_2	Wall-mounted gas boiler <= 25 kW	Natural gas	0,96	-	-	Yes		x		NA
HC_3	Floor-standing gas boiler > 25 kW [INOX]	Natural gas	0,96	-	-	Yes	?		x	NA
HC_4	Wall-mounted condensing gas boiler <= 25 kW - without DHW	Natural gas	1,05	-	-	No		x		3363,54
HC_5	Wall-mounted condensing gas boiler <= 25 kW	Natural gas	1,05	-	-	Yes		x		3660,00
HC_6	Floor-standing condensing gas boiler <= 25 kW- without DHW	Natural gas	1,05	-	-	No		x		4116,97
HC_7	Floor-standing condensing gas boiler <= 25 kW	Natural gas	1,05	-	-	Yes		x		4479,84
HC_8	Floor-standing condensing gas boiler: 100-150 kW	Natural gas	1,05	-	-	No	?		x	19100,00
HC_9	Floor-standing condensing gas boiler: 200-250 kW	Natural gas	1,05	-	-	No	70000 ?		x	33600,00

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

HC_10	Installation of an electric air-air HP - multisplit <= 15 kW	Electricity	-	4,5	4	No	?	x		2916,00
HC_11	Installation of an electric air-air HP - multisplit <= 15 kW - only cooling	Electricity	-	-	4	No	?	x		?
HC_12	Installation of an electric air-water HP <= 15kW - without DHW	Electricity	-	4,5	4	No		x		?
HC_13	Installation of an electric air-water HP <= 25kW	Electricity	-	4,5	4	No		x		15400,00
HC_14	Installation of an electric air-water HP - 100-150kW	Electricity	-	4	3	No			x	62000,00
HC_15	Installation of an electric air-water HP - 200-250kW	Electricity	-	4	3	No			x	105000,00
HC_16	GSHP - Ground Source Heat Pump - 100-150kW	Electricity	-	4,29		No			x	126000,00
HC_17	GSHP - Ground Source Heat Pump - 200-250kW	Electricity	-	4,33		No			x	180000,00
HC_18	Biomass boiler	Woodchips or pellets	0,876		-			x		900,00
HC_19	Biomass boiler	Woodchips or pellets		-	-				x	900,00
HC_20	MicroCHP - Gas turbine	Gas	0,8				?			16000,00
HC_21	MicroCHP - Internal combustion engine	Natural gas/Diesel					?			NA

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

HC_22	District heating						?			3.800,00
HC_23	Absorption chiller + Solar thermal	RES					?			
HC_24	Microtrigeneration with internal combustion engine + Absorption chiller	Natural gas/Diesel					?			

Table 86- HVAC- Slovenia

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

	Description	Energy vector	Efficiency	COP	SFH-Single dwelling (costs calculated per single apartment)	MFH	ZRMK Slovenia /Cost [€/UFR] - only for equipment procurement & installation
DHW_0	Combined with Heating				x	x	
DHW_1	Electric boiler - SFH	Electricity	0.99		x		725.00 €
DHW_2	Electric boilers [20 apartments]	Electricity	0.99			x	5,000.00 €
DHW_3	Gas boiler with high efficiency	Natural gas			x		1,900.00 €
DHW_4	Gas boiler with high efficiency [20 apartments]	Natural gas				x	5,018.00 €
DHW_5	Solar thermal				x	x	770.00
DHW_6	air-to-water Electric Heat pump - SFH	Electricity	-	4.5	x		1,900.00 €
DHW_7	air-to-water Electric Heat pump - MFH [20 apartments]	Electricity	-	4.5		x	-

