Envelope Approach to improve Sustainability and Energy Efficiency in multi-storey multi-owner residential buildings

PROJECT FINAL REPORT

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1 FINAL PUBLISHABLE SUMMARY REPORT

1.1 Executive Summary

The EASEE project was launched in March 2012 responding to the need to promote buildings' energy efficiency in Europe in order to achieve the EU's 202020 ambitious climate and energy targets. The concept behind the EASEE project was the development of a toolkit for energy efficient envelope retrofitting of existing multi-storey and multi-owner buildings (particularly the project targets **residential buildings with cavity walls built before the 70's**) allowing a relevant energy demand reduction.

Indeed, EASEE proposed both **innovations on the technological side**, developing different types of advanced insulating components and materials for the three envelope parts (namely for the outer façade, for the cavity wall and for the interior) **and innovations on the software side**, offering a new consulting service tool for building retrofitting (namely the Retrofitting Planner including the Design Tool). These new technologies, processes and softwares developed within the project will be part of a **new holistic approach to building retrofitting** aimed at reducing time and costs associated to this activity while guaranteeing higher energy efficiency, minor burden to building occupants and façade original aesthetic preservation.

Concerning the exterior retrofitting, an innovative prefabricated panel made of Textile Reinforced Mortar (TRM) with a core made of Polystyrene foam obtained without any further interface material has been designed. These panels have been tested first at material level (optimization of mortar mix, adhesion of material, etc.), at prototype level (mechanical, thermal and hygrothermal behavior) and then at real scale level (Ultimate (ULS) and Serviceability (SLS) tests and displacement controlled tests) till the final characterization of the panel's design. Their unique manufacturing process (a dedicated formwork) has been also designed, manufactured and optimized. **Concerning the cavity wall retrofitting**, an advanced hydrophobation process was developed and scaled up for Natural Expanded Perlite (NEP), from 20-60% repellency to 60-90%, or 100% floaters (hydrophobicity) and for the Synthetic Expanded Perlite (ESP), from 40-80% water repellency to 83-91 %, or 100% floaters (hydrophobicity). Moreover, a new formulation of Synthetic Perlite was developed, using mainly mineral waste, recycled materials and industrial by-products, fine tuning the recipe in order to meet the various applications' requirements. **Concerning solutions for the interior retrofitting**, three different kits (namely perlite board, aerogel wallpaper and flat laminated aerogel board) have been developed for the esthetical and energy efficient renovation.

These solutions have been first installed **at test façade level** and properly monitored, showing a decrease in heat loss (U-value) of around **65% concerning the exterior envelope, of more than 85% for the cavity wall and from 25% to 45% for inner kits**.

After testing at small scale, the EASEE retrofitting approach was then implemented **at real scale level**. Three residential buildings in three different countries (Poland, Spain, Italy) have been selected towards the validation of the external retrofitting solutions, two demo buildings in Greece and Spain validated the performances of advanced hydrophobized perlite in the cavity wall and finally interior retrofitting kits have been tested both in Italy and Poland.

A monitoring campaign showed relevant **environmental impacts** (in terms of energy savings, CO_2 reduced emissions and increased indoor comfort), **societal impacts** (in terms of new jobs generation, regeneration of urban areas and safety in installation) as well as **economic impacts**, namely financial savings and accessible payback periods.

Activities at demo buildings allowed the consortium not only to validate the retrofitting approach, in terms of technologies and software developed and implemented but also to think about how to propose the EASEE approach to the market, and thus to real clients through dedicated business models and market strategies.

1.2 Summary description of project context and objectives

In 2012, when the EASEE project was launched, Europe already had set a 20% energy savings target by 2020 when compared to the projected use of energy in 2020 – roughly equivalent to turning off 400 power stations. At the EU summit in October 2014 European countries agreed on a new energy efficiency target of 27% or greater by 2030. The European Commission had proposed 30% in its Energy Efficiency Communication[1]. In this framework, the EU's main legislations when it comes to reducing the energy consumption of buildings were the 2010 Energy Performance of Buildings Directive and the 2012 Energy Efficiency Directive.

The 2010 Energy Performance of Buildings Directive (EPBD: Directive 2010/31/eu of the European Parliament and of the Council of 19th May 2010 on the Energy Performance of Buildings) introduced the requirement of implementing energy efficiency measures for major renovations in order to encourage more ambitious renovation. The EPBD also asked EU Member States to introduce cost-optimal energy performance requirements that can be used for new buildings as well as for renovation activities. It also encouraged the elimination of market barriers that affect the full cost-effective potential from being achieved and it pushed for economic support instruments to stimulate the renovation of the existing building stock.

The 2012 Energy Efficiency Directive complemented the EPBD by fostering ambitious renovations through the requirement for Member States to establish strategies for the renovation of the national building stocks by April 2014.

By recognizing that the existing building stock (with a particular focus on buildings constructed when there was no consciousness of the importance of energy efficiency (1925-1945)) **represents a substantial share in the EU's total energy consumption** (40%[2]), the EASEE project aimed at finding the proper way to remove barriers and overcome market failures that impede efficiency improvements of the retrofitting process, targeting residential buildings with cavity walls built before the 70's.

In this framework, **EASEE proposed a holistic approach for energy efficient envelope retrofitting** which included novel design and assessment strategies (including software like Retrofitting Planner and Design Tool as well as procedures for building energy and geometrical assessment), modular prefabricated elements, advanced insulating materials and new scaffolding-free installation approaches to reduce energy demand, minimizing the impact on occupants while preserving the façade original appearance. The new range of specific solutions developed within the project could be combined according to the characteristics of the building to be retrofitted as well as other non-technical but relevant parameters to be taken into account as for example the solutions' cost, payback period, return on investment and location of the building within the district.

In order to put in place and diffuse the abovementioned retrofitting approach, the work programme was broken down into a series of technical objectives listed hereafter to be fulfilled, according to reference targets defined at the beginning of the project.

- To design and develop a **multi-layer panel** made of an insulating material and shells of Textile Reinforced Mortars (TRM) with small (1,2m x 1,2m), medium and big dimensions (maximum 1,5m x 3 m) to adapt to different façade geometries. The challenge was to achieve a mortar layer thickness below 2 cm (average weight below 40 kg/m^2) with a ready-finished surface and shapeable by selecting appropriate TRM mix designs, self-levelling and with low statistical deviation of experimental results, both in fresh and hardened state. The panel shall be safe, fire and impact resistant, according to ETAG 04 norms.

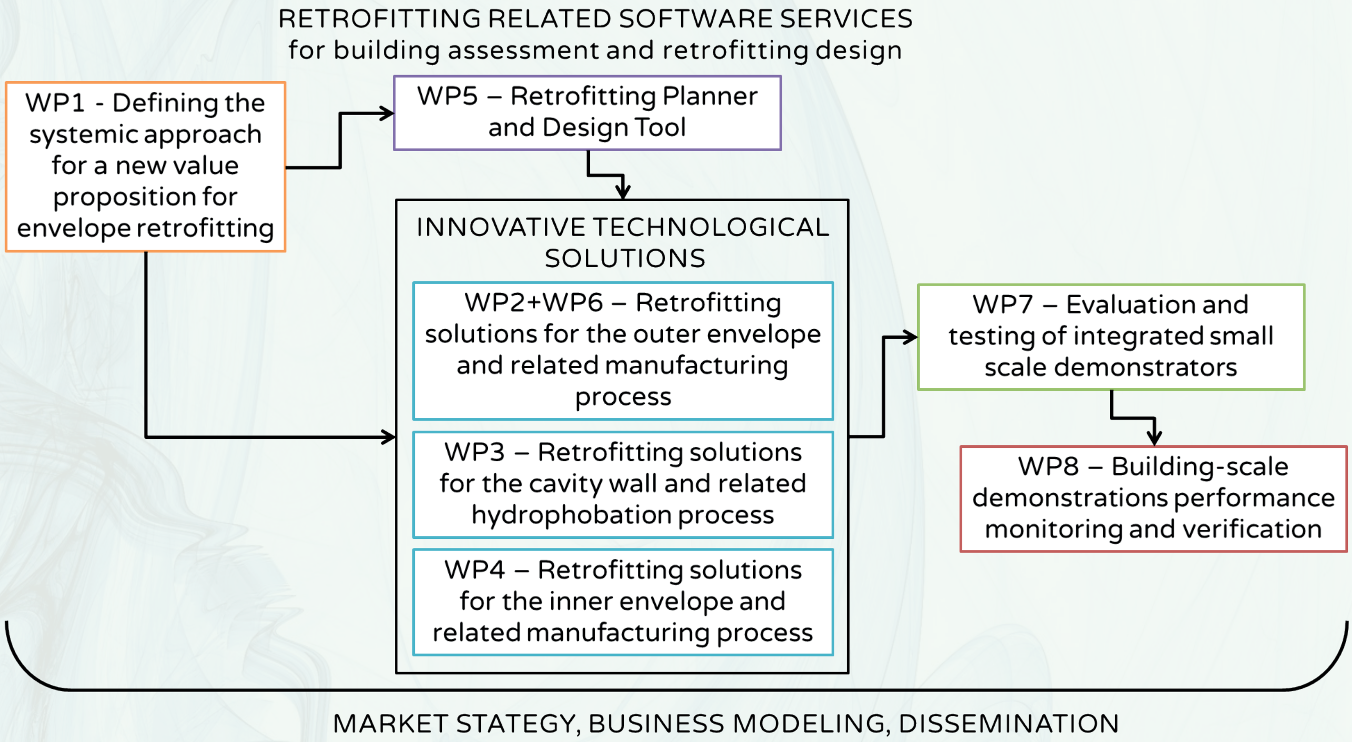
[1] https://ec.europa.eu/energy/en/topics/energy-efficiency
[2] International Energy Agency

- To develop **pre-installed (in the pre-casted panel) and post-installed (drilled in the façade) anchoring systems**, able to guarantee a degree of vertical and horizontal adjustability of at least ± 10 mm to compensate on-site tolerances in connections, hold a vertical load between 400 and 500 N for each anchoring, which is compatible with an estimated facade weight of about 600-700 N/m^2 and made of materials with the lowest possible thermal conductivity and highest strength to minimize thermal bridges.
- To develop **manufacturing processes for the pre-fabricated panels** based on a casting procedure supported by experimental testing on adjustable/flexible moulds starting from the 3D CAD of the building envelope and generating the target surface, thus enabling the production of the module. The best trade-off between the system's flexibility (possibility to produce the largest part of shapes) and stress resistance (in order to enable the largest part of forming processes) shall be selected and developed.
- To develop an **advanced insulating kit for the inner walls** able to increase the energy efficiency of the existing envelope by at least 20% if applied alone, reducing installation time by 20% or more, compared with other typical five to ten years inner renovating works (traditional plaster and painting; plasterboard; wallpaper; false ceiling). The proposed system shall guarantee wall transpiration, continuity of insulation around junctions, the possibility of electrical integration and a washable and adapt to finishing surface, ensuring at the same time durability and recyclability of at least 80% of the constituting elements.
- To develop **hydrophobation technology** for cavity walls inorganic fillers completely different from the existing conventional ones (i.e. spraying of silicone emulsions). This technology is expected to reduce the addition of the hydrophobic agent from 2-4% w/w down to 0,2-0,3% w/w. and providing an hydrophobic perlite with: thermal conductivity of λ:0,040 W/mK, less than 7% humidity absorption in 90% relative humidity environment, at 70 °C after 24 h, less than 5% shrinkage (sedimentation) in 90% relative humidity environment after 24h.
- To **reduce hygroscopicity of Synthetic Perlite** by replacing raw materials that have been used so far and substituting them with natural mineral which poses similar eutectic properties and most of them are industrial rejects, or by applying the above mentioned new dry hydrophobation technology on the new recipe of Synthetic Perlite particles.
- To define a **standard and SME-friendly procedure for the assessment of the building** to be retrofitted, in terms of envelope structural conditions and energetic performances, based on innovative combinations of state of the art technologies (i.e. 3D laser scanning, thermography/etc.), allowing the collection of a complete set of data with standard formats to be used as a starting point for the planning of retrofitting intervention.
- To develop a planning tool (**Retrofitting Planner**) with characteristics of interoperability, ease of use, acceptance of various input file formats and able to evaluate the energy performance of the building and to simulate its behaviour after retrofitting with different combined solutions developed within the project and also providing an estimation of costs, service life, return on investments, and savings on energy bills.
- To develop a supporting tool (**Design Tool**) for Retrofitting SME assistance in the design of customized (by size and thickness) patterning of facade panels and specification of panels fabrication on demand and just in time for prefabricated elements manufacturing.
- To develop a **building performance monitoring platform** with remote acquisition and all season statistical data processing.
- To develop **protocols and guidelines** for the components' installation, comprising procedures to be followed during the retrofitting as well as a checklist and detailed troubleshooting tables for the different insulating components and also for anchoring and joints.

Additionally, non-technical objectives were proposed for those tasks related to dissemination, consultancy and policies development as well as exploitation activities.

