CIP Entrepreneurship and Innovation Programme

Public Administration Procurement Innovation to Reach Ultimate Sustainability

D 2.2 – State-of-the art of innovative solutions

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Acronyms

BIPV - Building-Integrated Photovoltaic

EPS - Expanded Polystyrene

HVAC - Heating, Ventilation, and Air Conditioning

ILC - Intelligent Light Control system

LED - Light-Emitting Diode

MLI - Multi-Layer Insulation

RSL - Remote-Source Lighting system

PIR - Polyisocyanurate

PCM - Phase Change Materials

PV - Photovoltaic

TES - Thermal energy storage

VIG - Vacuum Insulated Glass

VIP - Vacuum Insulated Panel

XPS- Extruded Polystyrene

1 Introduction

Buildings represent 40% of the European Union's final energy consumption, and buildings owned by public bodies account for a considerable share of building stock and have a high visibility in public life. As the total public spending is equivalent to 19% of the EU gross domestic product, the public sector constitutes an important driver to stimulate the market transformation towards more efficient products, buildings and services.

Considering this fact, the overall objective of the cross-border PAPIRUS project is to promote, implement and validate Innovative Solutions for the achievement of sustainable construction through new Public Procurement process, focusing on Nearly Zero Energy Buildings.

There are a lot of innovative technologies in the market that could help to achieve this goal; however, this kind of solutions does not penetrate in the market for different reasons, economic, lack of knowledge, lack of critical mass, and lack of effective dissemination… among others.

The present deliverable summarises the search and analysis of different innovative solution previously identified in the de DOW of the project. The idea is to look for materials, technologies or systems that present a considerable grade of innovativeness and whose presence among designers is limited or even non-existent.

This document initially presents a general analysis of the energy performance in the building sector in order to understand the construction reality that encloses us. Throughout the document more data related to this matter is presented in the chosen subcategories, e.g. fenestration typologies or current glazing properties.

Secondly, there is an overview of potential solutions. Currently, there are several materials and systems that help us to reduce the energy consumption. Nevertheless, the new aims established by more demanding standards force us to consider innovative, more effective and less-known technologies. Therefore, in this overview of potential solutions five categories are suitably presented. Technologies will act reducing energy losses through building envelope, providing quality natural lighting, storing thermal energy, and using solutions that reduce the buildings construction phase related energy use.

Finally, the main bulk of this deliverable is formed by the chapters that encompass those five categories with their general description, subcategories and list of commercial products currently available in the European market.

2 Objectives

To achieve PAPIRUS objectives, the activities are structured in five WPs. These WPs cover five types of activities that are expected in the project: preparation, procurement, validation, dissemination and awareness, and management. *WP2 – Procurement of innovative solutions development* will focused on, as the title states, the procurement process.

The work included in this deliverable is developed in the frame of Task 2.2 State-of-the art of potentially solutions whose two objectives are to provide a deep review of the potentially available solutions as well as compiling the best practices in public procurement for addressing the common needs of innovative solutions detected in Task 2.1. Specifically, the work related to the first objective is expressed within the present document.

The task will identify, describe and categorize which innovative solutions are in use or near application. In order to reach a user friendly and clear structure, concise descriptions will answer the three main questions: WHAT (short description of the technology), WHY (description of advantages and in case disadvantages) and WHEN (conditions under which it works fine).

For this purpose five categories have been selected to compile the studied technologies and solutions. Each category can be divided in some subcategories. Within each subcategory, the innovativeness, identified constraints, technological situation and market size have been also analysed in order to facilitate the understanding of each material or technology. Within each category a list of commercial products is included. The physical and technical properties of each product are gathered in brochures that can be easily found in internet.

3 General analysis of energy performance of buildings

Energy performance of buildings is directly related with parameters, such as the construction year, building size and neighbour situation, type and age of the supply system and implemented energy saving measures.

Buildings are responsible for 40% of EU energy, related to greenhouse gas emissions. Energy efficient buildings represent the greatest opportunity for energy saving and greenhouse gas reduction.

Understanding energy consumption in buildings requires an insight into the energy levels consumed over the years and the mix of fuels used. Figure 1 shows the historical final energy consumption in buildings in EU27, Norway and Switzerland since the 1990s. The consumption is made up of two main trends: a 50% increase in electricity and gas use and a decrease in use of oil and solid fuels by 27% and 75%, respectively.

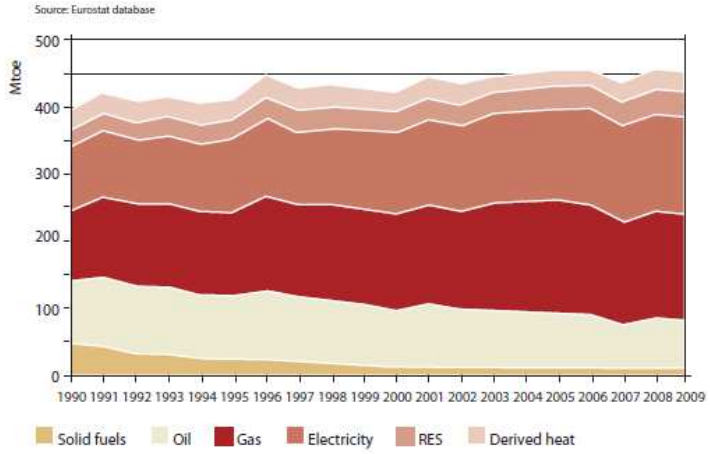

Figure 1: Historical final energy consumption in the building sector since 1990. *Source: Europe´s Buildings under the Microscope. Buildings Performance Institute Europe (BPIE). 2011*

Overall, the energy use in buildings is a rising trend with an increase from around 400 Mtoe to 450 Mtoe over the last 20 years. This is likely to continue if no action is taken to improve the performance of buildings.