Table 87_DHW_ Slovenoia

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

Code	Ventilation	equivalent air flow (n air change/h - m3/h)	ZRMK Slovenia Cost [€]
V_1	Controlled VMC	0.42	
V_1a	VMC - Hygrosensible ventilation	30 m3/h	400.00
V_2	Controlled with thermal exchange (Heat Recovery System)	0.6	
V_2a	Controlled with thermal exchange (Heat Recovery System)	30 m3/h	841.80
V_2b	Controlled with thermal exchange (Heat Recovery System)	60 m3/h	1,451.80
V_3	Free cooling- Night ventilation	10	0.00
Code	**Air tightness**	**n50**	**ZRMK Slovenia Cost [€]**
A_1	Soudal window system	3	NA
A_2	Passive house solution	0.5	NA

Table 88- Ventilation Slovenia

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

Code	RES electricity	Technical Characteristics		ZRMK Slovenia Cost [€/kWp]: materials + installation + project
RES_E_1	Photovoltaic (costs per kWp - from 1 kW up to 7 kWp)	1-7 kWp		1,300
RES_E_2	Photovoltaic (costs per kWp - from 7 kW up to 20 kWp)	7-20 kWp		1,300
RES_E_3	Photovoltaic (costs per kWp - from 21 kW up to 50 kWp)	21-50 kWp		1,300
Code	**RES thermal**	**Technical Characteristics**	**SFH or MFH**	
RES_T_1	Biomass (woodchips or pellets generators) (cost in kWt)	efficiency 0,9	SFH	900.00
RES_T_2	Solar thermal (cost per m2)	% DHW covered (e.g. 50% Spain)		770
RES_T_3	Geothermal (HP - cost per kWt)_Ground-Water System	COP / EER 4,5 /5	SFH	25,500
RES_T_4	Geothermal (HP - cost per kWt)_Ground-Water System	COP / EER 4,5 /5	MFH	63,400
RES_T_5	Geothermal (HP - cost per kWt)_Water-Water System	COP / EER 4 /5	SFH	28,000
RES_T_6	Geothermal (HP - cost per kWt)_Water-Water System	COP / EER 4 /5	MFH	50,000

Table 89- RES Slovenia

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

9.5.1 Energy Prices

Energy prices			
Electricity	0.16	EUR/kWh	price on 15.03.2019
Gas	0.06	EUR/kWh	price on 15.03.2019
District heating	0.056	EUR/kWh	price on 31.01.2019

Table 90- Energy Prices Slovenia

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

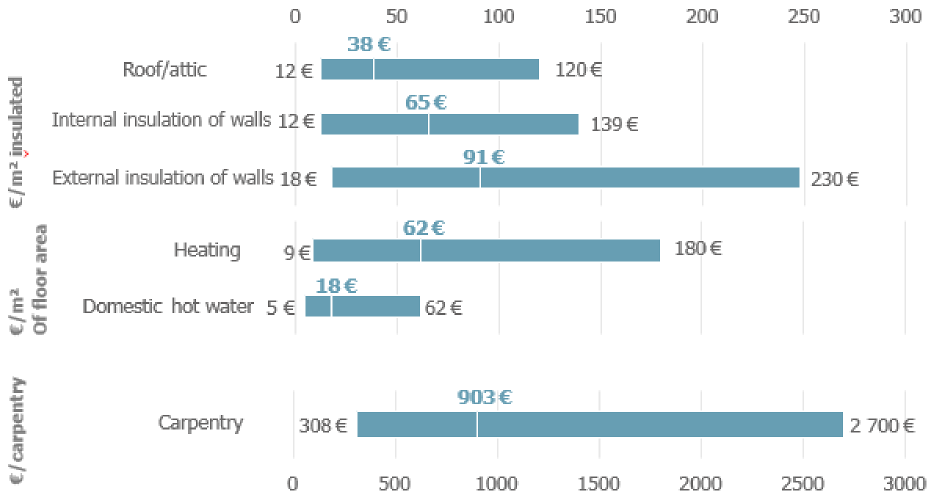
9.6 France

Technical and financial analysis of energy renovation, Provence Alpes Cote d'azur region, France

The following results come from an analysis that had been realized in 2016 on the base of financial assistance cases. 335 dwellings of Provence Alpes Cote d'Azur region were studied.