1.3 Main S&T Results/Foregrounds

The EASEE work plan was structured in a straightforward and simple manner, starting from the building envelope assessment and retrofitting design based on the Retrofitting Planner and Design Tool in WP5, over to the development, prototyping and manufacturing of insulating components for exterior (WP2), cavity walls (WP3) and interior (WP4) retrofitting and related manufacturing and installation procedures guidelines (WP6). Components were first installed at small scale test facades in WP7 up to large scale retrofitting activities in existing residential buildings in WP8.
WP 9 included transversal activities with cross-cutting tasks which not only dealt with techno-economic analysis but also with market strategies and business modeling development towards the penetration of the market with the EASEE products.



1.4 Work Package 1: Definition of systemic approach and new value proposition for envelope retrofitting

Objectives of the planned investigations of the work package

One of the aims for this Work Package was **to identify and define the main technical and non-technical requirements towards the definition of the EASEE systemic approach for the facade energy efficient retrofitting.** Based on this analysis, the general guidelines for the research activities needed for development of the different components for each solution of the EASEE retrofitting approach have been provided, defining the main technical specifications according to relevant standards and norms. Finally, the list of tests to be carried out on the different retrofitting components to assess their performances in compliance with standards has been defined to be taken as a reference along the overall project duration.

What is hampering the diffusion of energy efficiency measures?

In the framework of the EASEE project, several interviews were performed towards the analysis of technical and non-technical barriers related to the deployment of insulation measures in multi-residential buildings and set-up of proposals for the future project activities.

In terms of technical issues, high costs and climatic limitations were usually the main barriers. Long winters often hinder the smooth execution of retrofitting works and in many cases installations simply cannot be technically conducted in adverse conditions. Buildings under heritage protection can only be insulated internally causing space issues or in certain cases indoor air quality problems. Non-technical barriers were investigated from the point of view of the different players in the construction sector value chain. For the building owner, typical hindrances were related to awareness issues, misalignment of desired benefits, competitive purchasing decisions, knowledge obstacles, lack of funds and multi-ownership problems. Disruption, long procedures, planning issues and administrative burden were usually the main complications related to project management. For construction companies, the barriers were substantiated in four main categories: financial issues, market obstacles, capacity building and industry structure. For material and components manufacturers, the widespread adoption of innovative materials was the main challenge to be faced.

In view of these bottlenecks and challenges, the consortium identified the key areas upon which any new successful solution should be based in the context of the EASEE research activities. These were related to cost competitiveness, clearly stated benefits, climate adjustments, minimum disturbance and easy installation, durability, aesthetics and certificates/EU marking (see Figure below).

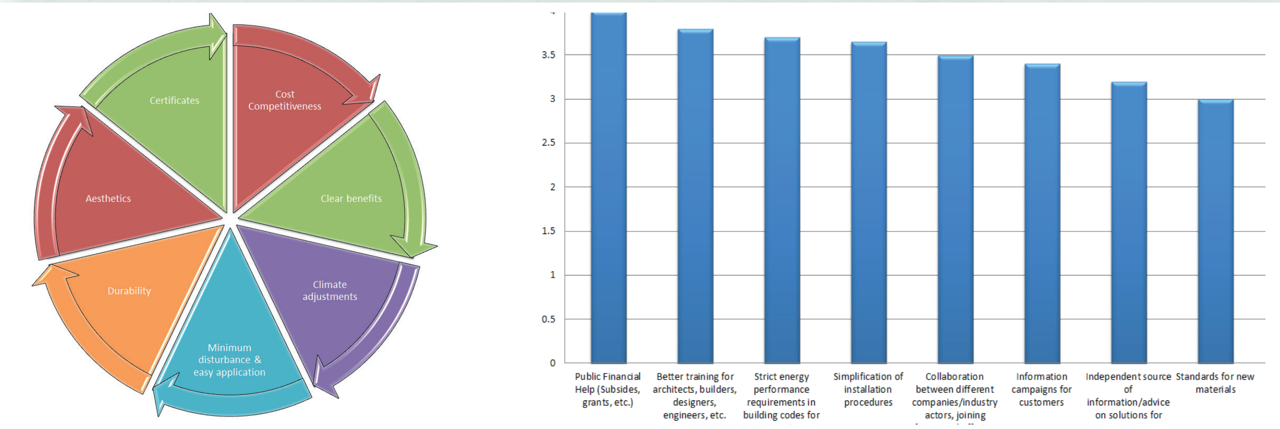
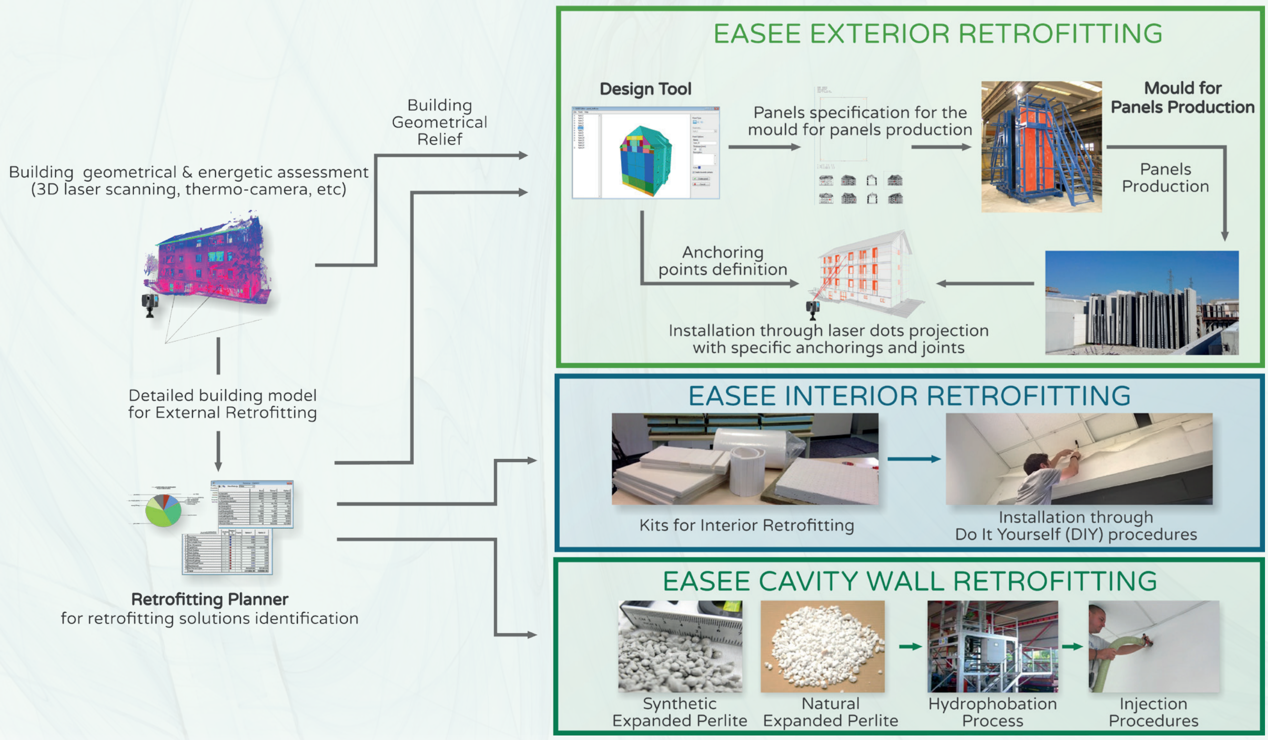


Figure 1: Success pillars for the research activities of the EASEE project (on the left side) and factors for a better functioning-market as identified by the EASEE partners [where 0 denotes no relevance and 5 crucial importance](on the right side)

With these factors in mind, the EASEE consortium developed an all-rounded set of solutions which could indeed offer a pragmatic approach for retrofitting multi-storey multi-owner buildings (see schema below) to be largely deployed.



1.5 Work Package 2: Retrofitting solutions for the outer envelope

Objectives of the planned investigations of the work package

This Work Package dealt with **the design and development of an innovative lightweight modular element reproducing 3D elements and finishing of the building façade** while providing superior insulating characteristics, to be installed without fixed scaffolding, with an easy and dry procedure, thus minimizing discomforts for the occupants as well as duration of the intervention.

Lightweight prefabricated insulating panels: from lab prototypes to real scale panels

Initially, different concepts of pre-fabricated shapeable retrofitting panels were taken into account, based on the technical requirements and specifications drafted in Work Package 1 and design issues originating from the analysis of European existing stock characteristics.
Different approaches were investigated, starting from single layer solutions based on single formed mats of XPS[1] with surface finishing, to multi-layer solutions in which the insulating mat was coupled with one or two layers of thin FRC[2] or TRC[3].
Preliminary quantitative and qualitative assessments (through testing on lab scale samples), based on the analysis of mechanical properties, hygrothermal behaviour and environmental impacts, were performed towards the selection of the best option. The multi-layer panel, constituted by one internal layer of EPS[4] insulating material covered on both sides by two layers of TRC, was selected as the best option to be carried on and optimized within the project in view of demonstration activities. In this solution the insulation layer works also to transfer the shear forces between the external TRC layers.

Conceptual design was further detailed according to the main outputs from experimental tests and numerical simulations, towards the optimization of the single panel's component (anchoring systems, EPS, TRC layer, etc.). In particular, four point bending tests were carried out on two different size lab-scale beams to understand the sectional behavior of the multi-layer panel. Results allowed researchers to validate the numerical model since a good agreement was obtained comparing the finite element and the experimental curves. Thanks to this good correlation, it was possible to extend the numerical model adopted to the real scale panel and to foresee its bending behavior and its mode of failure. In parallel, the assemblage and casting process first at lab-scale and then at real scale level was investigated (see Work Package 6).

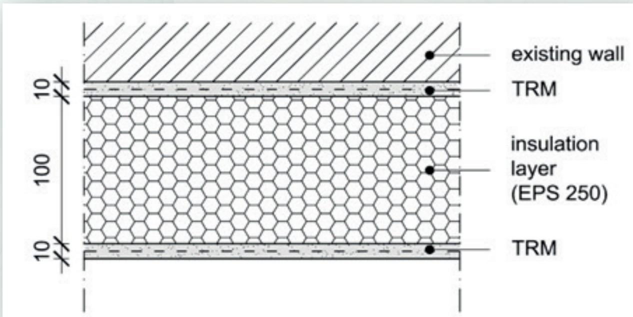


Figure 2: Conceptual design of multi-layer panel

Thus, the geometry and design of the multi-layer panels have been carried on. In particular, further details and characteristics of the panel components - as TRC and EPS layers, the anchoring system and the fire resistant connectors - were provided together with the most appropriate panels' joint solution selected to guarantee high performances in terms of capacity in avoiding thermal bridges between panels and maintaining, at the same time, the desired aesthetic aspect of the façade. Potential anchoring systems for the prefabricated panels were also deeply evaluated towards the identification of the proper solution to be adopted, able to avoid load concentration or low energetic performances.

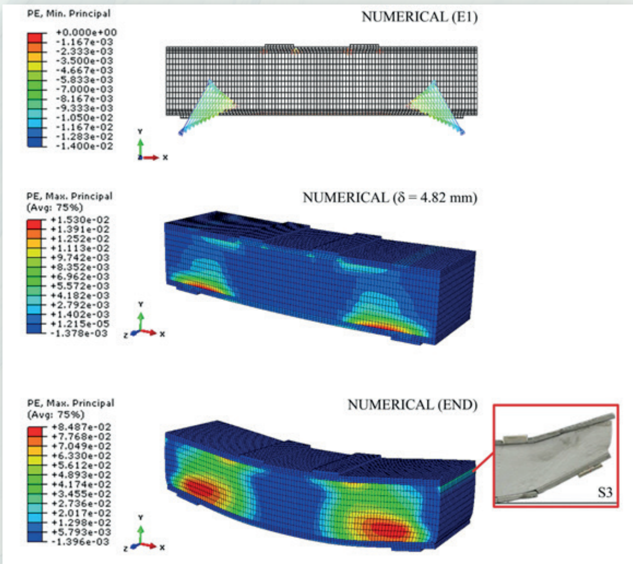


Figure 3: FEM Analysis on small scale prototypes

[1] Extruded Polystyrene
[2] Fiber Reinforced Concrete
[3] Textile Reinforced Concrete
[4] Expanded Polystyrene

A proper anchoring system has been designed to transfer the loads acting on the panel to the bearing structure of the building. It is made by an innovative HPFRC[5] anchoring box, designed to be embedded in the prefabricated panel and able to transfer the loads from the panel to the anchor, and by the anchor itself, which is directly fixed on the building bearing structure. The performances of this system were verified by testing it on small scale specimens, taking into account that it has to withstand the self-weight of the panel (both during and after the installation) and the out of plane load due to wind pressure and suction.

After optimizing the production process, full-scale panels (with dimension of 3300 x 1500 x 124 mm) were tested in order to characterize the mechanical behaviour of the final product proposed. In particular, on these panels the following tests were performed:

- load-controlled tests on panels anchored through the anchoring system considering service loads (both wind pressure and wind suction were considered). Looking at the results, and in particular at the distributed load versus crack opening displacement graph, it is possible to note that cracks - which occurred during tests - were not visible to the naked eye (crack width lower than 50 μm) , thus satisfying an important requirement for a façade panel.