The average specific CO2 emission in Europe is 54kgCO2/m2 where the national values of kgCO2 per floor space vary in the range from 5-120kgCO2/m2. The building performance is a key component in this. In addition, CO2 emissions are linked to the particular energy mix used in buildings in a given country. For example, the extent to which renewable energy is employed in the buildings, the use of district heating and co-generation, the sources of electricity production in each country affect the CO2 emissions related to buildings.

Residential buildings comprise the biggest segment of the EU's building stock and they are responsible for the majority of the sector's energy consumption. In 2009, European households were responsible for 68% of the total final energy use in buildings[1]Energy in households is mainly consumed by heating, cooling, hot water, cooking and appliances where the dominant energy end-use in homes is space heating.

[1] Marina Economidou. Europe´s Buildings under the Microscope. Buildings Performance Institute Europe (BPIE). 2011. ISBN: 9789491143014. www.bpie.eu/eu_buildings_under_microscope.html

The Energy Roadmap 2050 identifies the need for implementation of nearly zero energy buildings. In this sense EU has implemented different directives establishing the maximum level of energy consumptions allowed in buildings. Next table presents the latest European directives on energy efficiency:

EUROPEAN DIRECTIVES	ESTABLISHED CRITERIA
Directive 2002/91/CE	First European directive on the **energy efficiency of buildings**. It requires a methodology of calculation of energy efficiency in new buildings and existing ones in particular cases. It requires energy certification of new buildings to ensure energy efficiency.
Directive 2006/32/CE	It defines a new framework to boost **energy efficiency**. It sets a target of reducing energy consumption of 9 % by 2016.
Directive 2008/98/CE	Concerning waste, regulating also the **construction and demolition waste.** It establishes that the amount of waste destined for recovery, reuse and recycling should be increased to 70% of its weight.
Directive 2009/125/CE **Directive** ErP	Concerning the requirements of eco-design applicable to the (ErP) **energy-related products**. Its application is articulated through the EC label of products to be commercialized in Europe.
Directive 2009/98/CE	Related to the promotion of the use of **renewable energy**. It requires the definition of national plans. It requires implementing at national legislation level the percentage of renewable energies (in Spain up to 20 of the total energy produced in 2020).
Directive 2010/31/CE	**Energy Performance of Buildings Directive** (EPBD) Related the energy efficiency of buildings. Strengthen the minimum requirements for energy efficiency with respect to the directive 2002/91/CE. Increases the scope for buildings of less than 1000m2 of floorspace. Requires all buildings built from the 2020 will be almost zero energy consumption; those of public ownership by 2018.

Regulation (EU) 305/2011	Concerning the conditions of construction products. Applicable from 1 July 2013.
Directive 2012/27/UE	Energy Efficiency Directive (EED) Related to the energy efficiency in sectors of final consumption, industry, transport and buildings

Table 1: European directives on energy efficiency

The transposition of these directives is directed above all to buildings of new construction. In this sense each country has adopted different measures to meet this goal.

According to the **Energy Efficiency Directive (EED)** (2012/27/EU).) all Member States shall submit revised National Energy Efficiency Action Plans(EEAP) to the European Commission every third year to meet the European objectives. Norway, as a non-EU Member State, does not have a National Energy Efficiency Action Plan in place.

The table below points out each of the PAPIRUS partners National Energy Efficiency Strategy.

SPAIN[2]
• The 2nd Action plan for energy efficiency (2011-2020) have proposed urgent measures to achieve the proposed goals: *Energy Saving & Efficiency Activation Plan 2008-2011* and *Energy Saving & Efficiency Intensification Plan* • In the building sector savings concentrate on the tertiary sector, since final energy for heating, derived from the proposed measures on the building envelope • Therefore improvements on the envelope at 73%, and to the improvements in lighting energy efficiency at 29% are expected by 2020.
GERMANY
• Germany had reached practically their goals of reduction of CO2 emissions in a 21% by 2012. It expects to generate a minimum of 30% of its energy by 2020 • The National Sustainability Strategy, together with the Integrated Energy and Climate Programme defines measures of increase of energy efficiency, conservation of energy and the use of renewable. • Related to buildings, the objectives of the National Energy Efficiency Action Plan include a reduction of 20% on the heating requirements by 2020 • Other objective is to reduce the primary energy requirement in the building sector by 80% by 2050
NORWAY[3]
• Norway's current energy policy is that environmental objectives will determine the limits of energy production. • Since 2001, ENOVA (a government agency) implements energy efficiency measures in industry and households. • Legislative instruments support Energy efficiency for buildings and the residential

[2] 2nd Spanish Energy Efficiency Action Plan 2011-2020 Executive Summary. IDAE. www.idae.es

[3] 2011 survey of resource efficiency policies in EEA member and cooperating countries – NORWAY. European Environmental Agency.

sector. At the local level, public procurement is used to promote sustainable energy consumption. • Related to buildings, Energy guidance label "Enova recommends" promote the best products in terms of energy (e.g. windows and insulation)
ITALY[4]
• Based on the EEAP 2007 *National Guidelines for Certification of Building Energy Performance* were implemented in 2009. Measures to improve the energy efficiency are minimum required standards for new buildings and restructured buildings in the residential and tertiary sectors • 70% of the annual energy saving achieved by 2010, came from the residential sector. • The 2nd Energy Efficiency Action Plan 2011 encourages Green procurement for efficiency improvement • Financial and regulatory instruments have been adopted in the public sector (central and local administrative level) as an exemplary role, using renewable energy and improving efficiency and save energy in public buildings by implementing emblematic and replicated programmes • Goals for 2020 are: - level of renewable energy equal to 17% of gross final consumption (10% from renewable sources in the transport sector); - Reduction of 21% in emissions in the ETS sector; - Reduction of 13% in emissions in the non-ETS sector (compared with 2005).

