



Sustainable solutions for affordable **REtroFIT** of domestic buildings

Call: H2020-LC-SC3-2018-2019-2020

Topic: LC-SC3-EE-1-2018-2019-2020

Type of action: IA

Grant Agreement number	894511
Project acronym	SUREFIT
Project full title	SUustainable solutions for affordable REtroFIT of domestic buildings
Due date of deliverable	28/02/2025
Lead beneficiary	ISQ
Other authors	

WP1 - Deliverable D 1.5 **Final public report**

Dissemination Level

PU	Public	X
CO	Confidential, only for members of the consortium (including the Commission Services)	
CI	Classified, as referred to in Commission Decision 2001/844/EC	

Document History

Version	Date	Authors	Description
1	24/02/2025	ISQ, Sérgio Tadeu	Final version to Partners
2	27/02/2025	All partners	Partners' contributions
3	28/02/2025	ISQ, Sérgio Tadeu	Coordinator's review

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No **894511**.



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Abbreviations

A/C	Air condition
CAD	Computer-aided design
CO ₂	Carbon Dioxide
DX SAHP	Direct Expansion Solar Assisted Heat Pump
EPC	Energy Performance Certificate
GSHP	Ground Source Heat Pump
HVAC	Heating Ventilation Air Conditioning
IT	Internet Technology
KER	Key Exploitable Result
OSS	One Stop Shop
PCM	Phase Change Material
PV	Photovoltaic
PVD	Physical Vapor Deposition
PV-VG	PV vacuum glazing
RES	Renewable Energy Sources
ROI	Return of investment
SAHP	Solar Assisted Heat Pump
TP GSHP	Thermal Pipe Ground Source Heat Pump
TRL	Technology Readiness Level
U-value	Thermal transmittance
WP	Work package

Publishable summary

SUREFIT technologies aim to significantly reduce primary energy use, carbon emissions, renovation time, and costs. Achieving these ambitious goals presents a challenging path to market scalability. The project adopted a systematic approach, engaging key stakeholders such as building owners and users, manufacturers, and product and service developers. It focused on space heating, cooling, domestic hot water, lighting, and power generation.

A range of innovative, energy-efficient, and cost-effective technologies were sized for optimum performance to reduce installation time and maintenance requirements, and to increase reliability and affordability. By extension, this increased accessibility for all stakeholders, from product manufacturers to building owners and users, which had a wider impact on energy reduction across the EU. The technologies included bio-aerogel, prefabricated panels, phase change materials, photovoltaic vacuum glazing windows, roof and window heat recovery devices, solar-assisted heat pumps and ground source heat pumps, evaporative coolers, integrated solar thermal and photovoltaic systems, and lighting devices.

These technologies were manufactured by the industrial partners of the project consortium and demonstrated in real-life contexts in five existing buildings across three different European climates (Mediterranean, Atlantic, and Northern) to ensure their excellence in operation (UK, Greece, Spain, Portugal and Finland).

Post-retrofit, the installed technologies operated to maximize energy gain from renewable sources through smart controls while minimizing heating, cooling, and ventilation losses. Socio-economic analyses were then conducted to assess how the installed measures impacted the houses and district scales with respect to energy reduction in the thermal and electrical energy networks, as well as occupants' satisfaction. Guidelines and effective operational tools were also developed to optimize the renovation process and decision-making.

Based on the Business Model Canvas and the Key Exploitable Results, an overall business model approach for SUREFIT technologies and services has been designed. This approach aims to create a network of stakeholders that will facilitate the coordinated exploitation of results, while also accommodating the unique characteristics of the entities within the SUREFIT Consortium. A SWOT analysis was undertaken to help the partners overcome challenges and determine which path to take. To ensure continuous goals and active contributions beyond the project's lifetime, the SUREFIT Consortium presented its strategic concepts.

The SUREFIT business model aims to create a network of experts and policymakers, facilitating the exploitation of project results. It will particularly focus on raising awareness of the return on investment in SUREFIT's innovative technologies, which include energy conservation and cost-optimal measures for renewable energy sources, meeting both environmental and economic criteria.

1 Introduction

When the SUREFIT project was designed, buildings accounted for approximately 40% of the EU's energy consumption and 36% of its total CO₂ emissions. At the time, around 35% of the EU's buildings were over 50 years old, and nearly 75% of the building stock was energy inefficient. However, only 0.4-1.2% of these buildings were renovated annually due to the slow and costly nature of renovation processes.

This project aimed to demonstrate a fast-track renovation approach, reducing implementation time by 40%, for existing domestic buildings. By integrating innovative, cost-effective, and environmentally conscious prefabricated technologies, the project sought to achieve near-zero energy targets. This involved reducing heat losses through the building envelope and minimizing energy consumption for heating, cooling, ventilation, and lighting, while simultaneously increasing the share of renewable energy in buildings.

The project adopted a systematic approach, engaging key stakeholders such as building owners and users, manufacturers, and product and service developers. It focused on space heating, cooling, domestic hot water, lighting, and power generation.

A range of innovative, energy-efficient, and cost-effective technologies were sized for optimum performance to reduce installation time and maintenance requirements, and to increase reliability and affordability. By extension, this increased accessibility for all stakeholders, from product manufacturers to building owners and users, which had a wider impact on energy reduction across the EU. The technologies included bio-aerogel (BA), prefabricated panels (PP), phase change materials (PCM), photovoltaic vacuum glazing windows (PV-VG), roof and window heat recovery devices, solar-assisted heat pumps (SAHP) and ground source heat pumps (GSHP), evaporative coolers (EVC), integrated solar thermal and photovoltaic systems (PV/T), and lighting devices (DL).

These technologies were manufactured by the industrial partners of the project consortium and demonstrated in real-life contexts in five existing buildings across three different European climates (Mediterranean, Atlantic, and Northern) to ensure their excellence in operation (UK, Greece, Spain, Portugal and Finland).

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Guidelines and effective operational tools were developed to optimize the renovation process and decision-making. Additionally, innovative business models were created.

The project intended to contribute to European excellence by addressing fuel poverty and improving the quality of life for its citizens. It aimed to strengthen the European Union by fostering stronger collaboration between industry and academic institutions with complementary skills.

2 Background of SUREFIT assessment

Building renovations primarily use conventional technologies and commercial renewable products, significantly reducing building energy consumption from existing levels and maximizing the perceived comfort of individual users. This project aimed to go beyond current practices to bring about a step change in renovation.

Some technologies available for renovation are expensive, and the processes are time-consuming and disruptive to occupants, making deep retrofits unattractive to building owners. This project employed innovative modular/prefabricated technologies to rapidly renovate a selection of domestic buildings, reducing energy consumption not only from existing levels but also meeting the aspiration for near-zero energy buildings and personal comfort levels. The SUREFIT technologies were adapted and optimized for different climate conditions and cultural and comfort standards.

Some of the technologies were suitable for specific climates and building types, so not all modules were installed in a single building. The project involved the optimum sizing, manufacturing, and demonstration of technologies for rapid renovation and performance monitoring in five buildings across three different climates. Key technologies for building renovation included: i) bio-aerogel for insulation and PCM for passive heating/cooling, ii) heat pumps for space and water heating and thermal storage, iii) evaporative cooling, iv) PV/solar collectors and PV vacuum glazing for windows, v) window heat recovery, and vi) daylight louvers.

Many similar technologies had been used in buildings for heating, cooling, ventilation, or lighting. For example, heat pumps had been used for space heating, and PCMs had been used for heat or coolth storage, especially in solar heating and cooling systems, to compensate for solar radiation fluctuations and energy demand variations. Desiccant systems had also been used for cooling/heating applications. However, they were expensive and time-consuming compared to conventional heating, cooling, and lighting systems.

The project not only demonstrated innovative technologies but also aimed to improve understanding of material and component behaviours throughout their life cycle to produce high-quality and cost-competitive products for building renovation. This resulted in delivering deep cuts in energy use and carbon emissions of nearly 60%, while also achieving high levels of thermal and visual comfort at attractive costs. Rather than using individual components or technologies, each integrated whole-building solution was optimized to address all aspects of the building that could be used to reduce heat losses and gains through the building envelope, minimize energy use for fresh air supply, hot water, and lighting, and maximize the use of renewables to significantly cut carbon emissions of existing buildings.

The renovation technologies were divided into two general themes: envelope enhancement and energy-efficient facilities or services (heating, ventilation, and air conditioning, i.e., HVAC, and lighting). The reduction in energy consumption was a major route to cutting carbon dioxide emissions, reducing the running costs of buildings, reducing reliance on imported fossil fuels, and increasing the security of our energy supply, making it important to tackle envelope losses.

As heating and cooling loads were reduced, the electric energy used in operating the building increasingly dominated, so energy-efficient and low-carbon facilities, including lighting and HVAC, were achieved. With heating, cooling, and lighting loads reduced, building services plant

and machinery could be reduced, and more efficient, low-carbon, and renewable technologies could be deployed.

The envelope was the main interface between the occupants of buildings and the outside, so it was important to minimize energy gains and losses with respect to heat transfer across the envelope. One of the main methods of improving thermal insulation, both to reduce heat losses in cold climates and heat gains in hot climates, was the installation of external or internal insulation.

Operating facilities that provided indoor thermal and visual comfort and good air quality consumed a large amount of energy. By reducing heat gains and losses while applying energy storage, the energy consumption of artificial heating and cooling systems was also decreased, allowing low-zero carbon technologies to be employed. State-of-the-art low-impact heating and cooling encompassed solar thermal heating for water and space heating in cold climates, evaporative/desiccant cooling in hot climates, heat pumps for space heating and hot water, and reversed heat pumps for cooling. The most efficient method for lighting was to make use of daylight through windows or by means of daylight louvers.