Figure 4: Experimental tests on simply supported real scale panel

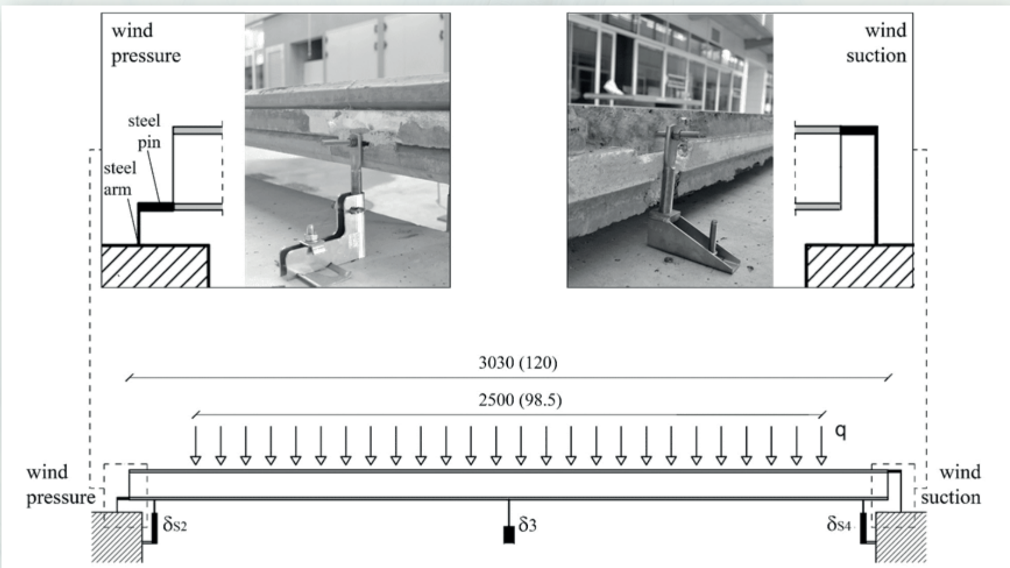


Figure 5: Load-controlled tests considering wind loads pressure and suction

[5] High-Performance Fiber-Reinforced Cementitious

- displacement-controlled tests on the same panels; in this case the panels were simply supported and were loaded up to failure. Two more panels, casted using a horizontal formwork instead of a vertical one, are also tested. The final failure in all the cases was due to the reaching of the maximum strength in the lower TRC layer.

Figure 6: Displacement-controlled tests on simply supported real scale panel

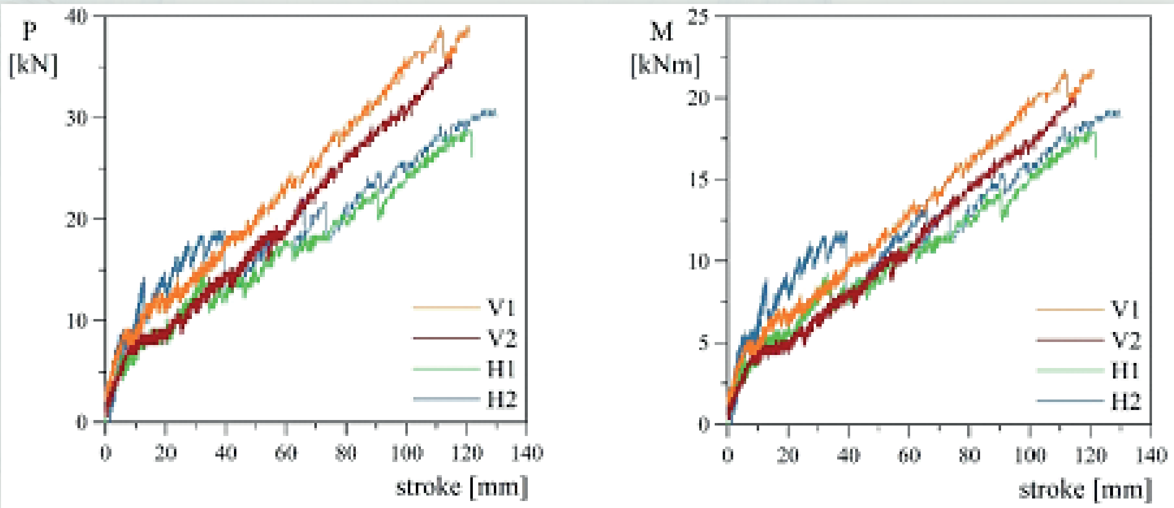


Figure 7: Results of displacement controlled tests at failure

The results clearly showed a good bending performance of the panel, which was able to resist a maximum bending moment of at least 17.5 kNm before failure.
The numerical analysis performed on both lab-scale and full-scale tests assessed the reliability of the numerical models in predicting the structural response of the sandwich solution considered.
Basing on the main results of the tests and numerical simulations performed, a final version of the detailed design of the lightweight prefabricated panel was then provided towards the production of full-scale panels to be installed in three existing residential buildings (see Work Package 8). According to the final design, the delivered panels provided a limited increase of weight (about 75 kg/m^2) and were characterized by high durability (expected: 30 years), high insulation properties (reduction of the wall thermal transmittance from 1,16 to 0,26 W/m^{2}K and minimization of thermal bridges), ensuring an installation without requiring scaffolding with an easy and dry procedure, good finishing and texture in order to reproduce or enhance the original façade appearance, and last but not least a quite high customizability in order to easily address every kind of façade. Easiness of replacement was also ensured.

1.6 Work Package 3: Retrofitting solutions for the cavity walls

Objectives of the planned investigations of the work package

Work Package 3 dealt with **the design and development of an innovative technology for the perfect hydrophobation of expanded perlite particles.** In addition to this, a **new chemical process for the manufacturing of Synthetic Perlite**, using mainly mineral wastes and industrial rejects, was investigated and developed; the innovative hydrophobation technology has been also made capable to transform this new Synthetic perlite into a 100% water-repellent insulating product. The key challenge of the loose fillers for cavity walls was to overcome the main limitation of natural perlite related to settling and/or shrinkage phenomena and consequent formation of thermal bridges, by developing a fireproof totally innovative technology aiming to the perfect hydrophobation of expanded natural and synthetic perlite particles.

Highly insulating loose fillers for cavity walls

Among the R&D activities within the project, the new process for hydrophobation of expanded natural and synthetic perlite particles based on coating of perlite with polysiloxane was firstly developed at lab scale. This process provided a water repellent expanded perlite, by evaporating solid siloxane and creating a hydrophobic film on perlite grains. Two different technologies were designed and the corresponding equipment was implemented and tested:

- a vertical fluidized bed lab scale reactor;
- a rotating horizontal tube-like lab scale reactor.

Figure 8: Rotating fluidized bed lab (on the left side) and rotating horizontal tube-like (on the right side) lab scale reactors

The technology chosen for the scale up was the fluidized bed reactor, because of the higher kinetics of the hydrophobation process, which resulted to higher capacity and lower cost.
The hydrophobation process was applied to both Natural and Synthetic Expanded Perlite, resulting to more than 99% hydrophobicity in terms of floaters test and more than 80% in terms of water repellency test.

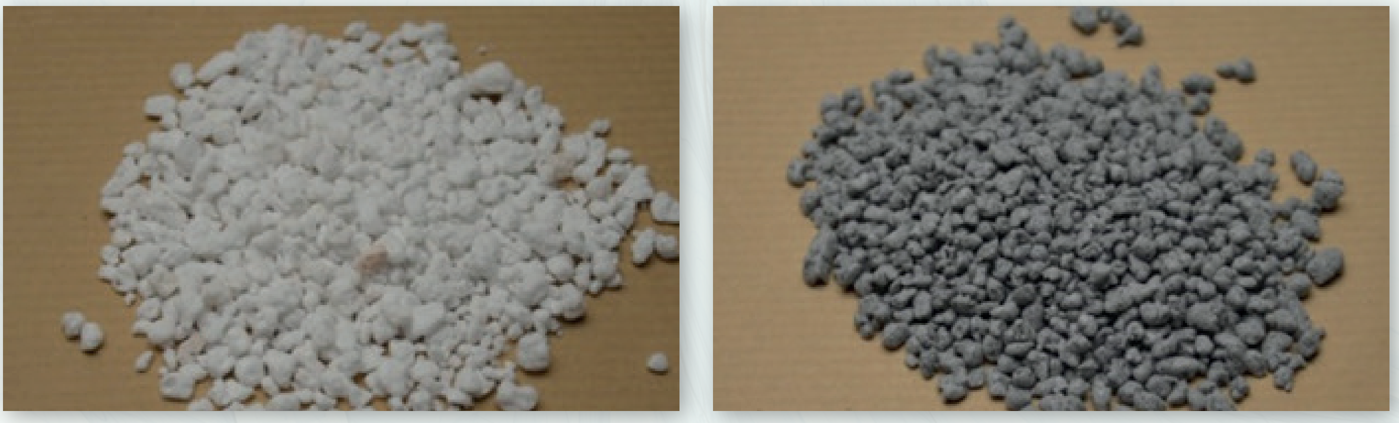


Figure 9: Natural Expanded Perlite for cavity walls (left side) and Synthetic Expanded Perlite for cavity walls (right side)

The work carried out and in particular the tests performed on the hydrophobized expanded perlite, confirmed its enhanced characteristics compared to non-hydrophobic samples. The hydrophobized natural expanded perlite was chosen so far as the most appropriate material to be used for loose filling of cavity walls for the demo sites, since it showed high resistance and adequate LBD[1], thermal conductivity and hydrophobicity.
In parallel, a lab scale IR expansion furnace was designed and implemented, for the expansion of the synthetic perlite, and preliminary experiments were performed towards the optimum formulation of a new expanded synthetic perlite, using mainly mineral wastes, recycled materials and industrial byproducts. The main advantage of this new Synthetic Perlite was that the properties of the material could be fine-tuned by properly adapting the formulation, in order to meet the various applications' requirements.
The optimum formulation was designed for producing synthetic expanded perlite for cavity walls insulation to be tested in a real environment. The material exhibited superior thermal conductivity at the targeted value (0.035 W/m^2K) with LBD at ~50 kg/m^3, enhanced water repellency (219 out of 250 mL water repelled) and adequate compaction resistance (28 psi at 2' compaction).
The deposition of siloxane vapours and the condensation in order to create a very thin hydrophobic film on granules surface were also achieved for synthetic perlite that showed significantly reduced hygroscopicity compared to commercial Synthetic Perlite, but not as low as Natural Expanded Perlite.
Several samples of synthetic perlite were also produced, for evaluating their application in mortars and boards, developed under Work Package 4.
After the completion of the R&D activities performed within the first half of the project duration, three different materials were considered suitable for cavity walls insulation: 1) hydrophobic commercial expanded synthetic perlite; 2) hydrophobic expanded natural perlite; 3) the new hydrophobic expanded synthetic perlite. All these materials were also hydrophobized by mean of the innovative process developed within the project.
Then, dedicated modifications were evaluated in order to improve the hydrophobic perlite production process towards the production of appropriate quantities of natural expanded perlite and the delivery to project partners for the retrofitting of small and large scale demo buildings.

1.7 Work Package 4: Retrofitting solutions for the inner envelope

Objectives of the planned investigations of the work package

The main objective of this Work Package was **to develop new indoor retrofitting solutions for enhancing the overall building envelope energy efficiency**, taking into account aesthetic concerns as well. In particular, the will expressed by the project consortium was to provide "solutions for the interiors that shall be applied according to the owner's decision, and however will have fast installation minimizing discomforts for the occupants". To this aim, design activities were based on the fulfillment of the following requirements:

- Easy installation in a minimally intrusive way;
- Optimise the worksite in general;
- Reducing installation time by 20% or more;
- Do It Yourself [DIY];
- Compatibility with existing building functions and aesthetics;
- Reduce the waste production by at least 30%;
- Lightweight;
- Low environmental impact using Life Cycle Assessment (LCA);
- Economic sustainability.

[1]Low Bulk Density

The research partners carried on the design work about the development of the retrofitting kits that were identified during the project, starting from the optimisation in the use of advanced insulating materials (i.e. perlite and aerogel) included in the lightweight insulating component or finishing material (i.e. textiles, paint, coatings, etc.).
Figure below provides the articulation of the proposed indoor retrofit kits.