Table 2: National Energy Efficiency Strategy

[4] Italian Energy Efficiency Action Plan. July 2011. PAE

4 Potential solutions overview

As energy efficiency is becoming a fundamental issue in the current context, especial efforts are being focused in those materials and technologies which contribute to improve the sustainability of buildings and urban districts. Thus, in the last ten years, several technologies have been developed in order to fulfil this aim. However, the new energy performance standards, more ambitious, are promoting the developing of new and more effective solutions.

Retrofitting solutions can be classified as active and passive. The meaning of these two categories changes from one author or publication to another. In the present document the active solutions are those that require the use of electricity to work properly. Those solutions that do not require any electrical contribution are catalogued as passive. The technologies and materials included in this deliverable are passive, apart from a couple of solutions that require a minimum contribution to perform its properties. Nevertheless, as they are very similar to the rest, the authors consider convenient their inclusion in the state-of-the art.

Among all the existing solution, PAPIRUS have focused on those materials and technologies that:

- Reduce the energy losses through the opaque envelope of both new and already erected buildings.
- Decrease solar gains in summer and energy losses in winter through windows and fenestrations.
- Technologies that provide good quality natural daylighting.
- Materials and elements that store thermal energy shifting heating and cooling peak loads.
- Reduce CO_2 emissions due to their industrialized manufacturing and easiness of implementation.

These five requirements will derive in five subcategories that include all the systems and solutions presented in this deliverable.

The envelope is one of the weakest points of buildings in terms of thermal energy losses. The energy consumption can be improved by means of increasing insulation levels. This is achieved by using insulation materials, a common practice in nowadays interventions. However, as has been stated, new performance standards target lower U values for the façade, therefore more material must be added, increasing the envelope thickness. Another possible alternative is the use of **super-insulated systems**; these materials would improve building energy performance without increasing considerably the envelope thickness.

Windows and fenestrations are also an inherent part of the envelope. Due to their nature, they represent an important source of heat losses in winter and undesired heat gains in summer. This fact influences directly in the use of HVAC systems both in winter and summer. Hence, the installation of **smart windows** would limit this issue. Low-e layers coatings or vacuum glazings are some of the materials and techniques that can be implemented in smart windows.

On the other hand, windows are also a valuable envelope component due to their contribution in terms of natural lighting. Daylighting is fundamental both for visual comfort and to perform visual tasks. Moreover, lighting has been considered as a primordial aim in terms of energy saving due to the real opportunities identified in this field. Remote source solar lighting systems, solar pipes, lighting by means of optical fibre,

shelves…etc. are some of the **technologies for the use of natural lighting** that are included in the present document.

One interesting consequence of the use of internal insulation materials, as new buildings become lighter, is the reduction of their thermal mass. This concept refers to the thermal energy that is stored in the massive materials used in the construction of buildings, such as concrete panels or ceramic elements. This fact contributes to higher fluctuations of the air temperature and, thus, higher HVAC demand in order to compensate this non-stored thermal energy. Phase change materials have the property of releasing/storing considerable amounts of energy while they are changing their state. The inclusion of materials which change their state within the buildings' operation temperature range in the manufacturing of construction elements such as panels, tiles or windows will improve the indoor comfort and reduce energy buildings consumption. These are **materials and solutions for thermal energy storage**.

Finally, the multiple uses of current buildings request easy-to-reconfigure spaces. Traditional materials, hollow bricks or plasterboards, have to be demolished if new internal distributions are required. The use of **industrialized internal partition with low carbon footprint** is gaining importance in nowadays rehabilitation projects. Construction and demolition residues are used in their manufacturing, reducing the use of raw materials and energy needs for the fabrication. Moreover, the possibility to configure easily the inner spaces, increase the value of the building and the user's perception.

These five categories are thoroughly presented in the following points. For each group a general description is exposed; all the different technologies included in the categories are presented with comments referred to their innovativeness, their identified constraints, and their technological situation and market size. A list of different products and brands is included.

5 Superinsulation

5.1 General description

Buildings' envelope is one of the main causes of thermal energy losses and contributes significantly to heating and cooling demands, especially in those buildings with poor insulation levels. Buildings can improve significantly their final consumption by increasing insulation levels with techniques or materials that reduce energy fluxes in the opaque façade are needed. These solutions should guarantee indoor hydrothermal comfort conditions and other construction requirements such us façade breathability, absence of dampness, ageing delay or fire safety among others.

This can be achieved by means of traditional insulation materials like mineral wools, expanded polystyrene (EPS) and extruded polystyrene (XPS), or by using very low conductivity materials which may require less volume to accomplish the same aims.

The formers are already well introduced in the rehabilitation market. They can be easily purchased due to the presence of several manufacturers and their affordable prices. Nevertheless, with new energy performance standards, and usual insulation's conductivity values within 0.03 and 0.04 W/mK, insulation layers of more than 20cm are usually needed to meet U target values. This often results in bulky constructions, difficult detailing and execution, and significant loss of space. Thus, in many cases, these thicknesses are not viable, because involves a non-acceptable reduction in net floor area of the building, roof eaves are not long enough to protect façade system or urban laws do not allow any façade re-growth. The charts below show how the use of different insulation types will increase the wall thickness to achieve different u-values.