To make the technologies affordable for building renovation, low-cost materials and manufacturing methods were employed, such as silica aerogel in place of expensive aerogel or vacuum insulation panels on the market for wall insulation. Additionally, the technologies were prefabricated to reduce installation costs and time, as well as lifetime costs.

In summary, the project deployed the most innovative, energy-efficient, and cost-effective prefabricated technologies for the rapid renovation of domestic buildings, ensuring personal comfort for the end user. This resulted in almost 60% reduction in primary energy use and carbon emissions, a potential cost renovation time reduction.

2.1 Technologies researched in the SUREFIT project

The performance of novel renovation technologies in the SUREFIT Project was studied first through building-level simulations. In the simulations, the technologies were classified into three renovation packages:

- **Passive Package:** This included bio-aerogel thermal insulation (BA), PV vacuum windows (PV-VG), and phase change material (PCM).
- **Ventilation Package:** This comprised insulating breathable membranes (BM) and window heat recovery (WHR).
- **Generation Package:** This included photovoltaic/thermal (PV/T) systems, solar-assisted heat pumps (SAHP), and a new application of daylight technology (DL).

Each technology researched is further described below:

2.1.1 Bio-aerogel (BA)

This thermal insulation is a novel, environmentally friendly insulating material made of starch-based aerogel. The highly insulative bio-aerogel requires less than 1/5 the thickness of conventional insulation. It significantly reduces heating loss through building envelopes when the external walls and roofs of the demo buildings are covered by bio-aerogel thermal insulation, thereby lowering the space heating energy demand.

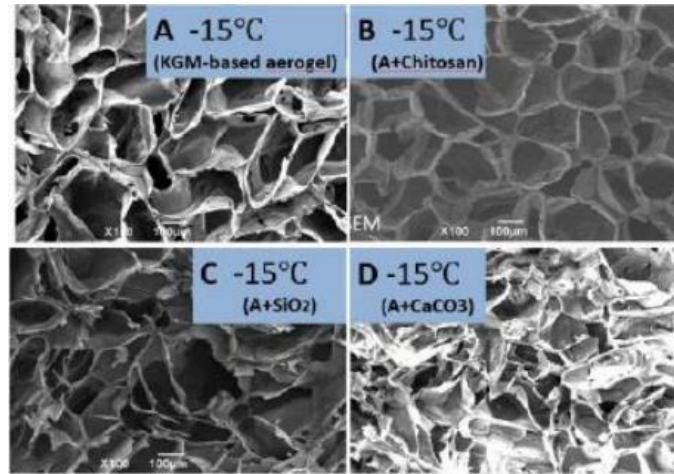


Figure 1 - Bio-aerogel materials

2.1.2 Phase change material (PCM)

It is a substance that released and absorbed sufficient energy at the phase transition between solid and liquid to provide useful heat and cooling. The PCM product S27, a salt hydrate, was chosen for the project, which changed phase between 18-36 °C. It was utilized as an independent PCM layer installed under the ceiling to absorb excess heat during summer daytime, decreasing maximum indoor temperature and increasing building thermal mass, thereby reducing space heating energy demand.



Figure 2 - PCM operation



Figure 3 - Schematic of PCM

2.1.3 PV vacuum window (PV-VG)

It is a daylight-management device with photovoltaic solar cells embedded in a window. It not only generates a small amount of electricity during the daytime but also decreases heat transfer through windows due to its low U-value. Thus, installing a PV vacuum window reduced the purchased electricity consumption and space heating demand of the demo buildings.

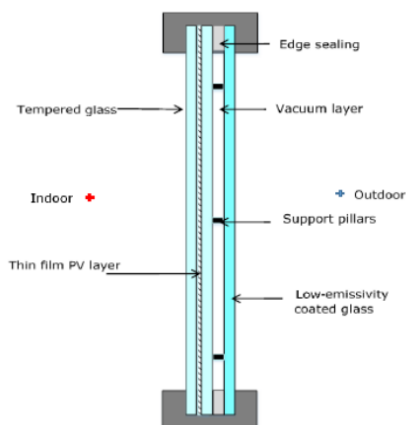


Figure 4 - Schematic of PV Vacuum glazing unit



Figure 5 - Photos of the PV Vacuum glazing systems

2.1.4 Window heat recovery (WHR)

It is an energy-efficient mechanical ventilation measure to solve the indoor air quality issue brought by the insulating breathable membrane. It was installed in windows and consisted of fans and heat pipes that transferred heat from exhaust air to supply air. The installation of WHR guaranteed that the indoor CO₂ concentration level was always lower than 1200 ppm in living spaces. However, it led to increased heating energy demand to heat the supply air in winter, as well as a minor rise in electricity consumption for fans. The larger concept for WHR was to install it with the PV-VG. As a unit, it would be basically self-powered.



Figure 6 - Photos and schematic of the Window Heat Recovery unit

2.1.5 Evaporative cooling (EVC)

It is a highly energy-efficient alternative where applicable. Dew point cooling can decrease the air temperature close to the dew point without increasing moisture, maximizing the cooling capability of dry air. However, most dew point cooling heat exchangers are complicated, costly, and not suitable for large airflow.



Figure 7 - Evaporative cooler - Installation at the UK demo building

2.1.6 Insulating breathable membrane (BM)

It is another thermal insulation material that improves building airtightness and decreases the building envelopes' thermal conductivity. When breathable membrane insulation was installed outside the external walls and roof, the space heating energy demand was effectively reduced due to decreased heat loss through the building envelopes and air infiltration. However, due to

the airtightness improvement in living spaces not equipped with mechanical ventilation systems, such as living rooms and bedrooms, the CO₂ concentration level could be higher.

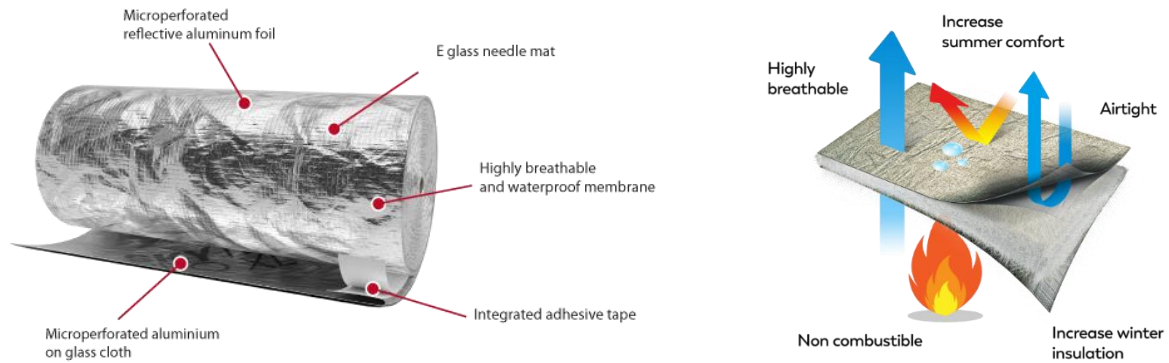


Figure 8 - SKYTECH Pro XL membrane

2.1.7 Solar-assisted heat pump (SAHP)

It is a heat pump whose evaporator is a solar thermal collector via a heat exchanger. The SAHP analysed in the study was an indirect expansion SAHP system, which covered space heating, DHW heating, or both in the case of the demo buildings. As it had a much higher COP for heat production than the existing heat pump systems, and the heating energy demand was significantly reduced after installation. The solar collector also operated more like an ambient heat exchanger than a solar thermal collector, transferring heat from ambient air through convection, allowing operation during times when solar radiation was not available. The system also included a thermal storage water tank, allowing the solar heat collected and upgraded by the heat pump to be stored and be used at night or extended periods of little sunshine. Thus, compared with the PV/T system, the performance of the SAHP was less dependent on local solar radiation.

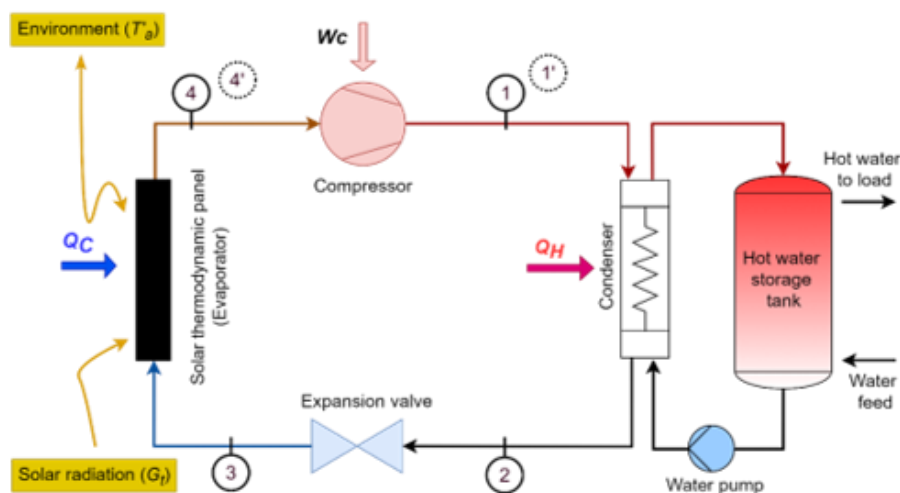


Figure 9 - Schematic of Solar Assisted Heat pump

2.1.8 Ground source heat pump (GSHP)

It is a system harnessed heat stored in the shallow ground for heating and cooling. Surface geothermal is more efficient and sustainable than conventional systems, as the ground serves as a constant source of thermal energy. A novel ground loop array allowed low-cost installation in small gardens typical in residential areas, unlike current systems that required large areas or costly deep boreholes.