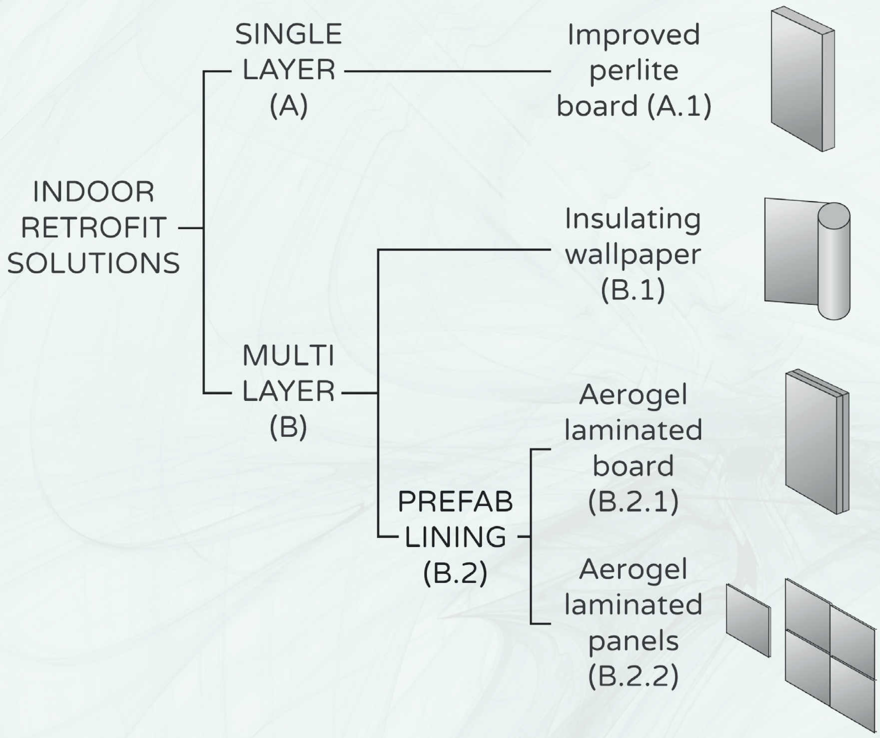


Figure 10: Articulation of the indoor retrofit kits developed in WP4

These solutions needed further refinement as the performance evaluation proceeded and more tests at lab scale level and software simulations were carried out by partners, in order to test some of their performances. In particular, activities concentrated on:

- The most important hygrothermal properties for solutions that were expected to be in contact with the internal environment, i.e. thermal conductivity, water vapour permeability and water absorption;
- The assessment of cold bridges and condensation risk in a variety of typical joints of residential construction – a very important aspect, since with indoor retrofitting it is impossible to guarantee the continuity of the insulating layers and it is imperative to avoid condensation and the build-up of mould;
- The Life Cycle Assessment (LCA) comparing the proposed kits with other, standard insulating solutions and comparing different jointing solutions to support the choice of the materials with a smaller impact on the environment.

Based on these activities, three different design hypotheses were particularly investigated and further designed:

1. Improved advanced perlite boards: insulation panel based on improved perlite from WP3, finished by thin reinforced render.
2. Aerogel laminated boards: aerogel-impregnated textile insulation material glued on expanded glass granulate panel, finished by thin reinforced render.
3. Permeable insulating wallpaper: flexible, aerogel-impregnated textile insulation layer; fabric finishing installed with a bespoke system.

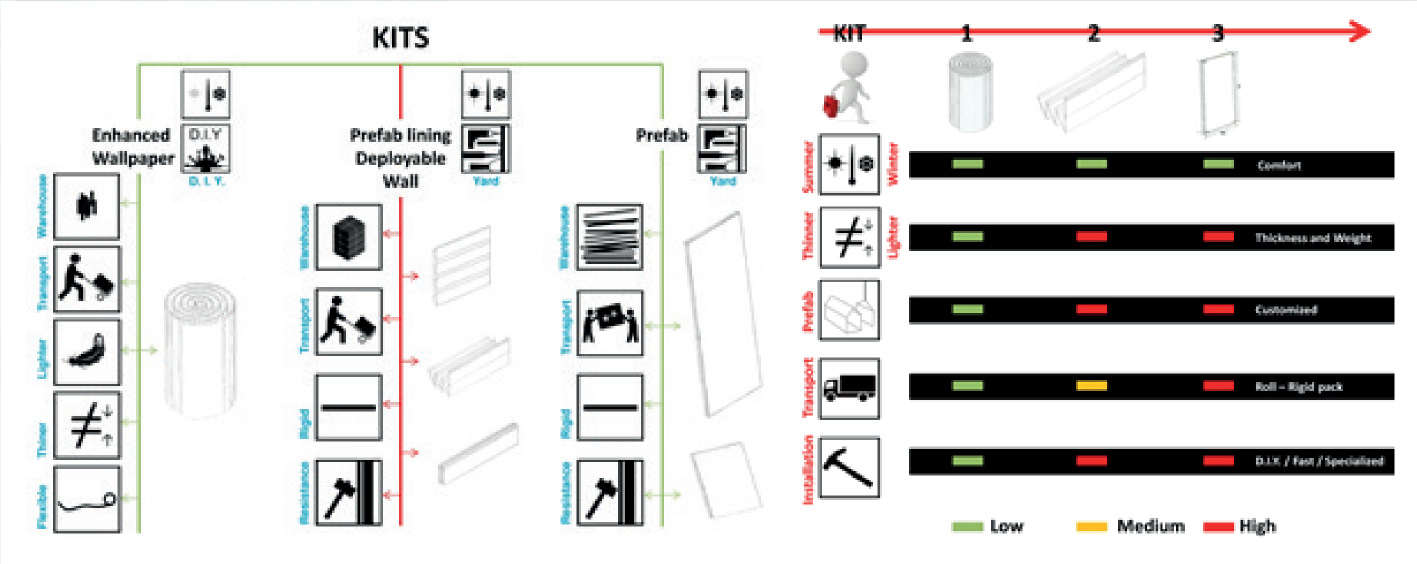


Figure 11: Characteristics of the different investigated design solutions.

Once the basic characteristics of the different kits were defined, specific materials and jointing solutions were identified and tested.

Improved advanced perlite boards

This solution was meant to integrate the enhanced perlite developed in Work Package 3, forming a rigid board which is lightweight and has insulating properties comparable to standard insulating materials. The board can be easy to cut on site (adaptation to existing geometry) and has to be applied to existing walls with a specific glue (based on adhesive mortar) that, together with the finishing (a mineral cement filler) layer, have been both developed specifically for this project. The expected advantages of this kit are the following:

- Limited cost (that is expected to be in the range of a standard insulation solutions such as EPS)
- improved thermal performances over similar existing products (λ= 0.060 W/m^{2}K)
- Control of moisture diffusion
- Rigid surface
- Skilled assembly (standard)

Flat laminated panel

This solution was based on pre-coupling the aerogel and the textile insulating layer with a rigid finishing layer (board). The choice of the type of boards depends on the climatic situation, taking into account the needs of both thermal capacity and thermal resistance. The materials suggested for the rigid board were standard plasterboard (heavier) and recycled glass aggregate (lighter). Thus, this kit was similar, in principle, to laminated insulation panels already available on the market (e.g. plasterboard + mineral wool or other insulating materials); these panels require on-site adjustments that can be easily achieved with a cutter or other simple tools. The panel can be attached (glued) to the existing wall, or fixed to a substructure.
The idea was to market a system that is well known, broadly tested and already largely accepted by future users.
This kit can be delivered as a large panel, in the standard size for drywall construction (3.00 x 1.20 m), or as smaller panels, that are easier to handle and more suited for Do It Yourself (DIY) works. The method for gluing the insulating mats to achieve the required thermal resistance and for gluing these insulation layers to the rigid finishing board was developed and tested as well.

In this case, due to the lack of an industrial partner for aerogel impregnation, partners were focused on the development of an alternative solution for interior retrofitting to be ready for the market deployment. Focus kept on investigating the aerogel-based product: while not delivering the same insulation properties of the aerogel based solutions, the alternative product had comparable properties in terms of mechanical resistance and surface characteristics (for gluing and finishing). This solution was not based on impregnation of aerogel but coated with it providing a very similar thermal performance to the kits developed for interior retrofitting.

Figure 12: Installation process for aerogel coated solution

Permeable insulating wallpaper

The idea behind the permeable insulating wallpaper design was to have an insulation system, which can be rollable, compact, lightweight, easily portable and handy, maneuverable even by one single person. Connections and fixing systems were designed following the will to create a finished product (insulation + finishing) that could be easily adaptable to the specific apartment needs according to the surface shape of the wall, not always regular especially in old buildings. Everything shall happen in a simple, intuitive, fast way, and most of all, Do It Yourself (DIY).
To preserve the lightness of the completed kit, a fabric finishing layer (polyester) was identified according to requirements of durability, maintenance, fire behaviour and water vapour permeability.

At the project moment, aerogel-based insulating products had little market penetration because of relatively high cost. The sales price of the developed solution will not be significantly lower than the ones currently available. To find a company willing to take the responsibility of the impregnation and lamination of the textile would allow to see if it is possible to improve on the production process to reduce costs and find a way to make the price acceptable because of additional advantages such as saved space inside, aesthetic appeal, etc.

1.8 Work Package 5: Retrofitting Planner and Design Tool

Objectives of the planned investigations of the work package

This Work Package was aimed **at developing the methodologies and software tools towards the implementation of the EASEE retrofitting approach**. In particular, activities dealt with the development of **a dedicated procedure for the assessment of the building envelope** from the mechanical/structural point of view as well as from the energy performance point of view. Based on this building relief, activities were targeted to develop a virtual "standard" test environment to evaluate best façade solutions (e.g.: EASEE retrofitting solutions) to facilitate the user to take informed decisions on the best option for the retrofitting of their building.
To this aim, the **Retrofitting Planner, based on the IES Virtual Environment simulation software** has been deployed in order to holistically optimise, quantify and validate the economic and environmental savings over the service life due to new façade option. In case the external retrofitting solution has been targeted as the most proper one, a further software application, called **Design Tool**, has been deployed in order to provide the manufacturers of the prefabricated elements with the technical specifications for the customized component fabrication according to the existing building geometrical relief and the designer with the patterns of panels customized to the façade.

How to make informed decisions on building envelope retrofitting and make the retrofitting process more efficient and effective

Focus of activities was the deployment of the Retrofitting Planner towards finally supporting:

- The owner and building manager in identifying the most suitable and affordable solution and compare performances/savings;
- The designer architects to prepare a detailed design, commission the supply and supervise the overall implementation
- The component manufacturers in producing customized options for the specific building optimizing materials and workforce
- The contractor to be fully involved in the decision making and facilitated in implementation through specific guidelines and work instructions originated by the tools

In order to meet the above listed needs, the different components of the sofftware tool known as Retrofitting Planner & Design Tool were developed as integrated services. Among these, the user may exploit the following functionalities:

- Geometric, thematic and structural analysis of the façade to support the building envelope assessment and development of Building Model. A dedicated methodology for the generation of the 3D model for the Retrofitting Planner and the Design Tool was deployed to take into account geometrical, structural and thermal aspects. Integrated methodology of data acquisition was based on ground based HR images (gnomonic projection for speditive Orthoimages), RGB and IR from DRONE FALCON8 as well as Laser Scanning data.

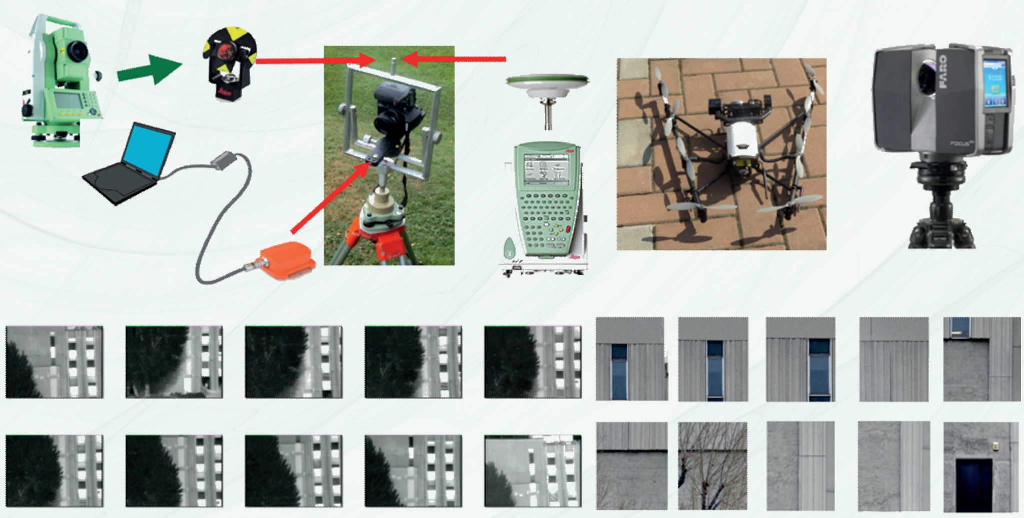


Figure 13: Integration of different methodologies for building envelope assessment preliminary tested at the test facade in Milan

Two methods of data format were examined: traditional CAD tools and BIM[1] tools for transfer of the model between software's. In addition to the geometrical assessment, thermal mapping was carried out to assess the quality of the structure before any retrofitting was applied to the façade. Two types of cameras were used to create the thermal image of the 3D envelope: a traditional thermal camera and a UAV camera. Info acquired by different sensors and platforms used for the building envelope assessment were then integrated by means of a dedicated tool able to give some fast indicators on the thermal performances of the building and capable to interfacing with BIM.