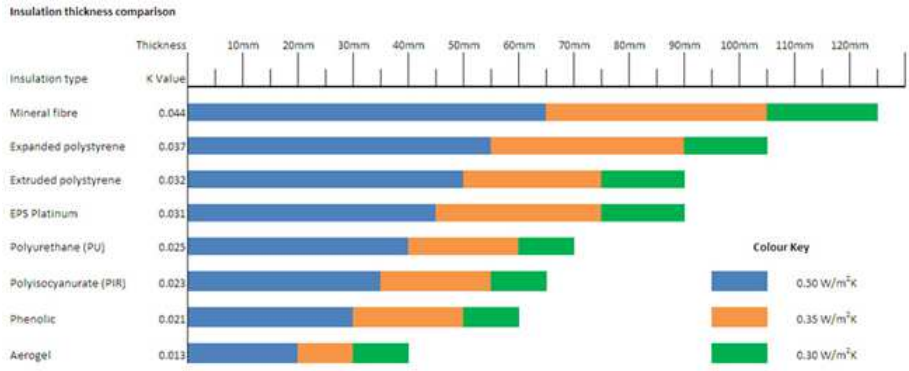

Figure 2: Insulation thickness comparison for different targeted U-values[5]

The latters, however, still have a long path to be considered as accessible materials. These, are generally, new or innovative materials that are not well-known by designers and engineers. Sometimes, they are manufactured by small companies with small presence in the market and low capacity to offer their products on a massive scale.

[5] A users' guide to choosing appropriate insulation. National Energy Action (NEA). Department of Energy & Climate Change, UK.

PAPIRUS have identified super-insulated system as potential solutions. The use of new insulation systems with reduced conductivities (0.005-0.020 W/mK) may help to achieve the targeted U values of the façade or façade's weak points such as thermal bridge and improve overall building energy performance with reduced thickness.

Despite their high prices, the increased EP standards for new and existing building approved recently in Europe (2010/31/EU) make these solutions cost effective in those areas where space represents a constrain, e.g. city centres, or land's prize is very high. For a target U value of 0.2W/m^{2}K, a traditional insulation solution requires 20cm thickness and costs 10€/m^2, while these new solutions would require 3cm and might cost between 67 and 150€/m^2, but save 0.17m^2 of floor plan per linear meter of façade.

Market solutions that may fall under this category are vacuum insulated panels, aerogels, fibre-reinforced aerogels blankets, polyurethane…

5.2 Identified subcategories

In this point, different identified subcategories have been developed. For each one of them, its innovativeness, identified constraints or drawbacks, and current technological/market situation will be analysed. Finally, a list of products will be displayed.

5.2.1 Aerogel

Description and innovativeness

Aerogel is a synthetic porous ultralight material derived from a gel, in which the liquid component of the gel has been replaced with a gas. The result is a solid with extremely low density and low thermal conductivity.

Most notably aerogels are known for their extreme low densities (which range from 0.0011 to 0.5 g·cm^{-3}). In fact, the lowest density solid materials that have ever been produced are all aerogels. A silica aerogel can be only three times heavier than air, and could be made *lighter* than air by evacuating the air out of its pores. Summarizing, typically aerogels are 95-99% air (or other type of gas) in volume, with the lowest-density aerogel ever produced being 99.98% air in volume[6].

Essentially an aerogel is the dry, low-density, porous, solid framework of a gel (the part of a gel that gives the gel its solid-like cohesiveness) isolated in-tact from the gel's liquid component (the part that makes up most of the volume of the gel). Aerogels are open-porous and have pores in the range of <1 to 100 nanometers (billionths of a meter) in diameter and usually less of 20 nm.

The term aerogel does not refer to a particular substance, but rather to geometry. They can be made of a wide variety of substances, including:

- Silica
- Most of the transition metal oxides (for example, iron oxide)
- Most of the lanthanide and actinide metal oxides (e.g. praseodymium oxide)
- Several main group metal oxides (e.g. tin oxide)

[6] What is aerogel? http://www.aerogel.org/

- Organic polymers (phenol-formaldehyde, polyacrylates, polystyrenes, polyurethanes, and epoxies)
- Biological polymers (gelatin, pectin, and agar agar)
- Semiconductor nanostructures (cadmium selenide quantum dots)
- Carbon
- Carbon nanotubes
- Metals (copper, gold)

Normally, this material is manufactured in the following formats: blankets, particles, blocks and panels. Moreover, it is possible to use aerogels in other insulation technologies such as aerogels reinforced with polymer coatings or Vacuum Insulated Panels.

By tailoring the production process, many of the properties of an aerogel can be adjusted. Bulk density is a good example of this, adjusted simply by making a more or less concentrated precursor gel. The thermal conductivity of an aerogel can be also be adjusted this way, since thermal conductivity is related to density (silica aerogel has an average thermal conductivity of 0.016 $W \cdot m^{-1} \cdot K^{-1}$)[7]. Typically, aerogels exhibit bulk densities ranging from 0.5 to 0.01 $g \cdot cm^{-3}$ and surface areas ranging from 100 to 1000 $m^2 \cdot g^{-1}$, depending of course on the composition of the aerogel and the density of the precursor gel used to make the aerogel. Other properties such as transparency, colour, mechanical strength, and susceptibility to water depend primarily on the composition of the aerogel. Besides, these properties can be enhanced if the air is extracted by means of vacuum technology. This fact will be analysed afterwards.

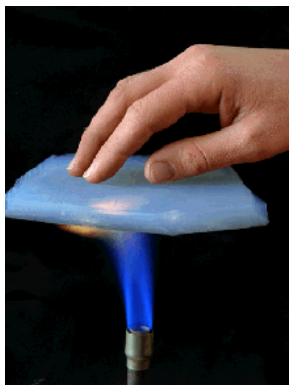

Figure 3: A demonstration of aerogel's insulating properties.

Aerogel's primary building-related application is a transparent or high-performance thermal insulator. Silica aerogel has a higher thermal resistance than the polyurethane foams which are widely used in refrigerators, boilers and building insulation. Since these foams are blown with ozone-depleting CFCs, aerogels could be an excellent CFC-free alternative. Aerogels in a partial vacuum are even better insulators, because removing most of the air from their pores eliminates half to two-thirds of the material's thermal conductivity (the portion due to gas conduction)[8]. Moreover, the thermal isolation capacity can be improved by adding carbon, to absorb infrared radiation in the material, another mechanism of heat transfer. Carbon-doped aerogels are perfect candidates for opaque insulators such as those used in refrigerators and pipes.