Analysis of the different renovation measures:

Minimum and maximum works cost, **the average cost**:



The costs mentioned for each item include the acquisition, the eventual removal of the old installation and the installation of the new one. The price range is important; it is linked to the technical choices as well as the typology of housing. It is important to remember that these costs only concern the 335 files studied, and that it is not a price reference chart of the energy renovation.

Roof and Attic insulation

Insulating material used:

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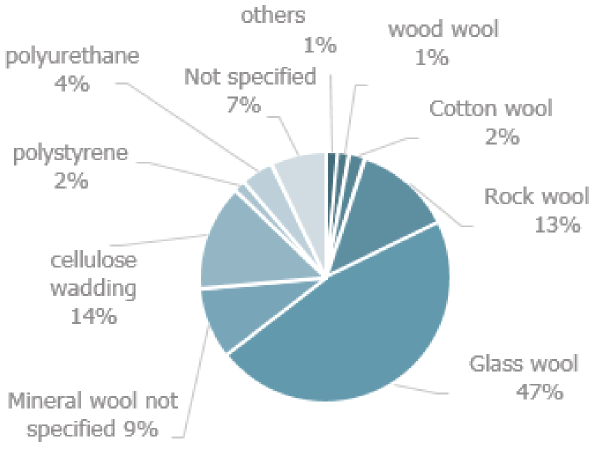
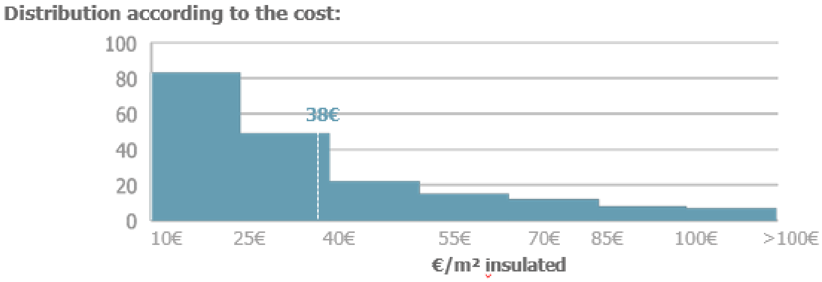


The average price observed for the insulation of a roof is 38 € / m² insulated. This average price varies according to the materials used: 33 € / m² insulated in glass wool and 29 € / m² isolated for cellulose wadding. In addition, the cost is lower in individual housing (35 € / m² insulated on average) than in collective (47 € / m² insulated on average).



If the distribution of housing is observed according to the cost of the post, a majority of housing is in the lower part, in the range of € 10 to € 40 / m² insulated. The dissociation between the installation and the material used is made in 20% of the invoices. The installation then represents on average 30% of the total amount of work (between 2 and 14 € / m²).
The removal of the old insulation is also invoiced in 8% of the files and corresponds for these files to 27% on average of the amount of work (8 € / m² insulated).

Internal insulation of walls

Insulating material used:

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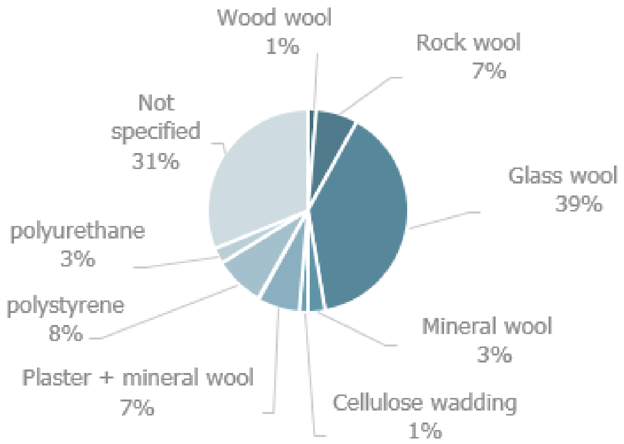
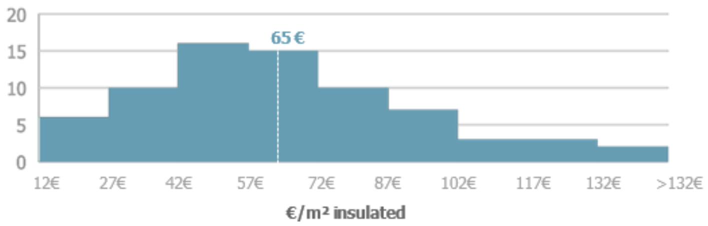