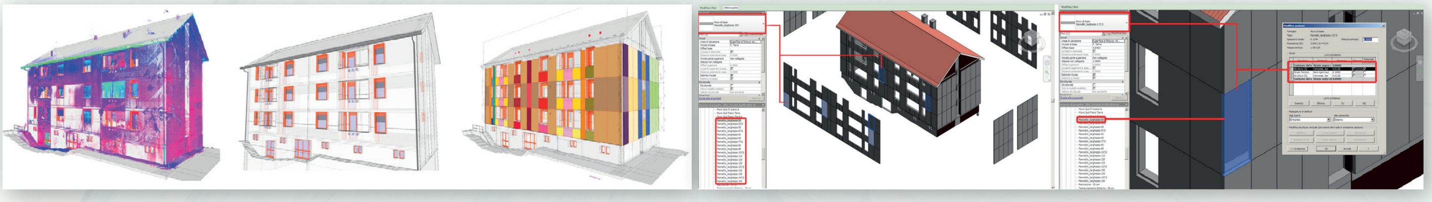


Figure 14: BIM Model of the Italian Demo Building

- The 'computer based procedure', built on the Virtual Environment software and designed to analyse building performance and for the purpose of EASEE to test and validate the innovative retrofitting solutions developed within the project. VE allows the various parameters and features of the insulating retrofitting solutions to be added to a Dynamic Simulation Model of the existing building in order to assess the expected performance of the solution over the life of the building. The user can then understand what are the benefits of each solution with respect to energy consumption, carbon use, capital cost, life cycle cost, return on investment etc. and make an informed decision on which option best suits their individual requirements. To this aim, four different software features were developed and added to the existing IES suite of tools, these are (i) Master Templates, (ii) Search and Replace, (iii) Parametric Batch and (iv) DEFT Value Choice Tool. These form a core part of the EASEE Retrofitting Planner.
  Master Templates enables the user to create simple models (and/or use common thermal attributes) using common building typologies (such as: office, hospital, school, supermarket, & more). These allow for a model to be created quickly instead of starting from scratch each time.
  The next feature developed was *Search and Replace* (now known as Design Options). This is an intuitive yet seemingly simple concept (without underestimating the complex development that went into the tool) taking an element of a building and replacing with another i.e. 'replace all windows with a U-value of >3 to 1.3', allowing this process to take place automatically, significantly improving the speed of altering/enhancing a model for the end user.
  In order to allow for multiple simulations to take place at once and allow for many different configurations of the various insulation options to be analysed, the Parametric Batch feature was developed. Its purpose was to collate all the chosen solutions, simulating them in a sequential order in 'batches'. This significantly reduces user time for user saving him/her having to manually launch simulations.
  Finally to allow the user understand the options that are available to him/her, a *Value Choice* feature called DEFT was developed. This feature allows for the various options to be displayed to the user in a comprehensive manner, allowing him/her to make the decision that best suits the individual needs and requirements.

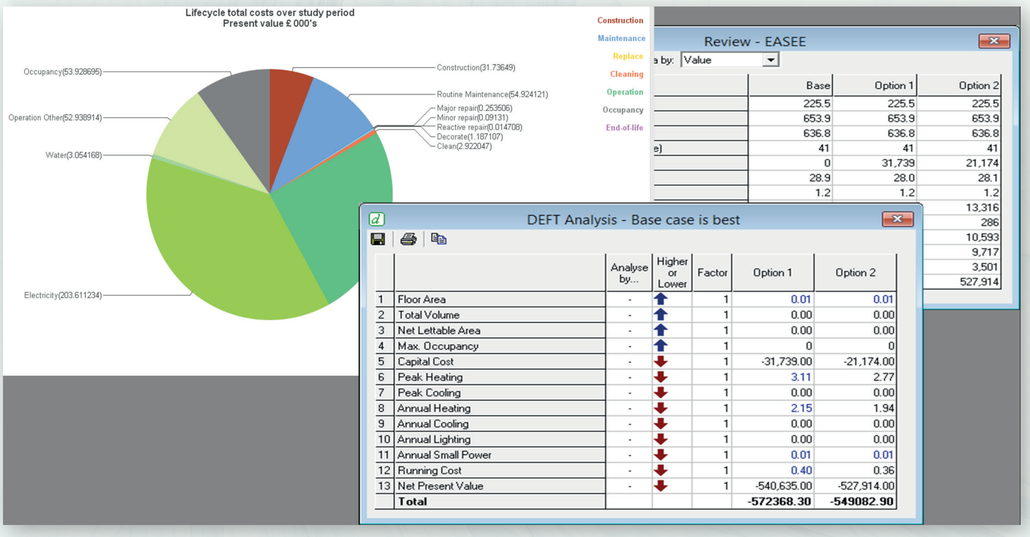


Figure 15: Extract from Value Choise feature interface

[1] Building Information Modeling

- The “Design Tool” module sometimes referred to as EASEE Editor supporting the Retrofitter (SMEs) to easely develop the requested configuration of facade by custom panels patterning (size, and thickness) and ordering from manufacturer customized (with cenfigurable mould set for requested size of panels) in the “just in time” delivery system.Indeed, the software is able to import 3D building model (which is an outcome of building assessment procedure) and to help the user to virtually plan panels’ distribution according to the specific building envelope, taking into consideration also potential constraints (such as constraints from the heritage conservation supervision, etc). Moreover, when planning panels’ distribution, all material and geometrical constraints which are results of simulations (performed within the Retrofitting Planner) can be taken into account. Finally, Design Tool exports documentation of the designed panels, in both text format (that can be easily interpreted by the numerically controlled reconfigurable mould) and HTML/PNG format, which is in fact the technical data sheet for each panel, as well as the assembling documentation.

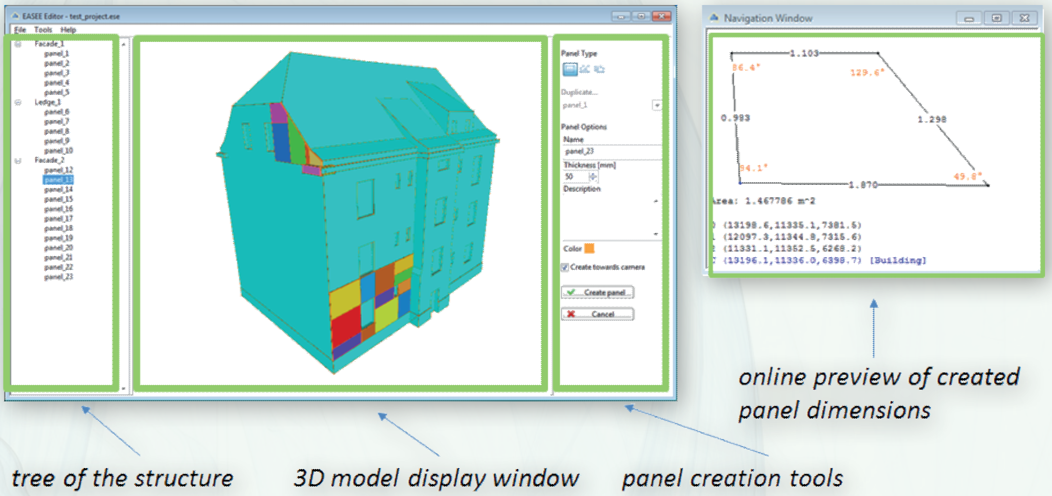


Figure 16: Design Tool interface

1.9 Work Package 6: Processes and application guidelines

Objectives of the planned investigations of the work package

This Work Package was aimed at **studying and optimising the manufacturing process of the customized prefabricated panels** (designed in Work Package 2), **and integrating the panels production in the building retrofitting workflow**. At the end, complete and user-friendly guidelines for the use and application of the developed products were developed.

From production process at lab scale till the design of an adjustable/flexible mold for customized pre-casted panels manufacturing

The preliminary process to cast panel prototypes at lab scale was implemented in a vertical formwork made of a steel frame and Plexiglas plates, as shown in the Figure 17. Once all the panel components were placed (EPS, anchoring systems, textile fabric, etc.), the concrete was pumped to the bottom of the mould, using a pressure tank. The use of Plexiglas sides in the mould allowed the operator both to monitor the casting process and to obtain panels with smooth surfaces.

The activities focused on the design and optimisation of the production process for the prefabricated façade modules at real scale level, starting from the investigation of available techniques done in the early stage of the project. In particular, the forming processes with fixed moulds were studied and optimised for the production of the sandwich panels composed by TRM and EPS.

Figure 17: Lab scale manufacturing process for prefabricated panels

Based on the analysis of system requirements and on a benchmark analysis of competing solutions performed in scientific literature, existing patents databases and on internet (technical catalogues of equipment manufacturers for pre-casters), the selection of the architecture of the adjustable formwork was done among several candidate solutions. The formwork was modelled with a 3D CAD (PTC Creo 1.0) in all of its parts and assemblies. The CAD was also used to simulate the operational steps and foresee any issue that could be avoided or addressed by the mould design.

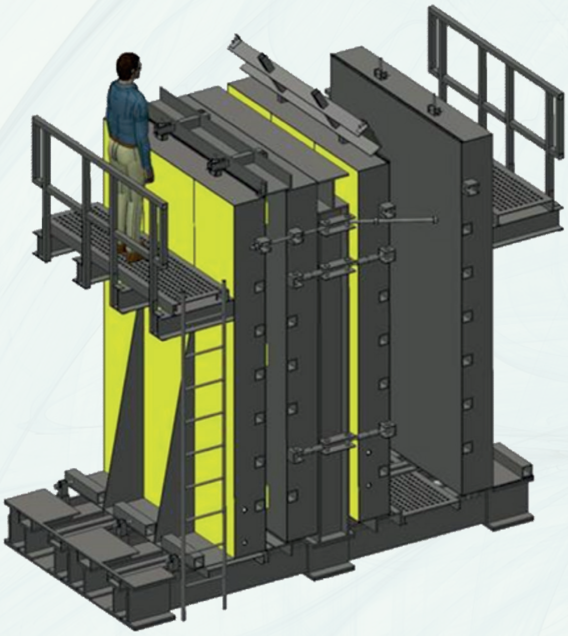


Figure 18: 3D CAD model of the formwork (on the left) and manufacturing of prefabricated panels (on the right)

A number of analyses and tests, including trials on mixture and EPS preparation, tests on pigments addition in the mix, etc. allowed the definition of EASEE panels production process, aimed at maximising the performances of TRM and keeping a high level of customisation on the panel dimensions. As long as the panels design was detailed, also the manufacturing process was further designed and detailed. This brought to the design of flexible moulding process for the production of panels with different shapes and geometries, aiming at the best trade-off between system flexibility (possibility to produce the largest part of shapes) and stress resistance (in order to enable the largest part of the forming processes) while customising the process to increase the automation level. The formwork was made by a large metallic structure (height: 3.8 m; length: 4 m; width: 2 m), mainly composed by steel beams (I-beams and box beams) and plates, arc-welded together to compose a stiff and resistant structure weighting about 15 tons.

The adjustable formwork was then installed at the panels manufacturer premises, where further optimisation was put in place, both to increase the panels quality and accelerate production. Among the improvements, the following were implemented:

- Gravity casting method (by means of an hopper integrated in the top shuttering) with the vertical formwork to guarantee high bond properties
  Lateral vibrating systems, to improve mortar compaction (especially for high panels)
- Some panels were cast horizontally (after verifying their structural behaviour through experimental tests);
- Accelerated panels curing by means of vapour, especially for winter periods production
- Several plastic sides were tested to improve the aesthetics and the surface finish of the panels
- Change of spacers, designed ad hoc to reduce the visual impact

Thanks to the above mentioned improvements, the formwork was able to manufacture more than 250 panels, of 30 different shapes, 4 colours and 2 textures, to be installed in existing residential buildings (see Work Package 8).

1.10 Work Package 7: Evaluation and testing of integrated small scale demonstrators

Objectives of the planned investigations of the work package

The main objective of this Work Package was **to integrate the project solutions developed** within Work Package 2, Work Package 3 and Work Package 4 **on a test façade in order to perform first trial of installation and then to evaluate the performances of the retrofitted façade in terms of energy performance under real conditions.** For this purpose, two different test facades were identified at POLIMI campus, respectively a facade for real scale prefabricated panels installation for external retrofitting (Building nr. 21) and a wall with cavity for injecting loose fillers and for installing prototypes for interior retrofitting (Building nr. 14).

Each of the test facades retrofitted was equipped with a dedicated set of sensors in order to collect data on temperatures, relative humidity, heat fluxes and moistures content. Hygrothermal behaviour, risk for hygrothermal damages, durability and maintainability, heat and moisture transportation, indoor environment comfort were evaluated.

Figure 19: Test facades retrofitted internally (a), in the cavity (b) and externally (c)

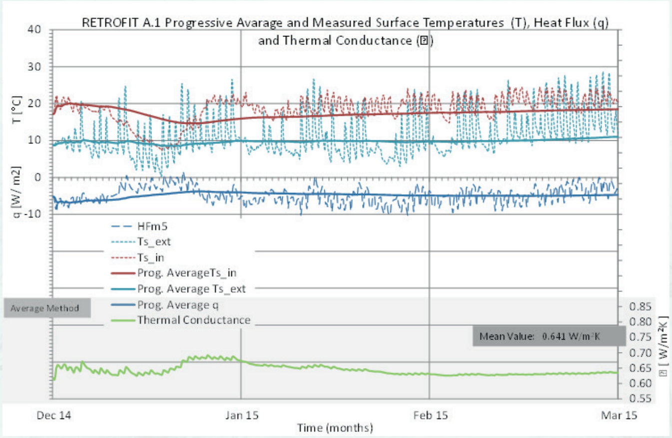
First trial of interior and cavity wall retrofitting

On 8-9 July 2014 in Milan the prototypes of the three solutions developed for the interior retrofitting, i.e. perlite boards, aerogel multi-layer boards and aerogel wallpaper were applied to the inner surfaces of the selected test facade and additional sensors installed on the inner surface to monitor the retrofitted walls. See video on EURONEWS: http://www.euronews.com/2014/09/08/new-skins-for-leaky-buildings/

On 11th July 2014 the South-West side (430x270) wall of Polimi Building nr. 14 was then retrofitted filling the air cavity (depth of about 34 mm) with natural hydrophobized loose perlite.