Figure 10 - Construction works at the UK demo building for the installation of the Ground Source heat pump



Figure 11 - Installation of the Solar assisted heat pump and the Ground source heat pump at the UK demo building

2.1.9 Photovoltaic/thermal (PV/T)

This system converts solar radiation into usable thermal and electrical energy. The system consists of PV-T panels, a hot water tank, and a backup heater. The PV/T panel combines photovoltaic solar cells, which convert sunlight into electricity, with a solar thermal collector, which transfers the otherwise unused waste heat from the PV module to a heat transfer fluid. Therefore, the building's purchased electricity consumption and heating energy demand decreased after replacing the existing heating system with a PV/T system. The impact of the PV/T system on building energy usage is highly dependent on local solar radiation.

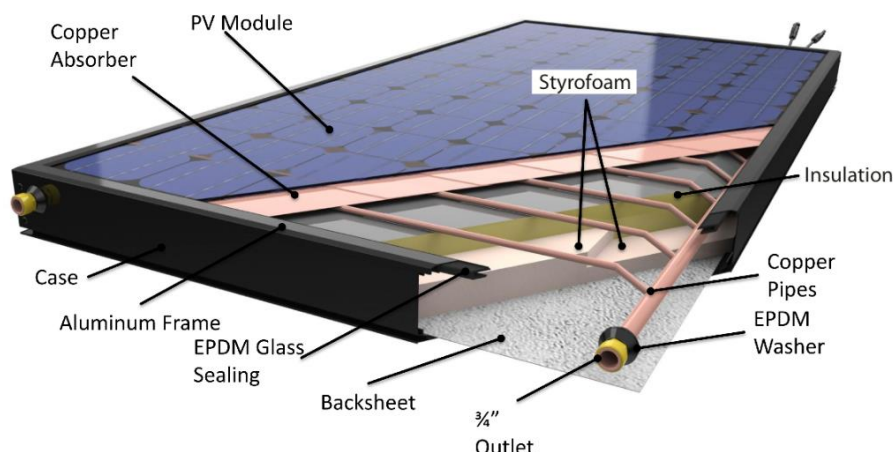


Figure 12 - Photovoltaic/thermal (PV/T) system

2.1.10 Daylight louvers (DL)

This device uses mirror optical louvers with a sophisticated reflection contour that unites two different optics in one louver. The first part of the louver towards the exterior is V-shaped and retro-reflects the direct sun back into the sky to avoid overheating, especially in summer. The adjacent part towards the interior forms a light shelf and guides diffuse light onto the interior ceiling for better daylight illumination. The advantage of this bifocal optics is an excellent view through the working position of the blinds. These blinds are integrated into the cavity of a compound window, making them maintenance-free and protected from dust and dirt.

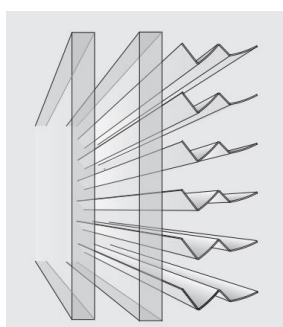


Figure 13 - Daylight louvers RETROLux 20 mm used in Spain and Finland

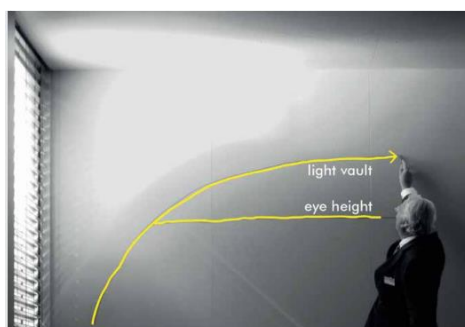


Figure 14 - Daylight louvers

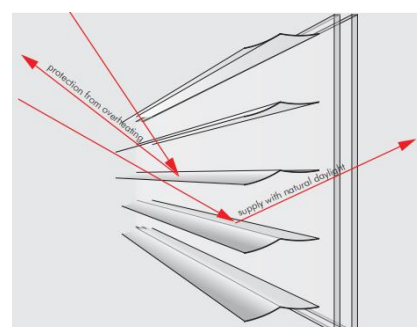


Figure 15 - Daylight louvers RETROLux 80 mm used in Finland

2.1.11 Prefabricated panel (PP)

This is like an External Thermal Insulation Composite System (ETICS). It uses a silica aerogel blanket between layers of extruded polystyrene (XPS), which can be replaced by polyurethane. This allows for a smaller wall thickness while providing better insulation characteristics. The installation process is as follows:

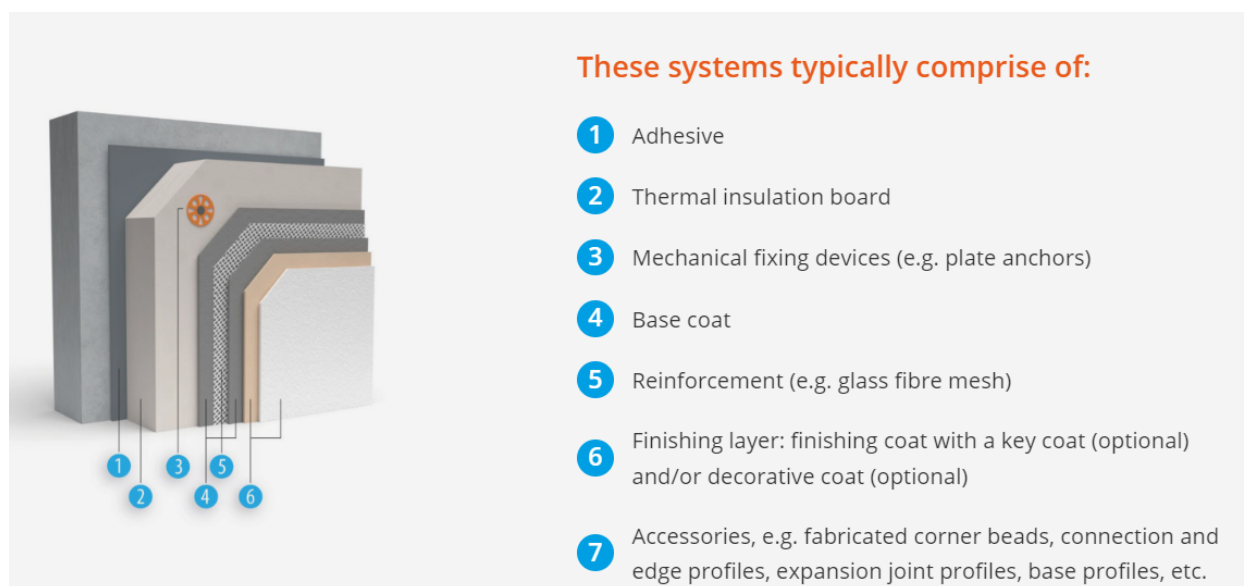


Figure 17 - Prefabricated composite system

[Source: European Association for ETICS]

2.1.12 Tool for planning and retrofitting of residential buildings (SURE³FIT)

It is a computer program designed to support the selection of optimal retrofitting solutions for various scenarios, thereby optimizing renovation and decision-making processes.

The SURE³FIT tool, built on Microsoft Excel®, comprises six modules distributed across four separate Excel files, as illustrated in the next figure.

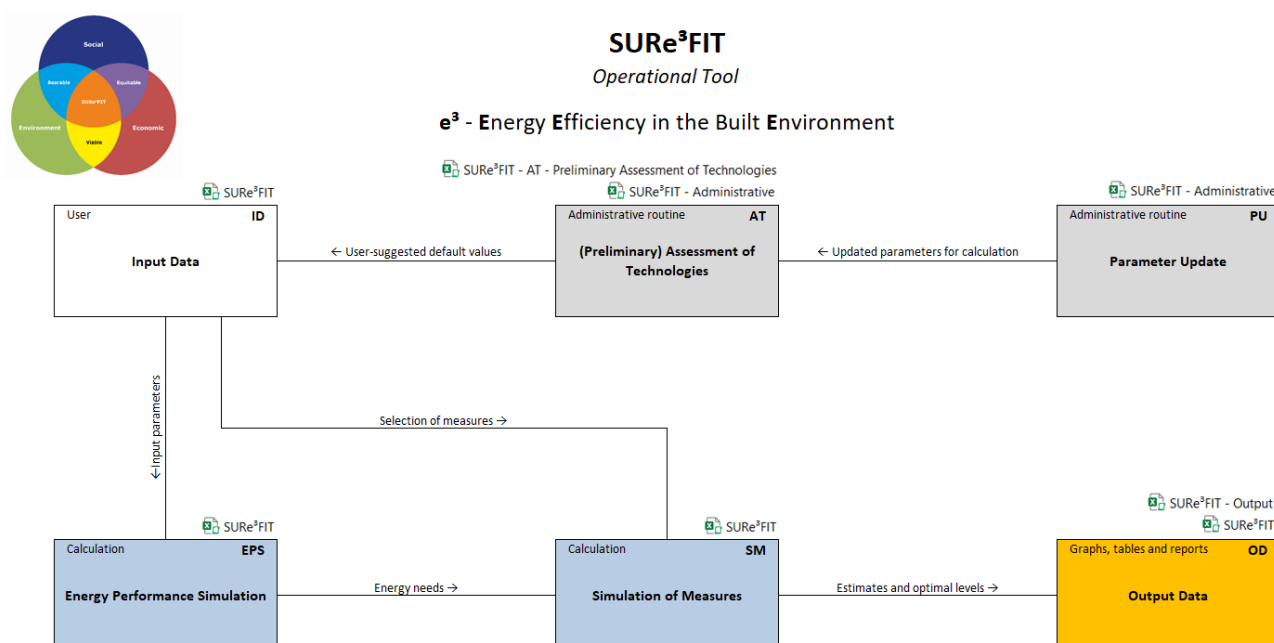


Figure 18 - SURE³FIT tool structure

This tool comes with a handbook that outlines the methodology and provides guidelines for conducting a building renovation process employing SUREFIT technologies. It aims to give to every end user of the operational tool (homeowner, contractor, etc.) the essential knowledge, the requirements, method and best practices for a guided implementation and decision making and needed for renovation and retrofitting.