[7] What is aerogel? http://www.aerogel.org/

[8] Arlon Hunt. http://energy.lbl.gov/ecs/aerogels/

Identified constraints or drawbacks

Aerogels are expensive because of the time and energy required to produce them. Aerogel production involves two main steps: the preparation of a wet silica gel and the removal of the wet matrix by supercritical fluid drying, a process requiring high temperatures and pressures.

Silica-based aerogels are not known to be carcinogenic or toxic. However, they are mechanically irritant to the eyes, skin, respiratory tract, and digestive system. Small silica particles can potentially cause silicosis when inhaled. They also can induce dryness of the skin, eyes, and mucous membranes. Therefore, it is recommended that protective gear including respiratory protection, gloves and eye goggles be worn whenever handling aerogels.

Current technological/market situation

The major drivers for aerogel global market growth are energy efficiency awareness, exclusive thermal performance of aerogel as an insulating material, environmental friendly life cycle of any aerogel form. The complicated and patented manufacturing process results in high costs of production reflected in high market price. This can be seen as a restraint for the aerogel market.

Different research reports indicate that aerogels will find a small but profitable niche in thermal envelope applications, with a market size of approximately $230 million by year 2020.[9]

North America holds major market share in aerogel market and Europe is the second largest manufacturer. R&D initiatives by American companies and government have helped its manufacturers to get the first mover advantage (The NASA has even created a company to commercialize this material). North America market share is 57% in the global aerogel production, Europe has 42% of share and Asian companies are still in the first stage and account for only 1% of the total production (data of 2011).

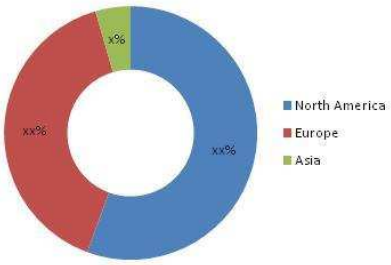

Figure 4: Global market share of aerogel production.

The aerogel market is segmented in three geographies namely North America, Europe and Asia. In North America, the United States is the largest manufacturer and market is led by Aspen Aerogel, American Aerogel and Cabot Corp. However in Europe, Germany dominates the market and Cabot is the largest manufacturer of aerogel in Europe. Small Chinese players and one prominent Malaysian company called MaeroTech leads the Asian markets.

[9] Nitin C. Shukla, Ali Fallahi and Jan Kosny. Aerogel for Thermal Insulation of Interior Wall Retrofits in Cold Climates. http://www.brikbase.org/sites/default/files/best3_shukla.pdf

The aerogel market by application is segmented in major five applications as building insulation, oil and gas, aerospace, automotive, industry and cryogenics.

Proposed materials, technologies or systems catalogue

- Pyrogel XT-E. *Aspen Aerogels*
- Spaceloft. Aspen Aerogels
- Cryogel. Aspen Aerogels
- Thermal Wrap. *Cabot*
- Themablock. *Thermablock*
- Spacetherm. *Proctor*
- Aerorock. *Rockwool*
- StoTherm In Aevero. *Sto*
- Blupor. Beck&Heun

5.2.2 Fibre-Reinforced Aerogel Blankets

Description and innovativeness

Although it is true that a typical silica aerogel could hold up to 2000 times its weight in applied force, this only holds if the force is gently and uniformly applied. Also, keep in mind that aerogels are also very light, and 2000 times the weight of an aerogel still might not be very much. Additionally, most aerogels as-produced are extremely brittle and friable (that is, they tend to fragment and pulverize). As a result, structural applications of aerogels were for a long time totally impractical.

There are four general ways to enhance the mechanical properties of aerogels:

- Liquid-phase crosslinking
- Vapour-phase crosslinking
- Fibre reinforcing
- Reduced bonding

Casting silica gel onto fibrous batting (a porous, flexible fibre mat) comes in producing reinforced aerogels, known as Fibre-Reinforced Aerogel Blankets. This flexible aerogel blankets show to be almost as insulating as the plain aerogel, except for unlike a typical silica aerogel, it could be rolled up and bent over and over.

Technically their materials are aerogel composites because they combine fibrous battings of inorganic or organic fibres with aerogels and, for high-temperature applications, carbon black as well. These meshes are made of polyimides, glass fibres, and many other materials.

Aerogel blankets have many potential applications, among them it is necessary to remark the use of blanket strips and aerogel wall wraps as home insulation in order to reduce heat loss through studs in the walls of a house.

Identified constraints or drawbacks

The constraints are the same as those identified in the previous point (5.2.1 Aerogel). There can be problems in the manufacturing process, but they are out of the scope of this study.

Current technological/market situation

Currently, the main aerogel manufacturers also produce this kind of material. In fact, both points, 5.2.1 Aerogel and 5.2.2. Fibre-Reinforced Aerogel Blankets, could be merged into a single one. However, bulk aerogel has also insulation possibilities so this differentiation is considered as convenient.

Proposed materials, technologies or systems catalogue

- Pyrogel XT-E. *Aspen Aerogels*
- Spaceloft. Aspen Aerogels
- Cryogel. Aspen Aerogels
- Thermal Wrap. *Cabot*
- Lumira. *Cabot*
- Themablock. *Thermablock*
- Spacetherm. *Proctor*
- Aerorock. *Rockwool*

5.2.3 Polyisocyanurate (PIR)

Description and innovativeness

Polyisocyanurate foam (polyiso foam) is a cellular, thermoset plastic formed when two basic liquid chemicals, isocyanurate and polyol, are combined in the presence of a catalyst that helps the molecules to rearrange and join, a blowing agent to create closed cells in the structure, flame retardants, and possibly other agents. If the “art” of the process is correct, the result is inert, non-nutritive, highly stable polyiso rigid foam that has the highest thermal insulating values of any conventional foam insulation commercially available today. Some authors inappropriately refer to polyiso as polyurethane (PUR), and they should not since polyiso’s physical properties are much better, including k-factor, flame/smoke performance, and dimensional stability.