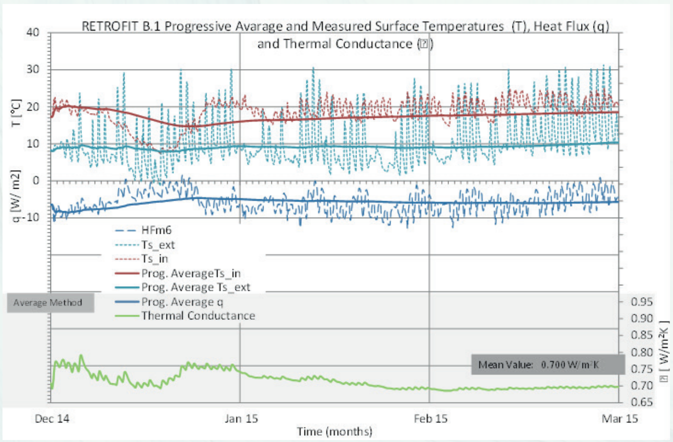
Installation of the small scale components prototypes of advanced perlite boards

1. Storage of perlite boards with frame protection before installation
2. Implementation of the grounding layer for the perlite insulation board installation
3. Application of the first line of the perlite insulation boards on the adhesive mortar
4. Application of the further lines to cover the wall
5. Application of mesh, corner protection, filler and base coat
6. Application of a resin overcoat – finishing layer.



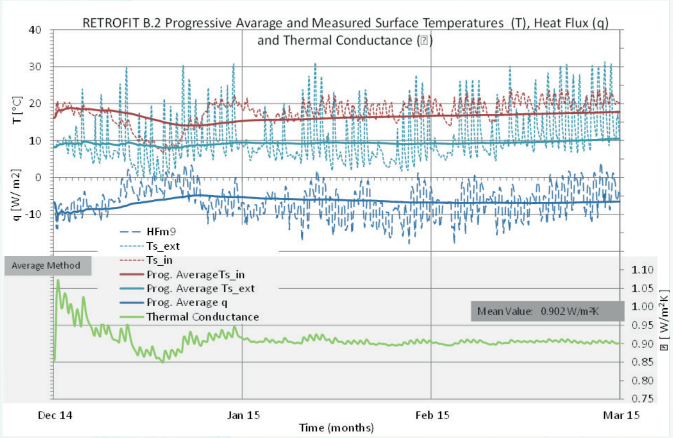
Installation of the small scale components prototypes of aerogel wall-paper

1. Storage of aerogel based wall-paper before installation
2. Implementation of the grounding layer for the permeable insulating wallpaper installation
3. Application of the wall-paper on the grounding layer
4. Encapsulating textile glued to the aerogel
5. Installation of the system of tension for the finishing fabric.



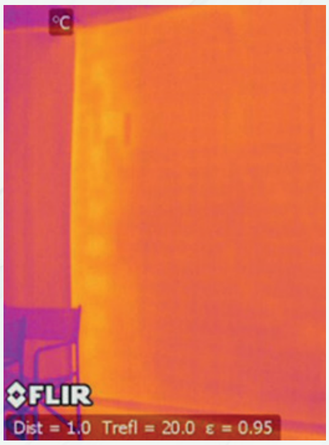
Installation of the small scale components prototypes of aerogel flat laminated boards

1. Storage of aerogel based flat laminated panels before installation
2. Implementation of the grounding layer for the flat laminated panels installation
3. Application of the multi-layer solutions on the grounding layer
4. Fix all the panels on the wall, before applying mesh, protective corners, filler and base coat



Hydrophobized perlite injection

1. Storage of the hydrophobic expanded perlite
2. Holes were drilled at the top of the cavity prior the installation of perlite.
3. Storage of the barrels containing hygrophobic expanded perlite delivered to Politecnico.
4. Positioning of the blowing machine on a lorry in order to deliver the loose perlite two floors above.



On 9-11 November 2013, a complete set of nodes was installed on the two adjacent façades of POLIMI Building n.14 (dedicated to cavity wall and internal retrofitting) to transmit inner air, inner surface and external air temperature and relative humidity as well as heat flow on the inner surface by wireless system. These data were used to determine the U-value prior to retrofit. A solar pyranometer (PYR solar radiation sensor) measured the total solar radiation flux density (W m2) on the South-East facing wall and on the South-West facing wall.
After the retrofit, additional SHT25 sensors were installed on the internal side at the same position in height as the previous ones, so on the warm side of the insulation layer. Two extra sensors were also installed inside the air cavity at a distance of about 3 cm from the surface of the inner bricks wall and at about 100 cm distance between them. The aim was to evaluate the trend of temperature and relative humidity and to understand how the convective flow inside the gap can affect the values. Data have been acquired, stored and transferred by means of a wireless communication system and GPRS modem, allowing on-line visualization and downloading in CSV format for the analysis. The recording time step was 6 minutes and the data were later transformed into hourly values for the following calculation steps.
The improvement in the cavity due to the developed solutions in thermal conductance and, consecutively, thermal transmittance of the wall was calculated by the Average Method and by dynamic analysis, before and after retrofit. A decrease in U-value of 45% for the advanced perlite boards, 40% for the permeable insulating wallpaper and 25% for the flat laminated panel has been obtained with respect to the base wall. For the hydrophobized loose perlite the improvement has been calculated equal to 85%. From the hygrothermal analysis of the developed solutions for inner retrofitting, it has been also noticed that the inner kits had a positive effect on indoor climate in winter thanks to an average rise of 1.5°C, while the most interesting result concerning the relative humidity, among the three kits in which a difference of 10% RH, at the cold side was visible in winter. During summer the difference was minimum.

First trial of external insulating panels at the test façade

Once selected the test façade for the installation of the prefabricated panels for external retrofitting (namely the West front façade of Building nr. 21, characterized by a rough concrete finishing), the design of intervention was performed based on a proper façade geometrical and energetic survey, following Work Package 5 methodology. The design foresaw the installation of 13 panels with three different colors (light gray, gray and charcoal) and the following dimensions and texture:

- 10 panels 302,5 x 150 cm (vertical line smooth texture)
- 1 panel 302,5 x 142,5 cm (smooth texture)
- 2 panels 302,5 x 55 cm (vertical line texture, see picture)

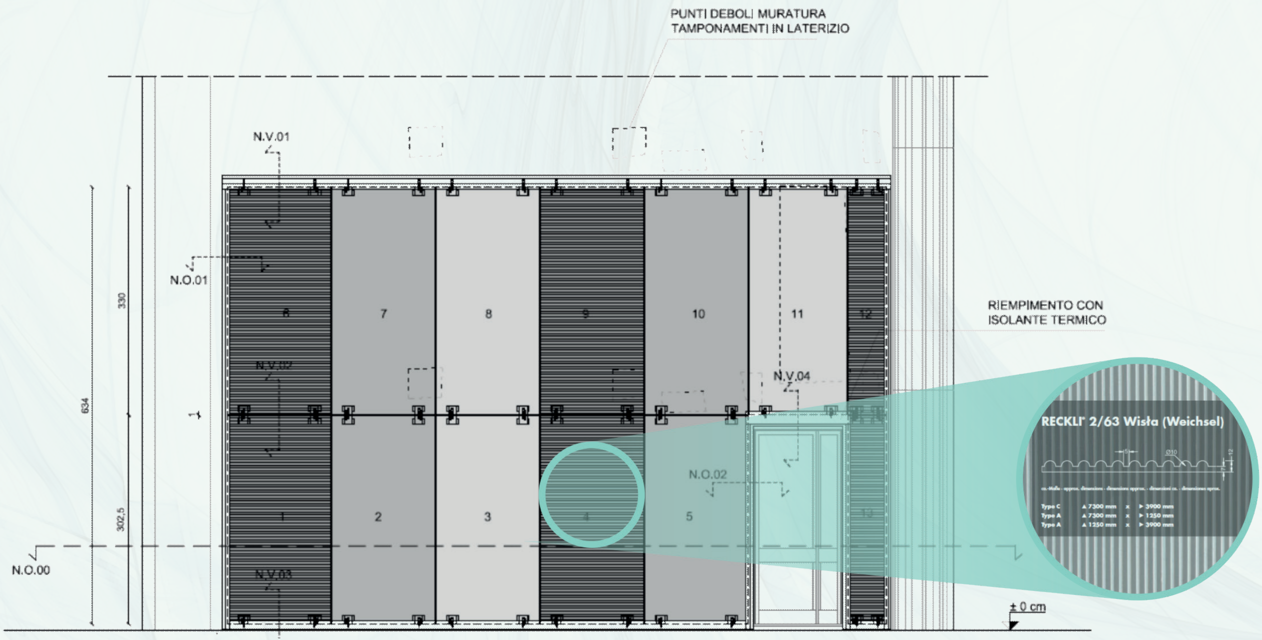


Figure 20: Drawing of the tests facade and Texture applied to two panels of the test façade

The prefabricated panels where thus transported by truck from Bergamo (where they were produced) to Milan where they were delivered at the test site and unloaded by the crane of the truck. The panel's installation was made without scaffoldings. A small crane vehicle trucks was used for both anchoring and panels' installation.

Figure 21: Some pictures of the installation process and final aesthetic and thermal result

The joints between panels were made using a low elastic modulus neutral-curing silicone sealant with outstanding ageing resistance. The silicon was placed on polyurethane backfill material in order to reduce the danger of cracking. The joints showed no trace of superficial cracks thanks to the high resistance to UV rays. Around the whole perimeter of the test façade, the cavity between the panels and the existing wall was closed using a polyurethane foam sealant. Thus, the air permeability was drastically reduced and a close air cavity created.

From the monitoring campaign, it was noticed that the prefabricated panels were well attenuating the heat flux, with positive effect to the internal temperature. Even with high external surface temperature, the internal one was always reduced by a mean factor of 0.83.

Taking into consideration also sensors' data collected between the 20^{th} of November 2015 to 10^{th} of January 2016 with time step of 6 minutes, the thermal transmittance of the renovated envelope was calculated according to the ISO 9869. The thermal transmittance measured (elaborated with the progressive average method) was equal to 0.31 W/m^2K, meaning a decrease in U-value of more than 65% with respect to the base wall.

1.11 Work Package 8: Building scale demonstrators, performance monitoring and verification

Objectives of the planned investigations of the work package

Big challenge of this Work Package and of the project itself was **to implement the EASEE energy efficiency retrofitting approach to existing residential buildings in different climatic zones** in order to validate it and assess its replicability. To this aim, different demo buildings have been identified towards external, cavity wall and interior retrofitting respectively in Poland, Italy and Spain for the prefabricated panels' installation; in Greece and Spain for loose filler injection and in Italy and Poland for interior retrofitting.

In order to acquire a detailed building survey and more information as possible taking into account that data on existing buildings are not often available, the following activities were further performed:

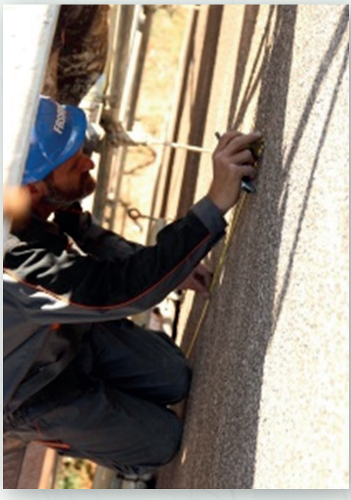
- Laser scanning of the outer envelope (with 3D laser scanner) to obtain highly detailed cloud of points an then building CAD model of the building;
- IR scanning of the building to detect major thermal breaks;
- Thermal bridges mapping through thermo-vision camera to evaluate existing thermal bridges;
- Setting up monitoring system to detect current thermal parameters of the building (inside and outside the building).

In this framework, all relevant technical and non-technical parameters and indicators related to the demo buildings were collected to characterize each building into the tool aimed at supporting the end-users to design the retrofitting and implement EASEE approach. Indeed, all the information was used as an input for the Retrofitting Planner. Moreover, SMEs were involved in the selection and in the use of the planner, representing a further validation of the goodness of the approach. Technical specifications for the prefabricated elements to be used in these buildings have been also provided by the Design Tool as inputs for the project partners involved in their production and by BIM software, as instruments helping the optimization of the retrofitting design and facilitating the panels' installation. Then monitoring system, already installed in order to evaluate the building performance before the retrofitting intervention, have been working for months to measure post-installation performance.

With respect to the exterior retrofitting, three demo buildings (in Gdansk, Madrid, Milan) have been externally retrofitted.