2.2 Defined Key Exploitable Results

The first exploitation plan of the SUREFIT project was created at an early stage. Since then, there have been regular updates to the Key Exploitable Results (KER).

There have been two results/products that are no longer considered as KER: i) the Solar Thermal and PV system and ii) the Daylight louvers. This is because these technologies already existed prior to the SUREFIT project. However, these important technologies of the SUREFIT renovations were considered for the overall business plan. In addition, the *KER#2: Renovation concepts* has no longer AALTO as main owner and it is considered as a joined results of all partners with different weight of contribution and shares.

The updated status is presented in the following table:

Table 1 - Key Exploitable results updated

No	Key Exploitable result	Description	Main owner	Contributing partners
1	Optimum design, operation and control of renovation technologies	Use of commercial software to achieve optimum design, operation and control of technologies	UNOTT	AALTO : study of the optimal sizing of the technologies, energy consumption and indoor conditions
2	Renovation concepts	Parametric optimization to find the most cost-effective energy renovation measures.	AALTO	ISQ: development of models for the technologies, cost analysis for the optimization. UNOTT: energy performance of the technologies, UK retrofit standards, indoor thermal & lighting comfort evaluation. Minor contributions from the rest of the Consortium.
3	Next generation bio/silica-aerogel panel and prefabrication	Alternative aerogel insulation panels, including bio-aerogel, silica-aerogel and other	UNOTT	WINCO : measurements of conductivity of bio aerogel panels combined or laminated with breathable membranes, reflective and breathable membranes and aluminium foils.
4	PCM panels	The PCM is encapsulated in a watertight container, utilizes waste heat/cooling to store thermal energy for later use which can be used passively or actively.	PCM	UNOTT : simulation the indoor comfort and provide suggestions on the selection of the PCM melting points.
5	PV vacuum glazing windows	A unique solution to conventional glazing. It is a power generator and a thermal insulator and can convert up to 10% of the solar irradiation into electricity and reduce air conditioning energy consumption by up to 75%. Meanwhile, it can provide a much lower U-value for windows (1 W/m ² K or lower).	UNOTT	AALTO : study of the energy and CO ₂ emission savings potential.
6	Window heat recovery devices	Small heat recovery and air filtering units can be installed on window frame. The system uses heat normally lost from the room to bring in and preheat fresh air and save energy.	UNOTT	ISQ : development of models and simulations to design and size the technology.

7	Evaporative coolers	This novel dew point core takes the same structure of the evaporative cooling pad structure. It has both advantages of the evaporative cooling pad, and dew point cooling, but without the drawbacks described above. Two core techniques are included in the novel cores, namely special corrugated plates for dew point cooling, and special sealing technology for the sealing. The core could be easily to be enlarged to treat large airflow without increase in pressure drop.	UNOTT	ISQ: development of models and simulations to design and size the technology.
8	Membrane wrapping	-100% non-combustible roofing and rain screen reflective membranes with swelling clay as raw materials -Black Rainscreen membrane with A1 classification for facades. -Hygro-variable vapor barrier non-combustible membranes for indoor application	WINCO	-
9	Innovative multipurpose heat pumps	A solar-assisted heat pump combines solar air collector with heat pump technology. Such a heat pump including direct expansion type and will be used for retrofitting in domestic buildings to provide heating and/or cooling and hot water for buildings. Also, it can be driven into the ground using a handheld ground drill and act as a heat source/sink for a heat pump. In comparison to conventional ground coil heat exchangers. The TP provides significant advantages, notably low cost, and easy installation, especially in locations inaccessible to drilling machines. The TP can either be a solid rod or a “hybrid” tube containing a liquid such as propylene glycol/water. Heat transfer from the TP to the heat pump is achieved via a glycol circuit that includes a heat exchanger on the top of the TP.	UNOTT	ISQ: development of models and simulations to design and size the technology.
10	User friendly computer program for planning and retrofitting of residential buildings	User-friendly computer program for supporting the selection of optimal retrofitting and technologies for different scenarios, with the aim of enabling optimization of the renovation process and decision-making.	ISQ	-
11	Methodology and guidelines for retrofitting	A method of generating a planning of building retrofit for a portfolio of buildings.	ISQ	AALTO: definition by simulations of the optimal renovation packages. UNOTT: suggestion of the retrofit installation methods and to avoid the overheating issues, grid stability and operational guidance.

2.3 Demo sites in 5 different European climates

This project employed prefabricated, energy-efficient, and affordable technologies for the rapid renovation of domestic buildings. The success and effectiveness of the technologies were demonstrated through performance monitoring of several renovated buildings in various EU countries, representing different climate zones. The types of building retrofits included those constructed over a range of ages, representing different types of inefficient construction in terms of walls, roofs, glazing, and energy systems. The quality of renovation was assessed based on measurements of air tightness, the indoor environment, energy savings, and surveys of occupants' views.

2.3.1 Semi-Detached House in Nottingham City, UK



Figure 19 - Demo building UK

Renovation technologies:

- Bio-aerogel insulation panel
- PV vacuum glazing
- PV systems assisting heat pump compressor
- Evaporative coolers
- Window heat recovery
- Solar-assisted heat pump
- Ground source heat pump
- Smart control systems

Impacts based on modelling simulations:

- CO₂ reduction: 67%
- Primary energy reduction: 62%

2.3.2 Small Apartment Building in Peristeri, Greece



Figure 20 - Demo building Greece

Renovation technologies:

- PVT
- PV vacuum glazing
- Breathable membrane
- Prefabricated thermal insulation panels
- Smart control systems

Impacts based on modelling simulations:

- CO₂ reduction: 62%
- Primary energy reduction: 62%

2.3.3 Mill Houses in Valladolid, Spain



Figure 21 - Demo building Spain

Renovation technologies:

- PVT
- PV vacuum glazing
- Breathable membrane
- PCM panel
- Window heat recovery
- Daylight louvers
- Prefabricated thermal insulation panels
- Smart control systems

Impacts based on modelling simulations:

- CO₂ reduction: 46% - 61%*
- Primary energy reduction: 45% - 60%*

*Variations depending on the final scenario/final dimensioning

2.3.4 Social House in Mafra Municipality, Portugal



Figure 22 - Demo building Portugal

Renovation technologies:

- PV vacuum glazing
- PV systems assisting heat pump compressor
- Window heat recovery
- Solar-assisted heat pump providing both DHW and space heating
- Daylight louvers
- Smart control systems

Impacts based on modelling simulations:

- CO₂ reduction: 75% - 84%*
- Primary energy reduction: 74% - 83%*

*Variations depending on the addition of insulation

2.3.5 Prefabricated House, Finland



Figure 23 - Demo building Finland

Renovation technologies:

- Daylight louvers

2.4 Economic assessment results

The SUREFIT technologies were economically evaluated to prioritize the most cost-efficient solutions for each demonstration site, considering the specific characteristics of the buildings and the climate conditions of the respective countries. The economic evaluation was based on prices and costs provided by the manufacturers. A Life Cycle Cost approach and discounted Payback Period calculation were used to evaluate and prioritize the solutions.

To understand how the technologies examined in the SUREFIT project could be compared and compete with other conventional technologies already available in the market, market research was conducted to identify common alternatives comparable to the SUREFIT technologies. A methodology was then followed, based on the already conducted energy simulations and economic study, with some additional assumptions and energy simulations where needed. This methodology helped define specific market products (type of window, type of PV panel, type of heat pump, etc.), whose characteristics could be used for comparison with the SUREFIT products. The technologies or products selected in comparison with the SUREFIT ones were:

- EPS (Expanded Polystyrene) insulation installed as a conventional ETIC system.
- PVC (Polyvinyl Chloride) windows with triple glazing (to reach the U value of 0.6 W/m²K, which is the U value of the PV vacuum windows) in combination with simple monocrystalline PV panels, to simulate the PV vacuum windows.
- Simple monocrystalline PV modules with 20% efficiency in combination with flat plate selective solar collectors, to simulate the PVT system.
- The SAHP was compared with a common type of Air Water Heat Pump with a COP value of 3.62.

The Ground Source Heat Pump was a more complicated technology that required additional and more costly preparatory works, space around the building to install thermal pipes into the ground, and drilling machines and works that could not be represented by a simple air to water heat pump (AWHP). Ideally, this system would be compared with a conventional ground source heat pump, but this would require additional and complicated studies for each demo site. For these reasons, this technology was only installed in the UK demo. The baseline for comparison with conventional products was to achieve the same energy consumption results as those obtained when the corresponding SUREFIT technologies were applied to the buildings. The results for each country and each different building are indicated in the following diagrams.