Polyisocyanurate foam insulation (often referred to as PIR foam) has been used successfully as foundation, wall, and roof insulation in both commercial and residential environments. Polyisocyanurate foam insulation in these applications is shaped as an insulated panel, typically consisting of a polyisocyanurate board that forms a rigid foam core, laminated on one or two sides with foil, fibre-reinforced felt, or coated-glass facers.

Due to its excellent thermal insulating efficiency at service temperatures, polyiso foam has become the standard for low temperature insulation applications such as:

- unfaced polyisocyanurate sheet (cut from polyiso bunstock) for commercial refrigeration insulation and freezer insulation
- polyiso sheet insulation for transportation vessels and containers such as railcars
- polyiso foam shape (fabricated from polyisocyanurate foam bunstock) to serve mechanical insulation for pipe insulation, equipment insulation, and other commercial and industrial applications, including cryogenic insulation, chilled water insulation, and HVAC duct insulation

This material are usually presented in boards, attached to fibre reinforced composites, foams, bubble wraps or to reflective foils.

Identified constraints or drawbacks

Different Bulletins have reported problems associated with polyisocyanurate insulation. Such as:

- Facer sheet delamination
- Edge cavitation
- Cupping or bowing
- Shrinkage
- Crushing or powdering

These problems are easy to identify in field conditions. The most prominent concern has been facer-sheet delamination[10]This is the separation of the facer sheet (glass-fibre-reinforced cellulosic felt) from the foam core of the polyisocyanurate insulation board. Edge cavitation is exhibited by depressions at the edges of the insulation boards. Unevenly distributed foam or a bow shape to the board illustrates cupping or bowing of the insulation board. Shrinkage can be seen in relation to other insulation boards and crushing is indicated when the foam turns to a powdered substance.

Current technological/market situation

Polyiso commands an impressive 60% market share in new construction and it is incorporated in nearly 50% of retrofit projects as well in the USA. Polyiso's well-known performance characteristics include high thermal resistance values, superior fire and wind ratings, and universal compatibility with all major roofing systems.

Proposed materials, technologies or systems catalogue

- Thin-R. XtraTherm
- HP-NP Polyiso. *Carlisle*
- EcoTherm. *EcoTherm*
- CG5000, CW4000, EL3000… *Celotex*
- BallyTherm. *BallyTherm*
- Utherm. *Unilin*
- Unipur. *Unilin*
- Eurothane. *Recticel*
- KoolTherm K5. *Kingspan*
- PIR-FA-TE, PIR Flatboard. *Bauder*
- QuinTherm. *QuinnTherm*
- Thermazone. *Icopal*
- Enertherm. *IKO Group*

5.2.4 Ultra-fine multi-layer reflective insulations

Description and innovativeness

[10] Polyisocyanurate Insulation: Concerns Revisited. http://www.roofingcontractor.com/articles/polyisocyanurate-insulation-concerns-revisited

It is not clear the name to define this subcategory: multi-layer insulation, multi-foil insulation, multi-layer reflective, ultra-fine multi-layer… In the present document this material is named as *multi-layer reflective insulation* (MLI). MLIs are formed by a whole of reflective foils and separation layers. The former reflect the heat transmitted by radiation and they are made of reflective materials, like aluminium; while the latter give the shape and rigidness to the material. For this role foams or bubble wraps are usually used.

Multi-layer insulation was developed to be used on spacecraft, as many other materials or technologies, it is a product derived from the space industry. Nowadays, it is one of the main items of the spacecraft thermal design, primarily intended to reduce heat loss by thermal radiation. In its basic form, it does not appreciably insulate against other thermal losses such as heat conduction or convection. It is therefore commonly used on satellites and other applications in vacuum where conduction and convection are much less significant and radiation dominates. As an anecdote, it is possible to appreciate how multi-layer insulation gives many satellites and other space probes the appearance of being covered with gold or silver foils.

The use of MLIs in buildings rehabilitation is possible if the separation layers are formed by insolation materials like polyurethane foams, polyisocyanurate or aerogels. By means of this contribution heat loss by convection is also reduced, resulting in a thermal performance superior to many conventional insulation materials.

Figure 5: Reflectix multi-layer sheet composition. 1- Anticorrosive layer. 2- Aluminium layer. 3- Bubble wrap. 4- Polyurethane foam.

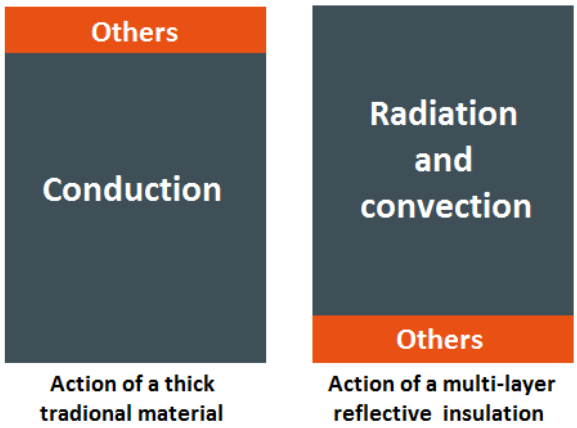

Figure 6: Different effects of conventional materials: EPS, XPS, mineral wool… (Ieft) and MLI (right).

One of the main characteristics of this material is its reduced thickness, no more than 30mm, despite the number of layers that compound this solution.