Polish Demo Building

The Polish demo building was a typical example of multi-storey multifamily residential building constructed after the second Word War, in the 1950's. Main purpose of intervention was the comparison among traditional and EASEE external retrofitting process, with respect to the installation process, durability and thermal behavior. (see video on https://www.youtube.com/watch?v=JiKhtDtfyNk)



PRE RETROFITTING
- Age of construction: 1950
- Owner: Municipality (Building under protection of Cultural Heritage Conservator (CHC))
- Number of floors: 3
- External walls: full brick 42cm, no insulation
- Monitoring campaign: December 2013 - September 2015; full reference season thermal assesment available
- U value before retrofitting: 1 W/m^{2}K

POST RETROFITTING
- Installation of 40 EASEE panels (50cm x150cm x12,4cm)
- Rest of the building retrofitted with External
- Thermal Insulation Composite System (ETICS) for benchmarking
- Monitoring campaign: since October 2015 going on; October 2015 - January 2016 partial season validation processed for average U and Heat transport
- U-value evaluated statistically and proved for 3 months observation period: 0,33W/m^{2}K

Spanish Demo Building

The Spanish demo building was a residential single family house owned by a mid-age Spanish family, built during the 1960's. Main purpose of the intervention was to evaluate the impact on the construction process practice and on the occupants as well as on energy efficiency of the building. Moreover, the façade was chosen also to evaluate improvement of the external and cavity wall retrofitting on the same façade.




PRE RETROFITTING
- Age of construction: 60s
- Owner: Private mid-age Spanish family
- External walls: 1 foot brick wall, revoked with Tyrolean plaster
- U value before retrofitting: 1,88 W/m^{2}K

POST RETROFITTING
- Installation of 12 EASEE panels achieving best design option
- Monitoring campaign: October 2015 on
- U value:

- after cavity wall retrofitting: 0.96 W/m^2 K
- after external retrofitting: 0,37 W/m^2 K

Italian Demo Building

The Italian demo building was a multy-storey and multi-family residential building (three floors above ground for six apartments) owned by the Social Housing Agency of Lombardy (Azienda Lombarda Edilizia Residenziale - ALER) Milan division and built in 1971.
By retrofitting the overall building (more than 580 m^2) the following aspects were validated:

- Panels' colours and textures
- Methodology for building (geometrical and energetic) assessment
- BIM approach applied to EASEE retrofitting approach
- Yard preparation and installation process
- Impact on the construction process practice and on the occupants as well as on energy efficiency of the building joints installation and technical details around balconies, corners, doors, windows, etc.
- Finishing activities
- Energy performance of the overall intervention.

WEST FAÇADE

BEFORE

AFTER

NORTH FAÇADE

BEFORE

AFTER

EAST FAÇADE

BEFORE

AFTER

SOUTH FAÇADE

BEFORE

AFTER

PRE RETROFITTING

- Age of construction: 70s
- Owner: Local Social Housing Agency (ALER)
- Externall walls: Reinforced concrete wall,
- Cavity and clay hollow bricks
- U value before retrofitting: 0,83 W/m^{2}K

POST RETROFITTING

- Installation of 186 EASEE panels with different colors & textures(28 typologies)
- Monitoring campaign: October 2015 on
- U value after retrofitting: 0.27 W/m^{2}K

With respect to cavity wall retrofitting, two main interventions were performed at the Spanish demo building and at Lavrion Technological Park in Greece, with different purposes. While in Spain, the main purpose was to evaluate the benefits achieved from the combined retrofitting of external envelope and cavity walls; in Greece there was the need to practically study the thermal behaviour of the two kinds of perlites developed and properly hydrophobized in a controlled environment taking into account the same boundary conditions and with the same benchmark (wall with no cavity retrofitted).

Figure 22: Demo buildings in Spain (a) and in Greece (b) where cavity walls were retrofitted

With respect to the interior retrofitting, two walls at Politecnico di Milano were internally retrofitted in order to trial and verify easiness of installation and DIY approach of the developed kit. Part of the attic of the Polish demo building was internally retrofitted as well. The two installations had different purposes. Indeed, the selected room at Politecnico di Milano had perimeter walls that reproduced the same type of construction technology (cavity walls in hollow bricks) and geometry (corners, windows, shutter box etc.) of an apartment building. It was then decided to use the demonstration activities as a simulation of a real construction site, testing the procedures required for the installation of the indoor retrofit kits, the potential problems that would arise in a realistic situation, the problems of fitting the dimensions of the insulating panels to the actual geometry, etc. Although the main focus of the indoor demonstration activities was not thermal performance (the solutions were not monitored in terms of energy flows and temperatures), the situation of the walls before the retrofit works was assessed qualitatively with infrared tools.

The Polish demo building attic was instead retrofitted in order to test the technology developed in the project together by POLIMI, RIDAN and SCHWENK, namely the flat laminated panels coated with aerogel, produced with an alternative process.

Figure 23: Interior retrofitting in Milan (a) and Gdansk (b)

The evaluation of the techno-economic feasibility and success of the EASEE retrofitting approach (including products, processes and services provided to the final user) was performed focusing on the following aspects:

- Energetic impacts for each demo building (energy performances evaluation and related energy savings in terms of building consumptions, thermal comfort, etc.)
- Economic impacts for each demo building (in terms of cost effectiveness during the life cycle of the building)
- Indirect industrial impacts for each demo building (i.e. savings in terms of installation timing and workforce, waste reduction, CO_2 emissions, burden minimization)

Indeed, dedicated monitoring campaign was performed before and after the retrofitting in order to have data useful for the validation of the panels' performances. The performance assessment, before and after the installation phase, was carried out coupling the infrared thermo vision technique with the heat flow meter method to acquire quantitative data of real thermal transmittances of the building envelope in a quasi-steady state condition for the demo buildings. The expected durability and the behaviour of the insulating options have been thus assessed, collecting temperature and humidity data from sensors installed on different parts of the envelope.

Other data related to the specific boundary conditions (e.g. external temperatures, particular weather events, etc) were also collected during demonstration activities in order to compare real and predicted performances.

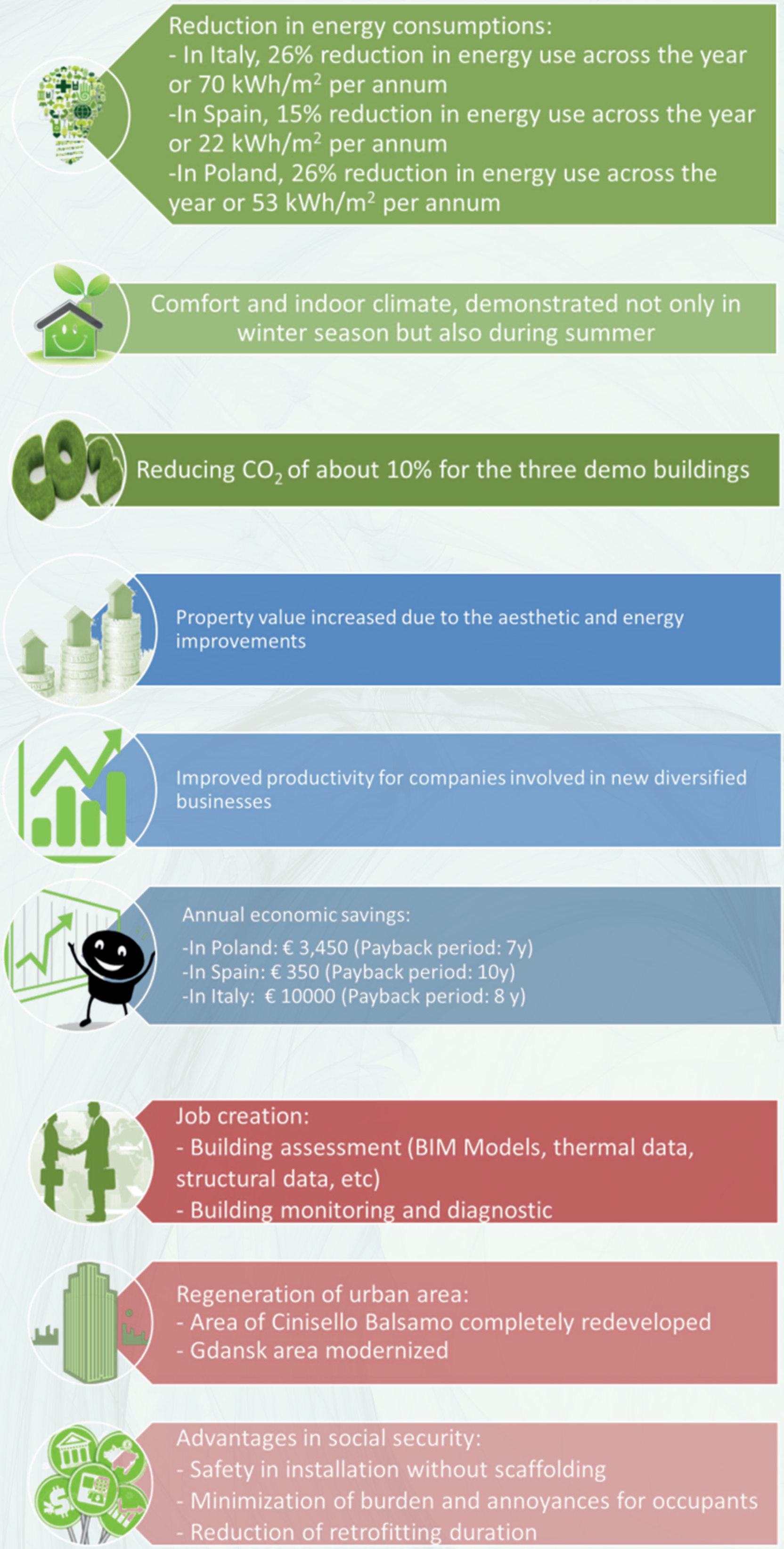


Figure 24: Energetic, economic and indirect industrial impacts of the EASEE project

Starting from the above numbers and considering as a target market 2% of the 10 million of residential buildings built before 1975, a potential annual energy saving of almost 8 million kWh corresponding to 2 billion euros per year can be obtained.

Of course these numbers referred to the optimized products, which according to the project partners could be achieved in 2 years from the project end.

1.12 Project impact and exploitation of results

One of the most important challenges of the European Community is to boost the application of sustainable and energy efficient solutions to the construction sector. There exist no doubts that one of the most promising sectors for the European future is the existing residential building stock, with particular focus on the envelope that represents massive wide-area surfaces of energy saving potential across Europe. The focus of EASEE was clearly concerning that line, developing a holistic approach for energy efficient retrofitting of existing multi-storey multi-owner buildings.

In this context, each partner is going to further detail and put in practise the commercialization strategies set-up within the project according to their current business and with respect to each of the main project scientific results they were involved in, among the following:

- Customized prefabricated façade insulating panels with different aesthetic options for outer envelope retrofitting
- Adjustable moulding for the production of the above modular panels with variable dimensions
- Hydrophobation process to reduce hygroscopicity of Natural and Synthetic perlite
- Highly insulating Synthetic Perlite to be used as loose filler for cavity walls retrofitting
- Perlite boards for the internal envelope retrofitting
- Aerogel wallpaper for the internal envelope retrofitting
- Aerogel laminated boards for the internal envelope retrofitting
- Methodology for energetic assessment and for the geometrical reproduction of the façade
- Building performance remote monitoring platform
- Retrofitting Planner
- Design Tool

1.13 Main dissemination activities

At the beginning of the project, with the aim of fostering results visibility, a dedicated Dissemination and Communication Strategy was set up in order to maximize the benefits of the project not only to partners but also to the external entities interested in acquiring a direct access and adopting the specific project results. The Strategy provided a clear definition of the dissemination tasks and the related responsible actors as well as of the target groups to be reached through appropriate dissemination tools and channels in order to eliminate a wide distribution of general information to an unspecified audience, which might be of little use.

In this context, the EASEE dissemination activities were implemented at three levels:

- European level: the main dissemination effort were focused on the European group of stakeholders as well as other beneficiaries e.g. various networks, technology platforms e.g. European Construction Platform and encompassed communicating information acquired from the EASEE Demo buildings as well as issues of European wide interest e.g. impacts of EASEE on policy, transferability/replication of best practices implemented locally/regionally, etc. This dissemination level also included the European research and academia community towards whom different communication channels and tools have been applied as well as international scientific, professional and non-professional journals.
- National level: the main dissemination effort was focused on decision makers in the construction industry and national owners associations, national associations of professionals, national technology platforms and clusters. This level included also financial organizations involved in construction or investors operating on national level.
- Regional/local level: the development and deployment of a new approach to envelope retrofitting and the set up a local supply chain of components shall be in principle built upon a local approach involving local stakeholders and end users. Therefore, the dissemination tasks addressed the groups regional/local stakeholders centred on demo buildings for which own local dissemination approach has been developed and implemented by relevant partners benefiting from the available dissemination materials and established contacts with the local stakeholders.

The main dissemination activities regarding EASEE consisted of scientific publications in journals and scientific papers and additionally a number of oral presentations and posters presented at conferences and workshops (reported per country in the following pages).