2.4.1 British demo building

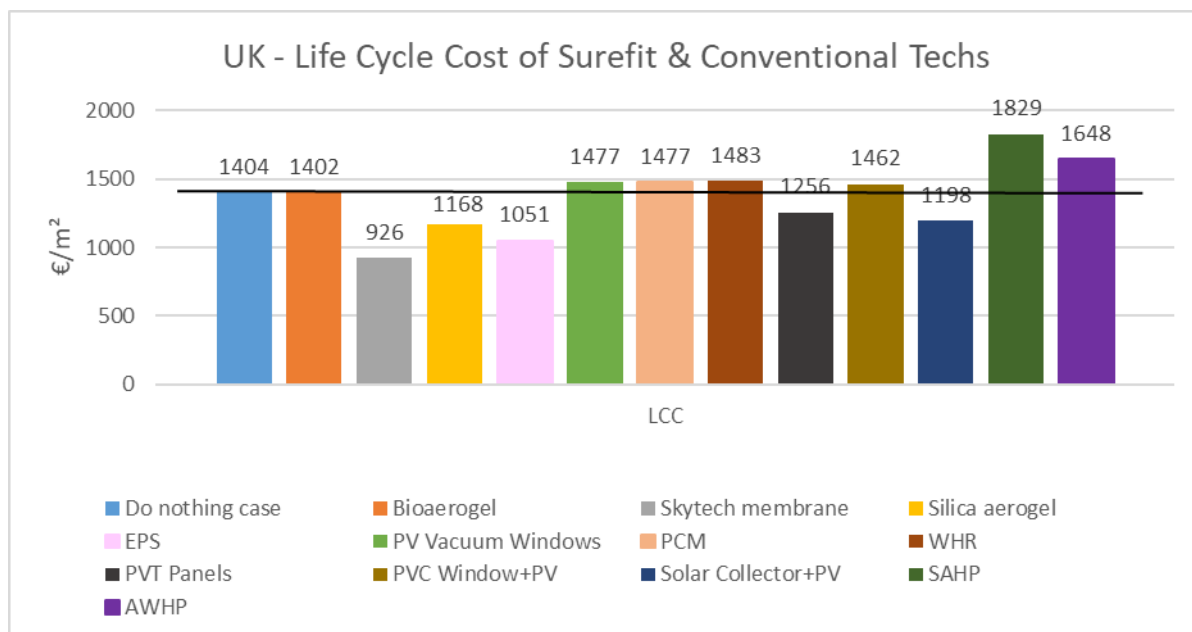


Figure 24 - Comparison of LCCs of the SUREFIT Technologies with conventional ones – UK

For the UK building, the most cost-effective solutions proved to be the Skytech membrane, silica aerogel, EPS, PVT panels, and the combination of solar collectors with PV modules. It was demonstrated that PVT is a technology capable of competing with other similar and common market technologies.

2.4.2 Greek demo building

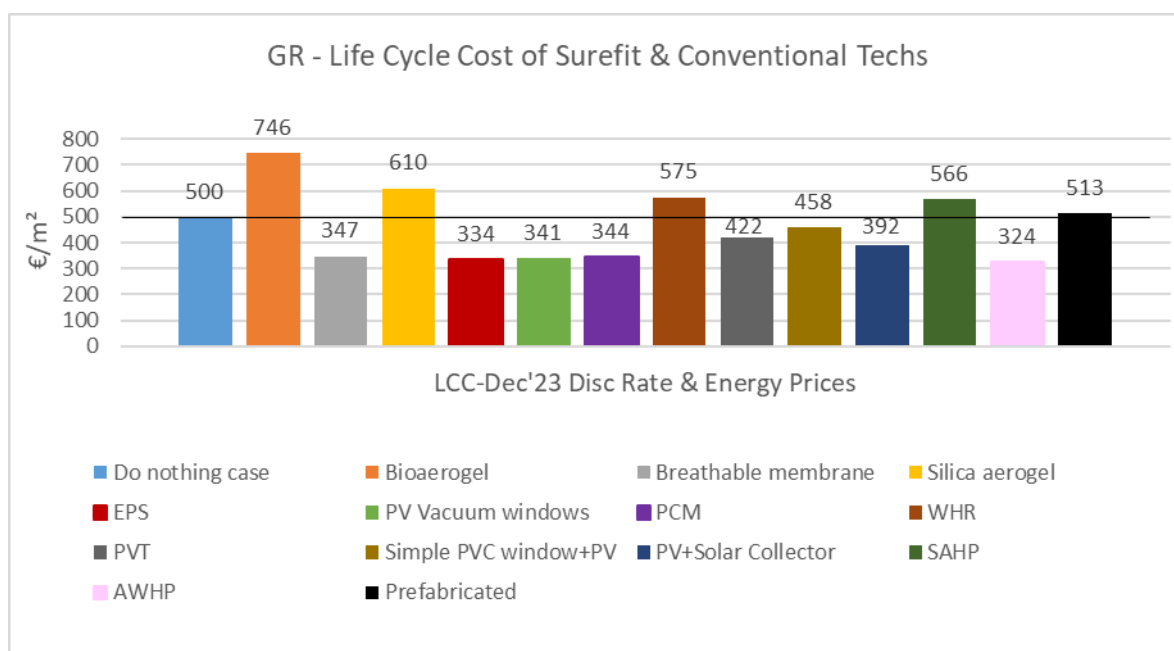


Figure 25 - Comparison of LCCs of the SUREFIT Technologies with conventional ones – Greece

For the Greek building, almost all the assessed technologies demonstrated good economic performance. The only non-cost-effective solutions were the bio aerogel and silica aerogel, which were quite expensive, and the WHR and SAHP, which increased electricity consumption. In Greece, electricity costs more than heating oil. It was indicated that PV vacuum windows were more cost-effective than the corresponding combination of simple triple-glazed PVC windows and PV panels.

2.4.3 Spanish demo building

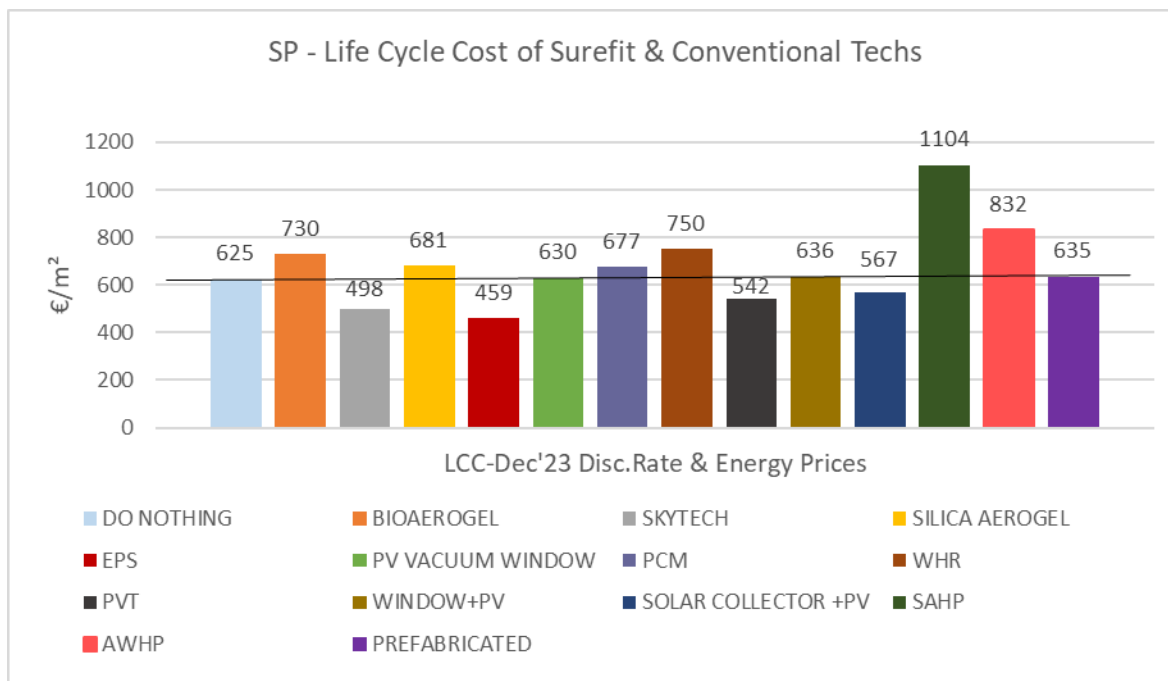


Figure 26 - Comparison of LCCs of the SUREFIT Technologies with conventional ones – Spain

For the Spanish building, Skytech, EPS, and prefabricated panels, along with PVT panels and the combination of solar collectors with common PVs, were the best solutions from an economic point of view.