It can be used in the rehabilitation of already erected buildings, both commercial and residential, reducing the HVAC related costs. Its main contribution is done by several aluminium layers, which reflect the 95-97% of the infrared radiation to its source (solar radiation in summer and building heaters in winter). Moreover, each inner reflective layer is and additional barrier to the heat loss by radiation. In parallel, this system avoids the infiltration of cold air in winter or heat in summer. Finally, due to its nature, MLIs prevents the formation of condensations and mould.

MLIs are easy-to-apply and have low maintenance costs. Moreover, they are not affected by dampness, hinder the nesting of birds or the presence of rodents, and they are non-hazardous and can be recycled easily.

In order to improve their insulation capacity, the air present within MLIs can be extracted by vacuum, creating a different technology that will be shown later, the Vacuum Insulated Panels.

Identified constraints or drawbacks

Initially, this material needs open air space on each side to reach their full R-value; this fact can complicate its massive use.

Furthermore, MLI blankets are constructed with sewing technology. The layers are cut, stacked on top of each other, and sewn together at the edges. Seams and gaps in the insulation are responsible for most of the heat leakage through MLI blankets.

Current technological/market situation

This technology, due to its success in the space industry, is spreading in the Construction sector. Currently, the main manufacturers are located in the United Kingdom, but there are also enterprises in Germany, the Netherlands and Italy. The thin multi-foil insulation market represents 6% of the total UK insulation market and is growing approximately 30% per year.

Proposed materials, technologies or systems catalogue

- Triso. *Actis*
- Air Cell. *Kingspan*
- EcoTherm. *EcoTherm*
- SF19, SFTV, SFNC. *Superfoil*
- Reflectix. *Sealed Air*
- GlobalFoil. *Pack Air*
- Gen-X. Euroform
- SuperQuilt. *YBS*
- Silver TLX. Web Dynamics Ltd
- Gold TLX. Web Dynamics Ltd
- XtraLiner. XtraTherm

5.2.5 Vacuum insulated panels

Description and innovativeness

A vacuum insulated panel (VIP) is a form of thermal insulation consisting of a nearly gas-tight enclosure surrounding a rigid core, from which the air has been evacuated. It can be used in building construction to provide better insulation performance than conventional insulation materials.

VIPs consist of:

- Membrane walls, used to prevent air from entering into the panel.
- A panel of a rigid, highly-porous material, such as fumed silica, aerogel, perlite or glass fibre, to support the membrane walls against atmospheric pressure once the air is evacuated.
- Chemicals (known as getters) to collect gases leaked through the membrane or off gassed from the membrane materials. These are added to VIPs with glass-fibre or foam cores, because cores with bigger pore size require a higher vacuum (less than about 1mbar) during the planned service life.

Considering the three heat transfer modes through a volume (convection, conduction and radiation), this system practically eliminates convection, due to the absence of gas molecules able to transfer heat energy through the material; and considerably reduces conduction, as there are far fewer collisions between adjacent gas molecules or between gas molecules and atoms of the core material.

For this reason, VIPs achieve a much lower thermal conductivity than conventional insulation. Commercially-available VIPs achieve a thermal conductivity of 0.004 W/mK across the centre of the panel, or an overall value of 0.006-0.008 W/(mK) after allowing for thermal bridging (heat conduction across the panel edges) and the inevitable gradual loss of vacuum over time.

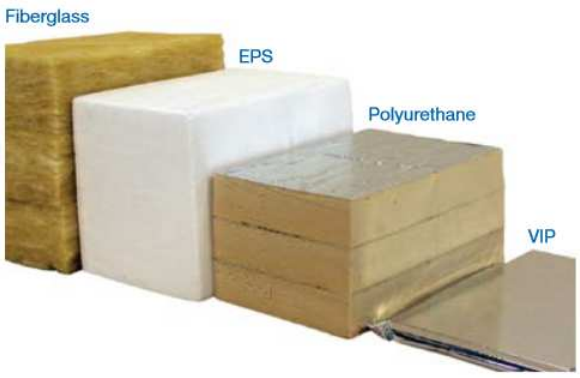

Figure 7: Traditional insulation materials' thickness versus Vacuum Insulated Panels. Extracted form Nanopore brochure.

Identified constraints or drawbacks

However, thermal resistance per unit price is much less than conventional materials. Aerogels are more difficult to manufacture than polyurethane foams or mineral wools, and strict quality control of manufacture of the membranes and sealing joins is important if a panel is to maintain its vacuum over a long period of time. Air will gradually enter the panel, and as the pressure of the panel normalizes with its surrounding air its R-value deteriorates. Conventional insulation does not depend on the evacuation of air for its thermal performance, and is therefore not susceptible to this form of deterioration.

In addition, VIP products cannot be cut to fit as with conventional insulation, as this would destroy the vacuum, and VIPs in non-standard sizes must be made to order, which also increases the cost. So far this high cost has generally kept VIPs out of traditional housing situations; however, their very low thermal conductivity makes them useful in situations where either strict insulation requirements or space constraints make traditional insulation impractical.

Current technological/market situation

In order to launch new construction materials on the market, not only must their functional efficiency and practicality be proved but various other parameters must be clarified as well. A substantial aspect is, for example, fire protection. Particularly with vulnerable vacuum insulation, durability and quality assurance also play an important role for its long-term success.

All VIPs with a national technical approval are classified as normally inflammable (Construction Material Class B2 to DIN 4102). In accordance with fire protection requirements, unprotected VIPs can only be installed in the external walls of the building envelope up to a height of seven metres. Laminating the elements with corresponding protection layers enables them to be used up to high-rise limit (Construction Material Class B1).

VIP elements age: permeating gases gradually but continually increase the thermal conductivity. Since the ability of the film and seams to act as a barrier against water vapour and gases depends on the humidity and temperature, the respective environmental conditions have an impact on the lifespan. Particularly higher temperatures facilitate the influx of gases. Tests conducted over several years in laboratories and in practical applications along with simulations and rapid test procedures indicate, however, that the thermal conductivity of VIPs used in the construction sector only increases marginally across several decades.