AUSTRIA

PARTNER	EVENTS WHERE PARTNER DISSEMINATED THE PROJECT (conferences, seminars, meeting related to energy efficiency, etc)	EVENTS PLACE	TYPE OF AUDIENCE	DISSEMINATION TOOLS (Poster, brochure, ppt, etc)
ECAP	EOTA 77 TB meeting (09 October 2013)	Innsbruck (AT)	European Technical-scientifical institutions dealing with innovative products in construction	Brochure
BPIE	WSED 2015 (25-27 February 2015)	Wels (AT)	International	Flyers

BELGIUM

PARTNER	EVENTS WHERE PARTNER DISSEMINATED THE PROJECT (conferences, seminars, meeting related to energy efficiency, etc)	EVENTS PLACE	TYPE OF AUDIENCE	DISSEMINATION TOOLS (Poster, brochure, ppt, etc)
ECAP	ECAP Working Group Meeting (16 May 2013)	Bruxelles (B)	European Technicians	Brochure
ECAP	ECAP yearly meeting (29 May 2013)	Bruxelles (B)	CEO of European firms of construction products	Brochure, Speach
ECAP	SMEs & Standardization conference (3 June 2013)	Bruxelles (B)	CEN, EOTA, European Commission, Members of the EU Parliament, various stakeholders of the European lobby scene	Speach and brochures (a slide of the ppt presentation showed the EASEE brochure)
ECAP	Building Test Expo (fair)/EOTA GenAssembly/CEN Construction Sector Network Conference (17-18-19 June 2014)	Bruxelles (B)	European construction world representatives / European Technical-scientifical institutions dealing with innovative products in construction	Brochure
ECAP	Workshop "Constuction needs and affordability: bridging the gap" (4 June 2013)	Bruxelles (B)	CEN, EOTA, European Commission, Members of the EU Parliament, various stakeholders of the European lobby scene http://www.construction-products.eu/news-events/events/past-events.aspx	Speach
ECAP	UEAPME Construction Platform (23 October 2013)	Bruxelles (B)	European lobbyists	Brochure
ECAP	SBS experts meeting (30 June - 1 July 2014)	Bruxelles (B)	European experts of standardization (all SMEs)	Brochure
ECAP	CPE General Assembly (11 June 2014)	Bruxelles (B)	European associations of construction products	Brochure
BPIE	i24C workshop (10 March 2016)	Bruxelles (B)	International	Brochures + slide
BPIE	EASEE Final conference (12 February 2016)	Bruxelles (B)	International	EASEE workshop

PARTNER	EVENTS WHERE PARTNER DISSEMINATED THE PROJECT (conferences, seminars, meeting related to energy efficiency, etc)	EVENTS PLACE	TYPE OF AUDIENCE	DISSEMINATION TOOLS (Poster, brochure, ppt, etc)
BPIE	2nd International & DHC Research Conference (5-6 November 2013)	Bruxelles (B)	International	
BPIE	Renovate Europe Day (8 September 2013)	Bruxelles (B)	EE in building stakeholders	Brochure
BPIE	EUSEW 2014 (26 June 2014)	Bruxelles (B)	European	Flyers
BPIE	IKEM Summer Academy 'Energy and the environment' (15-21 September 2013)	Bruxelles (B)	European	Brochure
BPIE	2nd International & DHC Research Conference (5-6 November 2013)	Bruxelles (B)	European	Brochure
BPIE	Investor's Day 2015 (November 2015)	Bruxelles (B)	EU	Brochure
BPIE	EUSEW 2015- Build Up stand (16-19 June 2015)	Bruxelles (B)	European	Brochure
BPIE	COHERENO final conference (15 October 2015)	Bruxelles (B)	EU	Brochure
BPIE	REDAY 2015 (15 October 2015)	Bruxelles (B)	EU	Brochure
BPIE	EPISCOPE final conference (18 November 2015)	Bruxelles (B)	EU	Brochure / Poster
DAPP	Impact workshop (24-25 March 2014)	Bruxelles (B)	EU	Ppt
DAPP	ECTP E2BA Conference (17-19 April 2014)	Bruxelles (B)	EU	EASEE Roll up poster
STAM	EUSEW (European Union - Sustainable Energy Week) (23-27 June 2014)	Bruxelles (B)	European Commission, stakeholders from Europe, entities from the EU research	TBC
FASADA	"Construction and Built Environment - ECTP-E2BA CONFERENCE Future Horizons" (17-18 July 2014)	Bruxelles (B)	Members of ECTP, ENCORD, ENBRI and ECCREDI	Brochure / Poster

FRANCE

PARTNER	EVENTS WHERE PARTNER DISSEMINATED THE PROJECT (conferences, seminars, meeting related to energy efficiency, etc)	EVENTS PLACE	TYPE OF AUDIENCE	DISSEMINATION TOOLS (Poster, brochure, ppt, etc)
IES	Building Simulation Conference (25-28 August 2013)	Chamberay (FR)	International	Flyers
BPIE	eceee Summer Study (1-6 June 2015)	Toulon/ Hyères (FR)	International	Brochure/ poster

GERMANY

PARTNER	EVENTS WHERE PARTNER DISSEMINATED THE PROJECT (conferences, seminars, meeting related to energy efficiency, etc)	EVENTS PLACE	TYPE OF AUDIENCE	DISSEMINATION TOOLS (Poster, brochure, ppt, etc)
ECAP	Fastener Fair (11-12 March 2015)	Stuttgart (DE)	Manufacturers of fastening systems	Brochure
RIDAN	TECHTEXTIL 2015 - Techtextil is the leading international trade fair for technical textiles & nonwovens. (04-07 May 2015)	Frankfurt (DE)	International	yes
BPIE	WSED 2014 (28-29 March 2014)	Linz (DE)	European	Brochure + poster
BPIE	IEPPEC (09-11 September 2014)	Berlin (DE)	European	brochure

ITALY

PARTNER	EVENTS WHERE PARTNER DISSEMINATED THE PROJECT (conferences, seminars, meeting related to energy efficiency, etc)	EVENTS PLACE	TYPE OF AUDIENCE	DISSEMINATION TOOLS (Poster, brochure, ppt, etc)
STAM	Restructura (26 November 2015)	Torino (IT)	National	EASEE workshop and stand, all partners involved
STAM	Sustainable Places 2015 (16-18 September 2015)	Savona (IT)	Academic & non-academic researchers, Energy generation systems manufacturers	Brochure
IES	Sustainable Built Environment (17-18 February 2016)	Torino (IT)	international	Flyers
IES	Sustainable Places (1-18 September 2015)	Savona (IT)	international	Flyers
BPIE	Restructura (26 November 2015)	Torino (IT)	National	EASEE workshop and stand, all partners involved
SandB	Smart and Functional Coatings Conference (25-27 September 2013)	Torino (IT)	Coatings Industrial sectors	Presentation
SandB	PROCOAT Workshop (Energy Saving and Reinforcing Minerals- Sustainable Additives improving Insulation-Resistance) (7 June 2014)	Alessandria (IT)	Coatings and Construction industrial sectors	Organization of the event, Poster, brochures
STAM	Smart Energy Expo (8-10 October 2014)	Verona (IT)	Professionals, Energy stakeholders	Brochure
EMPA	IBPC2015 Int. Conf. Building Physics (once in every 3 years) (14-17 June 2015)	Torino (IT)	International audience interested in Building Physics (Academia & Industry)	Presentation PPT and paper for proceedings

PARTNER	EVENTS WHERE PARTNER DISSEMINATED THE PROJECT (conferences, seminars, meeting related to energy efficiency, etc)	EVENTS PLACE	TYPE OF AUDIENCE	DISSEMINATION TOOLS (Poster, brochure, ppt, etc)
ECAP	Lesson at the Milan University Politecnico di Milano (22 January 2015)	Milan (IT)	Students of structural engineering	Brochure, speach
POLIMI	Seminars on Building Refurbishment (Edicom Edizioni) (21 May 2014)	Bergamo and Monza (IT)	Professionals	Ppt
POLIMI	20th CTE Congress (6-8 November 201)	Milan (IT)	Technicians in the construction field (e.g. engineers, technicians in precasting)	Paper, Ppt
POLIMI	ASITA 2015 (29 September - 1 October 2015)	Lecco (IT)	Professionals, industry	Brochure/ poster / Flyers
POLIMI	Round table about innovation in constructions (event parallel to ASITA 2015). Presentation of the EASEE project (30 September - 1 October 2015)	Lecco (IT)	Professionals, industry	Speach, brochure, slide
POLIMI	"39th IAHS conference on Housing Science - Changing Needs, Adaptive Buildings, Smart Cities Scientific paper The influence of insulation on the thermal intertia of existing residential building envelopes" (17-20 September 2013)	Milan (IT)	Academics, professionals	Paper, ppt
POLIMI	"Energy Forum on Advanced Building Skins Scientific paper ""Retrofitting the existing envelope of residential buildings: innovative technologies, performance assessment and design methods" (28-29 October 2014)	Bressanone, Italy	Academics, professionals, authorities	Paper, ppt
POLIMI	Seminars on Building Refurbishment (Edicom Edizioni) (11-12 March 2015)	Bergamo and Como (IT)	Professionals	Ppt
POLIMI	Seminars on Building Refurbishment (Edicom Edizioni) (15 April 2015)	Milan (IT)	Professionals	Ppt
POLIMI	Round table about innovation in constructions (event parallel to ASITA 2015). Presentation of the EASEE project (30 September - 1 October 2015)	Lecco (IT)	Professionals, industry	Speach, brochure, slide
POLIMI	International Workshop on Durability and Sustainability of Concrete Structures (DSCS 2015) (1-3 October 2015)	Bologna (IT)	International audience interested in Concrete Sustainability and Durability (Academia and Industry)	paper

POLAND

PARTNER	EVENTS WHERE PARTNER DISSEMINATED THE PROJECT (conferences, seminars, meeting related to energy efficiency, etc)	EVENTS PLACE	TYPE OF AUDIENCE	DISSEMINATION TOOLS (Poster, brochure, ppt, etc)
RIDAN	THE TRADE FAIR FOR TECHNICAL TEXTILES and INNOVATEX 2014 (16-17 October 2014)	Łódź (PL)	National	Exhibitor – poster, brochures – project will be presented during Innovatex 2014 conference (TECHTEX session)
RIDAN	BUDMA 2015 International construction and architecture fair (10-13 March 2015)	Poznań (PL)	International	yes
RIDAN	Warsaw Build 2015 (16-18 September 2015)	Warsaw (PL)	International	yes
BPIE	Future for Built (06-07 November 2013)	Warsaw (PL)	International	ppt
BPIE	Warsaw Build 2015 - Warsaw Build is an event dedicated to the business to business actions. (17 September 2015)	Warsaw (PL)	National	EASEE workshop and stand, all partners involved
FASADA	XI Congress of the polish participants of framework programmes (13-14 October 2014)	Katowice (PL)	polish researchers, SMEs, industry	Presentation ppt, brochures
FASADA	Meeting with Marshall Office of Gdańsk (Municipality) (15 July 2015)	Gdańsk (PL)	authorities that own public buildings (hospitals, schooles, police buildings)	presentation of EASEE solution for retrofitting
CIM-mes	Warsaw Build 2015 - Warsaw Build is an event dedicated to the business to business actions. (16-18 Sept 2015)	Warsaw (PL)	National	yes

SPAIN

PARTNER	EVENTS WHERE PARTNER DISSEMINATED THE PROJECT (conferences, seminars, meeting related to energy efficiency, etc)	EVENTS PLACE	TYPE OF AUDIENCE	DISSEMINATION TOOLS (Poster, brochure, ppt, etc)
IES	WSB14- World Sustainable Buildings 2014 (28-20 October 2014)	Barcelona (ES)	International	IES R&D flyers
Ancodarq	Technical Architects Associations of Madrid - Dissemination event (26 February 2015)	Madrid (ES)	Architects and Civil engineers	EASEE dissemination event with presentations from partners

UNITED KINGDOM

PARTNER	EVENTS WHERE PARTNER DISSEMINATED THE PROJECT (conferences, seminars, meeting related to energy efficiency, etc)	EVENTS PLACE	TYPE OF AUDIENCE	DISSEMINATION TOOLS (Poster, brochure, ppt, etc)
ECAP	European Commission Meeting on International Competitiveness (23-24 May 2013)	Stansted (UK)	European lobbyists	Brochure
IES	Ecobuild (3-5 March 2015)	London (UK)	Professionals	IES R&D flyers
IES	Ecobuild (4-6 March 2014)	Excel London (UK)	Professionals	Flyers

OUTSIDE EUROPE

PARTNER	EVENTS WHERE PARTNER DISSEMINATED THE PROJECT (conferences, seminars, meeting related to energy efficiency, etc)	EVENTS PLACE	TYPE OF AUDIENCE	DISSEMINATION TOOLS (Poster, brochure, ppt, etc)
IES	Greenbuild (22-24 October 2014)	New Orleans (USA)	Construction stakeholders	flyers
POLIMI	International Conference on Concrete Sustainability (ICCS16) (2015)	IT	Construction professionals, industry	paper
POLIMI	SSCS 2016 (2015)	Rio	Professionals	paper
POLIMI	10th fib International PhD Symposium in Civil Engineering (21-23 July 2014)	Université Laval, Québec, Canada	PhD students working on advanced cementitious materials	paper
POLIMI	Presentation to the Building Research Group - Department of Civil, Architectural and Environmental Engineering (CAEE) Drexel University (15 May 2015)	Philadelphia, PA (USA)	Academics, students	Ppt
POLIMI	Presentation to research groups at the Keio University and the Univerisity of Tokyo (March - April 2015)	Tokyo (Japan)	Academics, students	Ppt
STAM	INCONET GCC2 International Conference Collaboration for Innovation; Linking GCC and EU (6-8 December 2015)	Grand Hyatt Hotel, Muscat (Oman)	Stakeholders from Europe and from GCC countries	Brochure
STAM	Smart Cities for Sustainable Development: European and GCC Perspectives (14-15 October 2014)	Abu Dhabi (UAE)	Stakeholders from Europe and from GCC countries	Brochure

1.14 Consortium

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