2.4.4 Portuguese demo building

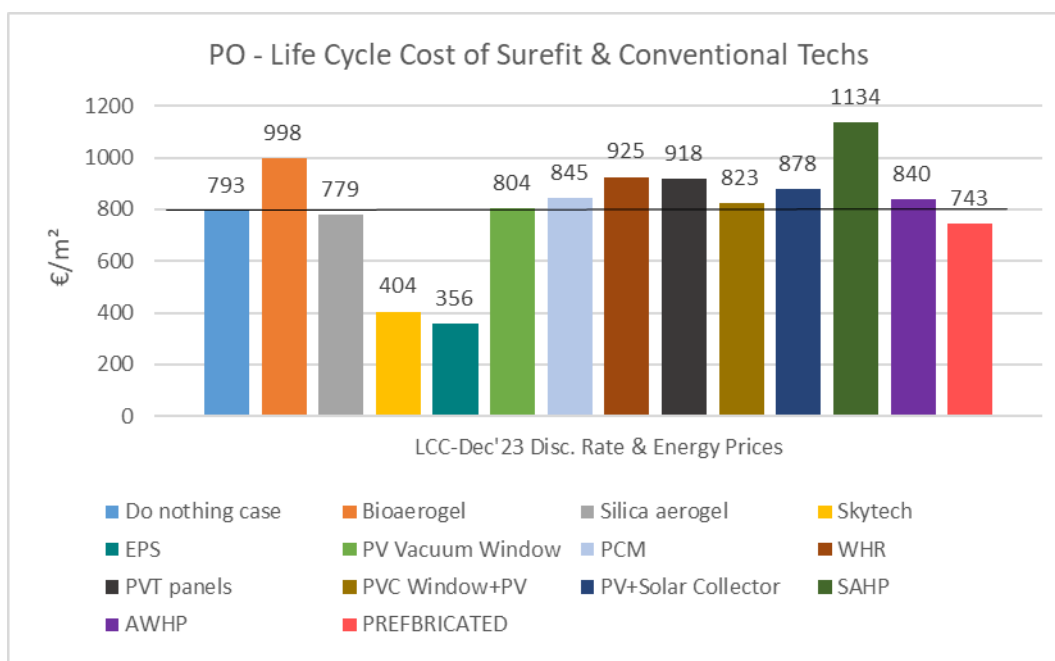


Figure 27 - Comparison of LCCs of the SUREFIT Technologies with conventional ones – Portugal

For the Portuguese demo site, the only cost-effective energy measures were the insulating measures: silica aerogel, Skytech membrane, EPS, and prefabricated panels. This indicated that for buildings like the demo one, the most important measure was to reduce heating and cooling needs, which could be achieved through thermal insulation. All other active solutions could not reduce energy needs but only energy consumption.

2.4.5 Conclusions from economic assessment results

The most important conclusions from the economic evaluation study were as follows:

- The insulation materials (except for bio-aerogel, which was quite expensive) had a better economic impact on all the demo sites.
- It was observed that an active system alone, such as a heat pump or a PV/PVT system, could not provide the required reduction in the energy consumption of a building if it was not accompanied by a reduction in the energy needs for heating and cooling.
- For Mediterranean countries, the reduction in cooling needs was crucial, especially during the last decade. In Greece, the cooling loads for most buildings were higher than the heating loads.
- Window heat recovery proved to be non-cost efficient for all the demos. The WHR system, a mechanical ventilation measure, led to increased energy consumption (therefore no energy savings) due to electricity consumption by fans. It could improve indoor air quality and be effective for humidity issues inside the house.
- The effect of light louvers could not be quantified and could not be demonstrated through the energy consumption of residential buildings, where the area of openings was limited. An improvement in the thermal and visual comfort of the occupants could be expected

from this technology. Additionally, the daylight louvers prevented overheating through the window glazing by reflecting at least 70% of the radiant energy transmitting through the glass. This was very effective in summer periods. Therefore, it might not be cost-effective in small houses due to the lack of active cooling. However, if there was active cooling, then a reduction in energy consumption for cooling would be achieved, especially in the case of larger windows. Besides preventing overheating buildings in summer, the technology also improved natural daylighting, reducing energy consumption for electric lighting.

- PCM panels acted mostly as a passive cooling method, and their effect could not be reflected in energy savings. This technology also depended on the roof structure of the building. As demonstrated in the Greek case, PCM seemed to have better energy results and thus better economic results when applied to a flat roof rather than a pitched roof.
- PV Vacuum Windows and the PVT system had similar results when compared with combinations of conventional solutions, indicating they could compete well in the market with other relevant solutions.
- Skytech and PVT panels had the best economic performance in almost all the buildings. This could be explained by the fact that these two products were already commercially available, and therefore, their prices were market prices and should be cost-efficient to compete with other similar market solutions.

As a general remark, many of the examined SUREFIT technologies seemed to be economically non-viable due to their high initial investment cost. Therefore, efforts should be made by the technology providers to minimize costs, especially for the laboratory technologies, to make them more competitive and affordable compared to similar conventional technologies.

As a final comment, it is worth mentioning that the methods followed for the economic study, as well as the results produced, were directly related to the quality and quantity of information provided by the manufacturers and technology providers of the SUREFIT Project. The results presented were affected not only by the characteristics and geometry of each building but also by the climate in each country and the prevailing inflation and energy prices, which also impacted on the products' purchase prices and investment costs.

2.5 Retrofitted buildings results

The obtained data for the field trials of the prototype were analysed to calculate the efficiency of the whole system, including the heating and cooling efficiencies, lighting efficacy, the possible energy savings for the building and CO₂ emission reduction. Next, summaries of the main results obtained are presented, in the opinion of those responsible for the demo buildings.

2.5.1 British demo building

Summary of the main results for the UK demo building:

- The retrofit led to a 62% reduction in total energy consumption before and after the retrofit work, primarily by shifting from gas heating to more efficient electric heating solutions such as heat pumps.

- With installation of the solar PV system and heat pumps, Natural gas consumption decreased by 86% (from 24,153 kWh to 3,359 kWh), largely due to the adoption of high-performance insulation and electrified heating. Electricity consumption increased by 79% (from 4,172 kWh to 7,484 kWh), indicating a transition toward electric heating systems, such as heat pumps. Final energy demand dropped from 28,324 kWh to 10,843 kWh, demonstrating the effectiveness of the retrofit measures.
- Insulation Improvement: October-December gas consumption declined from 3.787 kWh to 2,803 kWh, indicating that external wall insulation effectively 26% reduced heat loss and improved heating efficiency.
- Indoor air comfort: Temperature was maintained within a comfortable range (20-27°C), due to the effective insulation in winter which also allows no overheating in summer. Humidity was kept within 40-60%, avoiding issues related to dryness or excessive moisture.
- CO₂ Concentration Levels and Ventilation Efficiency: Post-retrofit CO₂ levels are lower and more stable. Before the retrofit, CO₂ concentrations were higher and fluctuated more, indicating Insufficient fresh air supply, leading to CO₂ buildup, especially at night, poor ventilation effectiveness, where stagnant air did not properly circulate or exchange, possible air leaks, causing uneven airflow patterns. After the retrofit, CO₂ concentrations decreased and stabilized, suggesting Improved ventilation system performance, possibly via ventilation with heat recovery (VHR) or demand-controlled ventilation (DCV), better air circulation, reducing CO₂ accumulation in occupied rooms, tighter building envelope reducing unplanned air infiltration, ensuring a more controlled ventilation strategy.

2.5.2 Greek demo building

Summary of main results for the Greek demo building:

- Tenant Satisfaction: The tenants were generally satisfied with the interventions. They noted significant improvements in thermal insulation due to the installation of thermal insulation panels from CJR and the replacement of old balcony doors and windows. The internal temperature was less affected by external conditions in both summer and winter, and the apartment cooled down and heated up much faster compared to the pre-renovation phase.
- Air Tightness: The air tightness of the apartment improved by 65% after the renovation, as confirmed by the blower door test conducted in December 2024.
- Acoustic Insulation: Tenants of the first-floor apartment reported improved acoustic insulation from outdoor noise, attributed to the new balcony doors and windows. They also experienced reduced noise from the ground floor, thanks to the ceiling insulation with the WINCO membrane.
- Temperature Normalization: Post-renovation, internal temperatures normalized to 17-25°C, compared to 22-29°C pre-renovation. This improvement was attributed to the

smart control systems installed by AMS, allowing tenants to remotely monitor and control the heating and cooling systems.

- **Air Quality:** There was no significant difference in air quality (CO₂, VOC, and PM levels) between the pre-renovation and post-renovation phases, due to the absence of ventilation systems in the apartment.
- **Energy Reduction:** Total primary energy consumption was reduced by 55% after the renovation. The project aimed for a 60% reduction, which was nearly achieved thanks to the SUREFIT interventions. This reduction was due to the external insulation on the north and south facades, ceiling insulation of the ground floor, replacement of old windows and balcony doors with more energy-efficient ones, and the PV thermal system, which improved electricity production and consumption, as well as more efficient heating with less oil and electricity.

2.5.3 Spanish demo building

Summary of main results for the Spanish demo building:

- The monitoring results indicate that House 40 has experienced the most stable post-renovation conditions, making it the primary subject of analysis. The other two houses, 42 and 44, presented challenges due to the malfunctioning of the PV system in House 42 and the ongoing refurbishment in House 44, which affected the consistency of the data.
- The installation of external insulation and improvements in the building envelope have contributed to reduced thermal losses, as confirmed by thermographic analysis. The comparison between pre-renovation and post-renovation thermal images demonstrates a clear decrease in heat leakage, particularly in previously exposed areas.
- The airtightness test shows an 18.58% improvement, but leakages in window frames and the perforations made for the installation of window heat recovery units have compromised the airtightness of the building envelope. These findings highlight the need for better execution of the installation process and potential design modifications in future projects.
- Indoor temperature conditions post-renovation have improved, particularly in winter, with a reduction in temperature fluctuations and lower heat loss. During summer, the implementation of Phase Change Materials (PCM) in some bedrooms contributed to thermal regulation, though data does not yet provide a definitive conclusion regarding its full effectiveness.
- The analysis of relative humidity levels indicates an increase in post-renovation, likely due to higher airtightness combined with issues in the ventilation system. The window heat recovery units have not functioned properly due to communication issues with the OnControl system, preventing adequate air exchange and contributing to the detected humidity increase.
- The assessment of CO₂ and VOC levels post-renovation suggests that no significant improvement has been achieved. The ventilation system's lack of proper integration and operational failures appear to be the main contributing factors, which need to be addressed in future interventions.