The cost of insulation (material + installation) varies a lot between the various renovations studied. This difference can be linked to several explanatory factors: taking into account the existing, choice of materials, thickness of insulation...
The choice of material seems to have an impact since glass wool has an average cost of 68 € / m² isolated against 56 € / m² insulated polystyrene, and 57 € / m² for a gypsum board system associated with mineral wool.

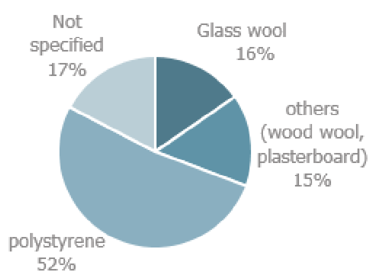
Distribution according to the cost:



If the distribution of the operations is observed according to the cost of the insulation of the walls, a majority presents a cost close to the average, between 42 € and 72 € / m² insulated. However, this distribution also shows that the wide range of costs (between € 12 and € 139 / m² insulated) is not due only to a few atypical projects. This is a realistic range of costs faced by households.
On the 74 invoices studied, only 4 show a dissociation between the cost of the material used and the cost of installation, the latter representing on average 6 € / m².

External insulation of walls:

Insulating material used:



The average cost for external insulation is 91 € / m² insulated. Polystyrene is the most expensive material with 123 € / m² insulated on average (from € 30 to € 230). The combined polystyrene and glass wool system costs on average 104 € / m² insulated.

Distribution according to the cost:

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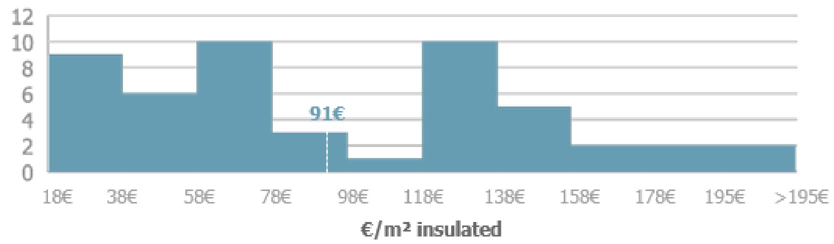
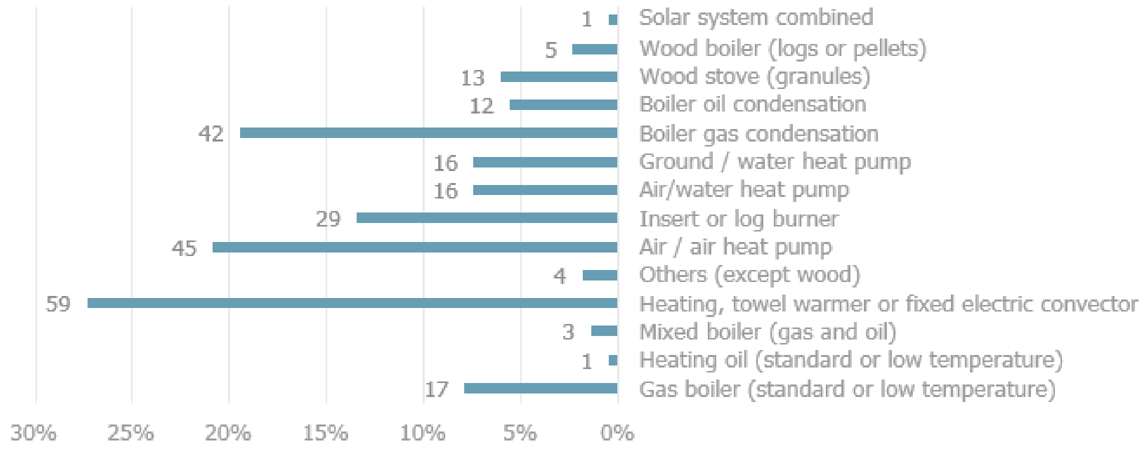
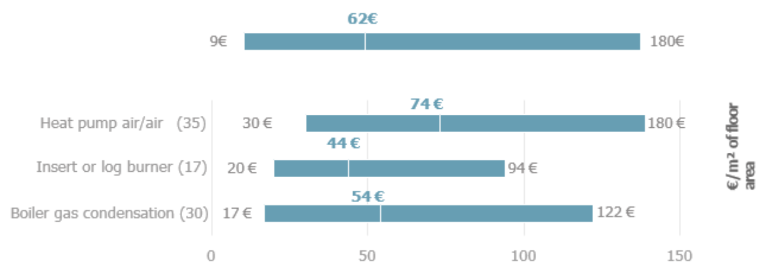


By observing the distribution of the insulation costs of the various projects, it can be seen that projects are recorded in all price bands (between 18 € and 230 € / m² isolated). One of the important factors of this scope is the choice of materials.
Indeed, all insulation operations based on mineral wool are found in the lower slices (<80 € / m² isolated) while all operations greater than 118 € / m² insulated correspond to insulation by polystyrene. Despite this, polystyrene is preferred, probably for reasons other than cost.
Of the 52 invoices studied, 7 show a dissociation between the cost of the material used and the cost of installation, the latter representing on average 26% of the total cost of the operation (19 € / m²).

Heating system



Minimum and maximum works cost, average cost:



The average cost of work on the heating station varies from 9 to 180 € / m² of floor area with an average of 62 € / m² of floor area.
This significant cost is related to the multitude of equipment that can be installed, and the possibility in some cases to use several complementary heating modes. Thus, 45 homes installed at least two heating systems simultaneously. Combinations of central heating and electric backup heating are the most common (32 files). Some homes, much rarer, install two central heating systems, usually a boiler associated with a reversible air conditioning or a wood stove.
Two cases with excessive costs have been excluded from the analysis: they are wood pellet boilers for 250 € / m² of floor area.
The average cost in collective housing is 56 € / m² of floor area, reminding that the electrical system is the most installed; so in individual housing, it is 66 € / m² of floor area, and gas condensing boilers are the most installed.

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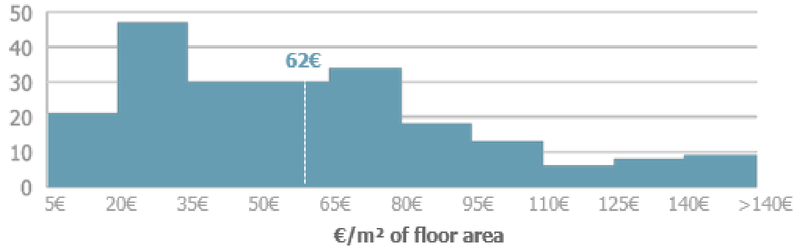
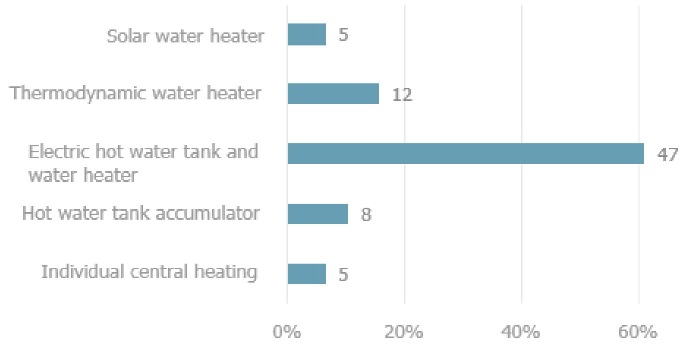
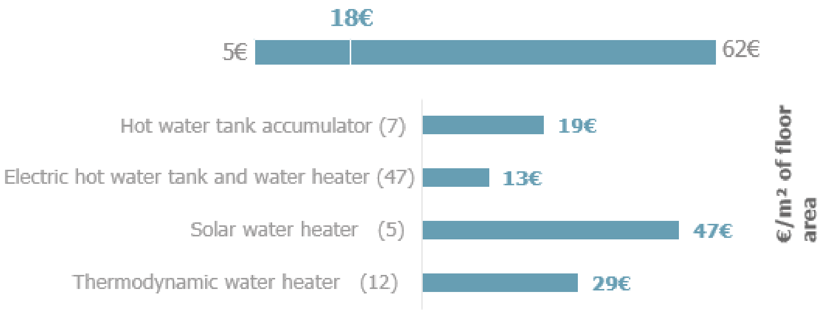