- Thermal flux measurements confirm the improved insulation performance, with a reduction in heat transfer across the building envelope. However, some thermal bridging effects remain, indicating that further refinement in insulation implementation may be necessary.
- The installation of photovoltaic panels has resulted in a notable reduction in grid electricity consumption. The energy production analysis confirms that House 40, with all panels facing east, produces less electricity than House 44, where three panels are east-facing and one is west-facing, highlighting the benefits of mixed orientations for better energy capture throughout the day.
- The total primary energy consumption of House 40 has been reduced by 59.81%, which is close to the project's initial energy efficiency target. The combination of insulation measures, heating system improvements, and renewable energy integration has played a key role in achieving this reduction.
- The overall results suggest that while the renovation has significantly improved energy efficiency and indoor comfort, certain technical and installation-related challenges have affected the expected performance. Future projects should focus on enhancing execution quality, ensuring proper ventilation system operation, and optimizing insulation strategies to maximize efficiency and indoor comfort.

2.5.4 Portuguese demo building

The renovation of the social housing in Carvoeira, Mafra, represents a critical step towards improving the energy efficiency and living conditions of the occupants. By incorporating innovative and sustainable technologies, this project not only enhances the building's performance but also contributes to broader municipal goals of sustainability and environmental responsibility. The collaborative effort between the Municipality of Mafra and technology providers highlights the importance of public-private partnerships in driving energy-efficient renovations across social housing sectors.

SAHP dataset currently available only covers the last two weeks instead of the full 12-month period initially planned. This discrepancy is due to a series of unforeseen technical and logistical challenges that delayed the full commissioning of the system. Below, we provide a comprehensive overview of the circumstances that led to this delay.

- **Installation and Technical Challenges**

One of the primary reasons for the delay was the need to secure a specialized technician for the installation of the SAHP system and the associated thermodynamic panels. Given the specific nature of this equipment, the availability of qualified professionals was limited, which resulted in an extended lead time before the installation could begin.

Furthermore, the complexity of the installation exceeded initial expectations. While the original design accounted for standard installation procedures, it became necessary to integrate additional components to meet operational requirements and client requests. In particular:

1. **Solenoid valves** had to be installed to allow the existing gas water heater to function as a backup system. This was an additional requirement that was not originally foreseen but was deemed necessary to ensure redundancy.

2. **An extra circulation pump** was required beyond what had been initially specified, as it became evident that the originally planned configuration would not provide the necessary performance.
3. **Electrical and Hydraulic** network was completely reconfigured to meet the requirements for the installation of the SAHP and radiators. This restructuring was essential to ensure compatibility and proper functioning of the system, which involved a detailed review of the existing infrastructure, as well as the implementation of new connections and technical adjustments.

Due to the complexity of this intervention, additional time was required to ensure that all modifications were carried out in accordance with the required standards, resulting in a delay in the installation. This process included coordination between different specialties, safety testing, and the adaptation of the network to optimise system performance.

These modifications required additional procurement, installation time, and system adjustments, all of which contributed to the overall delay.

- **Operational and User Comfort Adjustments**

After the system was physically installed, new challenges arose concerning its operation within the household environment. Specifically, it was found that the unit generated noise and vibrations that were not well tolerated by the resident. This necessitated additional mitigation measures to address comfort concerns. Adjustments to the system's operation were made incrementally, which further extended the commissioning timeline.

Additionally, in response to noise concerns, it was decided that the SAHP unit should be programmed to shut down during nighttime hours. Implementing this adjustment required careful configuration and testing to ensure that it did not compromise overall system performance. This process also contributed to delays in reaching a stable and reliable operational state.

- **Remote Access and Network-Related Delays**

The SAHP system is controlled remotely, which introduces an additional layer of complexity. During the commissioning process, it was discovered that an **update to the system's access ID** was required before the remote-control functionalities could be enabled. This update was dependent on external support from the system provider, which introduced unavoidable delays.

Once the system was ready to be fully connected, **network connectivity issues** arose, preventing remote access. Troubleshooting these issues took additional time, as coordination was required between multiple parties to diagnose and resolve the problem. Until a stable remote connection was established, certain operational parameters could not be fine-tuned, further delaying the collection of reliable performance data.

- **Timeline and Finalization**

Due to the accumulation of these challenges, the SAHP system was only fully operational by the **end of January**. From that point forward, it became possible to collect reliable performance data under normal operating conditions. As a result, the dataset currently available for analysis covers only the most recent period, rather than the full 12 months initially envisioned.

- **Conclusion**

While we fully acknowledge the importance of having a longer dataset, the delays encountered were unavoidable given the technical, logistical, and operational constraints outlined above. We remain fully committed to providing a robust and transparent analysis, leveraging the available data to extract meaningful insights.

2.5.5 Finish demo building

The SUREFIT louvers appear to be a promising technology for cooling indoor spaces during summer, based on measurements conducted at the Aalto offices. While their effect is relatively small and insufficient to resolve overheating issues on their own, they offer the advantage of zero operating costs for the owner, as the technology is passive. Achieving a similar result with conventional louvers would require them to be fully or partially closed, thereby obstructing the view outside. An additional benefit of the SUREFIT louvers is their ability to bring more natural light indoors during low-light conditions, such as Nordic winters, and to block glare in sunny weather without reducing the amount of light entering the space.

The performance analysis of the SUREFIT louvers installed at the Finnish demo building faced several challenges. Firstly, the two main physical quantities affected by the louvers - illumination and UV radiation - could not be measured over an extended period in the pilot apartment, as the measurement setup would have disrupted the daily lives of the occupants. Although indoor environmental conditions were measured, it was difficult to isolate the effect of the louvers from the results. Secondly, there was no apartment with conventional louvers for comparison within the building. An apartment with the same floor plan but no louvers was chosen as a reference for indoor condition measurements, but it was unoccupied for most of the time. Lastly, the measurements were frequently interrupted by both technical issues with the sensors and the behavior of the occupants.

User satisfaction would have been an excellent metric for evaluating the louvers, but unfortunately, the occupants of the pilot apartment were not interested in providing feedback despite several attempts. Consequently, the performance assessment relies almost entirely on tests conducted under controlled conditions at the Aalto offices. While these tests are reliable, they were relatively short (five days) and only represented conditions during sunny summer weather.

Future research should include a proper long-term comparison of the SUREFIT louvers and conventional ones in field conditions, with occupants who are committed to providing unbiased feedback. While physical measurements can offer some insight into the louvers' performance, their most significant impact is on user satisfaction, which cannot be assessed without feedback. Additionally, the optimal setting for the SUREFIT louvers should be considered, as the office tests in this project had them fully open, which was likely suboptimal due to their light-scattering properties.

3 Business model approach for SUREFIT outcomes

Based on a Business Model Canvas and the Key Exploitable Results, an overall business model approach for SUREFIT technologies and services has been designed. This approach aims to create a network of stakeholders that will facilitate the coordinated exploitation of results, while also accommodating the unique characteristics of the entities within the SUREFIT Consortium.

Thus, the beneficiaries were categorized into three groups based on their primary roles as contributors to this project: (1) service providers and/or non-profit entities, (2) industrial technology providers, and (3) non-industrial technology developers. These groups are detailed in Table 2.

Table 2 - Primary roles of the beneficiaries

Services providers and/or non-profit entities	Industrial technology providers	Non-industrial technology developers
AALTO	KOST	CJR
AMS	ONCONTROL	UNOTT
FSM	PCM	
ISQ	SOLIMPEKS	
	WINCO	

From this, a SWOT analysis was undertaken, as well as strategic concepts were defined and subsequently developed into a tactical plan, as follows.

3.1 SWOT analysis

A comprehensive planning process was initiated to assist the partners in overcoming challenges and identifying the best paths forward. To ensure the partners had a thorough understanding of all factors involved in making these business decisions, a SWOT analysis was conducted prior to the Consortium committing to any post-project actions or initiatives. Following a brainstorming session, this straightforward four-step process identified the subsequent factors:

3.1.1 Internal Factors

Strengths

The SUREFIT project boasts several key strengths that position it favourably within the market:

- **Market position and reputation:** The service providers and non-profit entities involved in the project are well-positioned in the market and are recognized as leaders in innovation within their respective countries.
- **Strong research and development:** Continuous investment in R&D ensures that the project stays at the forefront of technological advancements.

- **Attractive partnerships:** These institutions are highly attractive for partnerships due to their extensive research capabilities and well-maintained databases covering environmental, economic, and technical aspects.
- **Innovative solutions:** The project includes cutting-edge technologies and innovative solutions that can significantly improve energy efficiency in buildings.
- **Expertise in decision support tools:** ISQ has a long-standing history of developing decision support tools, supported by a highly qualified team capable of developing advanced platforms. Additionally, ISQ's Academy offers online training for specialist professionals, enhancing their expertise and reach.
- **Comprehensive training programs:** The availability of comprehensive training programs helps in building a skilled workforce capable of implementing energy-efficient technologies.