The dissociation between the installation and the acquisition of the equipment is available in 151 invoices out of the 216 studied. The pose of the installation represents on average 20% of the total amount, ie € 1,130 (from € 150 to € 4,000) or € 12 / m^2 of floor area.

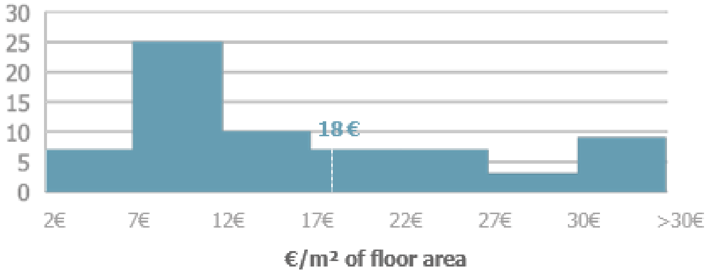
Domestic hot water



The solar water heater is the most expensive device, with 47 € / m^2 of floor area on average. The electric water heater has a low cost of 13 € / m^2 of floor area on average, but a low performance.
The average cost is lower in collective housing (34 € / m^2 on average) than in individual housing (43 € / m^2 floor on average). Households tend to install more efficient systems individually and therefore more expensive: 85% of electric water heater in collective against 42% in individual, 6% of thermodynamic or solar water heater in collective against 35% in individual.



Distribution according to the cost:



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By observing the distribution of the costs of work on the domestic hot water station, a strong difference can be seen between the different types of equipment: in the lower slices (between 2 and 17 € / m² floor) the vast majority is balloon and electric water heater. In the range 17 € and 27 € / m² of floor area, are found mostly thermodynamic water heater. Finally, the last tranche (between 30 and 60 € / m² floor) mainly includes solar water heaters and some thermodynamic water heaters.
The dissociation between the installation and the acquisition of the equipment is available in 21 invoices out of the 77 studied. The laying of the installation costs on average 150 € (2 € / m² floor) for an electric water heater and 1400 € (12 € / m² floor) for a solar water heater.

Ventilation

The installation of a VMC costs between 2 and 50 € / m². The average cost is 13 € / m² floor.

Low floor:

In average, the insulation of the low floor cost 57€/m².

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement n. 785072

9.6.1 Energy Prices

Here are the prices for the French energy vectors based on the government data base, those are the prices for September 2018

Energy prices			
Electricity	0,1580	EUR/kWh	price on September **2018**
Natuaral Gas	0,0791	EUR/kWh	price on September **2018**
Propane	0,1423	EUR/kWh	price on September **2018**
Oil	0,0955	EUR/kWh	price on September **2018**
Wood	0,057	EUR/kWh	price on September **2018**

Table 91- Energy Prices France