Weaknesses

On the other hand, the project faces several notable weaknesses:

- **Cost-effectiveness of technologies:** Many SUREFIT technologies are currently not cost-effective, posing a challenge for widespread adoption.
- **Investment requirements:** Significant investment is needed to scale these technologies, which can be a barrier for smaller entities or those with limited funding.
- **High initial costs:** The initial costs for implementing these energy-efficient technologies can be prohibitively high for some stakeholders.
- **Labour challenges:** There is a considerable difficulty in finding and training skilled labour to implement these advanced technologies.
- **Maintenance and upkeep:** Advanced technologies may require specialized maintenance, which can be costly and complex.
- **Limited-service integration:** Few services in the building sector can be associated with these technologies, limiting a more comprehensive market approach.
- **Market penetration:** Achieving significant market penetration can be challenging due to the niche nature of these technologies.

3.1.2 External Factors

Opportunities

These opportunities can significantly enhance energy efficiency in buildings, leading to cost savings, reduced environmental impact, and improved occupant comfort:

- **Addressing misinformation and awareness:** The primary barriers to investing in energy efficiency measures are misinformation and a lack of awareness.
- **Behavioural change programs:** Encouraging occupants to adopt energy-saving behaviours through education and incentives.
- **Public awareness campaigns:** Launching campaigns to educate the public about the benefits and methods of improving energy efficiency.
- **Energy certification challenges:** While energy certification is mandatory for all buildings, experts often struggle to recommend effective improvement measures.



- **Certification standards:** Certification ensures that buildings meet established minimum energy performance requirements.
- **Government incentives:** Taking advantage of government grants, tax credits, and rebates for energy-efficient upgrades.
- **Environmental funds awareness:** Most citizens are unaware of the possibility of using environmental funds.
- **Smart building technologies:** Implementing smart sensors and automation systems to optimize energy use in real-time.
- **Energy management systems:** Implementing comprehensive energy management systems to monitor and control energy use across multiple buildings (for example, mirror systems in the facades using the sun's angles of incidence for self-control).
- **Renewable energy integration:** Incorporating solar panels, surface geothermal, and other renewable energy sources to reduce reliance on non-renewable energy.
- **Green building materials:** Using sustainable and energy-efficient materials in construction and renovation projects.
- **Retrofitting existing buildings:** Upgrading older buildings with modern energy-efficient technologies and materials.
- **Expert and policymaker networks:** Establishing a network of experts and policymakers can meet market needs without incurring significant marketing costs.

Threats

The project faces several potential threats that could impact its success:

- **Economic fluctuations:** Economic downturns can reduce the availability of funding and investment for energy efficiency projects.
- **Regulatory changes:** Changes in government policies or regulations can impact the feasibility and attractiveness of energy efficiency initiatives.
- **Technological obsolescence:** Rapid technological advancements can render existing technologies obsolete, requiring continuous investment in upgrades.
- **Public perception and acceptance:** Resistance from building owners or occupants to adopt new technologies or practices can hinder implementation.
- **Market competition:** The emergence of new competitors offering similar or superior energy-efficient technologies can pose a threat.
- **Potential competition in the provision of services:** While no competing similar services are anticipated in the short to medium term, the possibility of new entrants cannot be ruled out.
- **Brand misuse:** There is a risk of inappropriate use of the partner entities' brands in the provision of these technologies and services.

4 Next steps: looking forward – scenarios for the future

SUREFIT technologies aimed to significantly reduce primary energy use, carbon emissions, renovation time, and costs. Achieving these ambitious goals presents a challenging path to market scalability. Therefore, a coordinated effort is essential to raise awareness about the potential future return on investment in SUREFIT's innovative technologies, such as cost-optimal energy conservation measures and renewable energy sources (RES) solutions, while meeting both environmental and economic criteria.

Given the market barriers and the potential size of the European market, the non-profit and non-industrial partners of the Consortium have adopted a conservative approach towards the institutional post-life model of the project. This cautious stance stems from the uncertainty surrounding the commercial exploitation of the patented solutions. Consequently, these partners have formed a mutual partnership to ensure the continuity and replication of the project at the European level.

Despite this conservative approach, the exercise demonstrates a sustainable basis for this model, enabling the generation of income sufficient to cover operational costs and enhance positive outcomes, such as consultancy services, while also allowing for a residual net income to finance future developments.

Combining the interests of entities with such diverse characteristics as those within the SUREFIT Consortium into a single results exploitation strategy proved to be a challenge. Despite this, to ensure continuous goals and active contributions beyond the project's lifetime, the SUREFIT Consortium presents five strategic concepts:

- Training for qualified experts in the use of the SURE³FIT tool

ISQ Academy offers online training for various stakeholders (suppliers of products and services, architects, engineers, constructors, and local authorities), focusing on preparing qualified experts for the use of the tool in a new generation of energy performance certificates (EPCs) context.

- Collaboration with local public energy authorities

Contribution to the establishment of one stop shops (OSS) with necessary infrastructure funded by municipalities.

- Exploitation through independent businesses

Marketing and commercialization of proprietary technologies by industrial partners through their established sales structures.

- Agreements with manufacturers for commercial exploitation

Exploitation of patented solutions developed by non-industrial partners through agreements with manufacturers outside the project.

- SUREFIT technologies dissemination network

Beyond the project's lifetime, maintaining the dissemination of its achievements through participation in strategic events across Europe.

The proposed SUREFIT tactical plan includes the following elements:

- Online training by ISQ Academy

ISQ Academy will offer online training focused on domestic buildings to qualified experts. Resources for this training will be obtained through a successor project, specifically within the scope of the LIFE-2024-CET-OSS call. The OSS will feature experts supported by an open-source application of the SURE³FIT tool, hosted on the ISQ webpage. This tool will assist stakeholders in deciding among various alternatives for domestic building retrofitting and renovation, including cost-optimal SUREFIT technologies. The program will analyse available technologies for specific functions (e.g., insulation, glazing, domestic hot water, heating and cooling, use of RES) or combinations thereof, providing an integrated economic and environmental analysis, as well as potential energy savings. This training should be sponsored by related entities or, preferably, subsidized by public funds.

- Expansion of SURE³FIT Tool by ISQ

ISQ will invest in a specific business plan to develop a new instance of the SURE³FIT tool, adding functionalities to extend the provision of services to large buildings. Resources for this expansion will also be sought through financing within the scope of a subsequent project.

- Commercialization by Industrial Partners

Industrial partners owning TRL 8-9 technologies and having established sales structures will commercialize these technologies, leveraging the experience, prestige, and networking gained through the SUREFIT project.

- Agreements for commercial exploitation by Non-Industrial Partners

Non-industrial partners will establish contacts with manufacturers to reach initial agreements for the commercial exploitation of patented solutions developed within the project.

- Dissemination of project achievements

All partners are responsible for maintaining the dissemination of project achievements to ensure that cost-optimal SUREFIT technologies are considered for specific building types and geo-clusters across Europe. This will be achieved through continuous involvement in meetings, workshops, and trade fairs promoted by clustering partners and other initiatives at local, national, and European levels.

Given the current stage, this overall business model of the combination of SUREFIT technologies provides a foundation for future developments. If successful, it will create projects that extend this approach beyond residential buildings.

Conclusions

SUREFIT technologies aim to significantly reduce primary energy use, carbon emissions, renovation time, and costs. Achieving these ambitious goals presents a challenging path to market scalability.

This project employed innovative modular/prefabricated technologies to rapidly renovate a selection of domestic buildings, reducing energy consumption not only from existing levels but also meeting the aspiration for near-zero energy buildings and personal comfort levels. The SUREFIT technologies were adapted and optimized for different climate conditions and cultural and comfort standards.

The 16-month evaluation period allowed the SUREFIT technologies to be fully assessed in actual European homes under daily life conditions. The results showed that SUREFIT technologies can easily reduce home energy consumption by more than 50%, with some combinations of the technologies offering greater than 62% reduction of energy consumption.

The passive technologies offered immediate benefits, where the new exterior insulation to include insulation vapour barrier and prefabricated insulated panels offered a way to rapidly insulate properties rapidly with minimal disruptions to the occupants. The permeable barrier was also shown to allow suitable air passage to maintain air tightness yet needed insulation. The use of aerogel insulation was shown to provide an effective method to insulate homes from the interior, where the minimal thickness required for the insulation did not significantly reduce the room size. The PCM panels were shown to moderate room temperatures, making rooms that were previously unusable in the hottest months comfortable to occupy, even in the hottest of Mediterranean summers. The PV vacuum glazing is a promising technology. They provided superior insulation and produce electrical power for the home.

The active technologies such as PV solar systems, ground source heat pump, solar assisted heat pump, and window heat recovery system were also evaluated in the SUREFIT program. The solar PV systems to include smart control systems greatly reduced grid electricity demand and the full implementation of smart controls allowed optimum use of the available solar power and home energy electricity consuming system operation. The ground source heat pump system proved an effective method to install ground source heat pump systems in smaller gardens, which are common in Europe. The solar assisted heat pump and thermal storage proved a very effective way to raise the heat pump's performance and effectively provide heat for the home throughout the night. The window heat recovery system, while effective, suffered from development issues such as noise which limited the user's acceptance and use of the systems.

Overall, the SUREFIT technologies were effective in reducing home energy consumption, user comfort, and improved air quality. The passive technologies will likely soon see pathways to common use in new homes and home renovations/upgrades. The active technologies proved effective yet most need additional development for full commercialization.

Finally, the SUREFIT business model aims to create a network of experts and policymakers, facilitating the exploitation of project results. It will particularly focus on raising awareness of the return on investment in SUREFIT's innovative technologies, which include energy conservation and cost-optimal measures for renewable energy sources, meeting both environmental and economic criteria.