The thermal conductivity design values specified in the national technical approvals particularly take into account, among other things, the expected ageing for the first 25 years[11]. Depending on the product, these should lie between 0.007 and 0.010W/(mK), which means that a lower heat transfer is to be expected during the first 25 years of use. This may only increase above the design value after this period of time.

Once VIPs reach the end of their service life as a result of “losing the vacuum”, they could in principle be sorted and recycled. It is assumed that silica used over a longer period of time in the VIP core can still be reused as part of cores once it has been separated from the fibrous materials and opacifiers and has undergone a drying process. It is much more complicated the recycling of bonded elements, such as those laminated with other materials or composite structures.

For VIPs with cores made of silica and silicon carbide, comparative ecological assessments conducted in Switzerland on glass wool, expanded polystyrene and VIP insulation materials showed that the environmental impact of VIPs is comparable to expanded polystyrene. Although the high proportion of electrical process energy used for manufacturing fumed silica has a negative effect on the ecological balance, this is compensated for by the considerably improved thermal insulation during its application.

This type of product was mainly used until now for those applications where space was critical (e.g. fridges, refrigerators…). There are several VIPs manufactures, especially in USA. Nevertheless, this technology is not very implemented among the big insulation manufacturers.

[11] Insulation through vacuums. High performance thermal insulation for building envelopes and windows. BINE Themeninfo I. 2011. http://www.bine.info/fileadmin/content/Publikationen/Englische_Infos/themeninfo_I_2011_engl_internetx.pdf

Proposed materials, technologies or systems catalogue

- Optim R. *Kingspan*
- SlimVac. Microtherm
- Vacuum Insulation Panel. *Dow Corning*
- NanoPore VIP. *NanoPore*
- Vacupor. Porextherm
- U-Vacua. *Panasonic*
- va-Q-vip. *va-Q-tec*
- Kevothermal VIP. *Kevothermal*
- Iso Vac. Isoleika

6 Smart windows

6.1 General description

Windows provide natural light, fresh air and allow solar radiation to come into dwellings. However, they represent one of the major sources of heat losses in winter and unwanted heat gains in summer, contributing significantly to heating or cooling loads depending on the climate. For northern climates this heat losses through window can reach up to 60% in winter.
The use of better energy performance window system, will reduce buildings energy consumption and indoor comfort, and allows designing and building with higher glazed areas, increasing visual comfort of users, both at residential and tertiary level.
Glazing is a traditional building material. Because of its relevance on building energy consumption and indoor comfort issues, glazing have evolved dramatically since 1970, especially since market penetration of the low-e coatings.

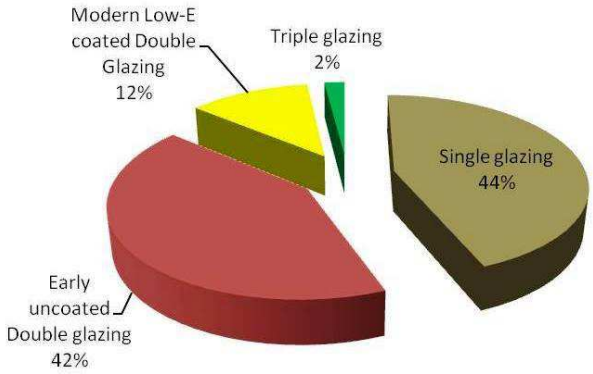

Figure 8: Glazing type distribution in the EU. Courtesy of **www.glassforeurope.com**.

Using advanced glazing solutions can significantly reduce the need for heating and cooling in buildings, thereby reducing energy consumption and associated CO_2 emissions. Different studies show that savings of more than 100 million tonnes of CO_2 could be achieved annually if all Europe's buildings were fitted with advanced energy saving glass.

The potential for improving the glazed facades and windows of Europe's building is enormous. A recent study on glazing type distribution in the EU building stock reveals that[12]:

- 44% of the windows in Europe's buildings are still single glazed.
- Less than 15% of Europe's windows contain energy-saving glass whereas these solutions have been available on the market for over 20 years.
- Early uncoated double glazing is still used in a vast number of buildings. Although their energy performance is limited compared to solutions available nowadays, they are too often regarded as efficient by poorly informed property owners.

[12] Energy saving glazing solutions and a low carbon economy. http://www.glassforeurope.com/en/issues/faq.php

In the USA the penetration of insulating glazing in the market is a fact when new sales are analysed.

Sector	1985	1990	2000	2005	2009
Residential	73%	86%	89%	92%	94%
Non-residential	63%	80%	84%	86%	89%

Table 3: Insulating Glass Historical Penetration, by Sector (Percent of New Sales). Includes double- and triple-pane sealed units.

Though glass panes production has always been related with large multinational industries (e.g. Saint Gobain, Guardian, Pilkington or AGC, among others), whole window manufacturing is local. The bet for this type of products may have the potential to revolutionize the way windows are produced, increasing the competitiveness of these types of SMEs within the European market.

The main properties of windows are the thermal transmittance, solar gain coefficient and visible transmittance. Windows with very low U values (0.6 W/m^2K) are usually characterized by low solar gains or solar factors (as low as 0.49), while window with a poorer U values of 1.2 W/m^2K, may have g-value or SHGC of 0.65. Thus, the type of the window will be conditioned by the outdoor temperature and solar irradiation availability in different seasons.

As main conclusion, high performance fenestrations are needed, in order to limit winter energy losses and reduce solar gains in summer. Besides, energy efficient windows are also designed to eliminate drafts. Drafty windows are one of the most common complaints when it comes to older, non-energy efficient windows. Cold glass creates uncomfortable drafts as air next to the window cools and drops to the floor. This creates a movement pattern that feels drafty and increases heat loss. Moreover, by protecting the home against leaks, drafts, and condensation, energy efficient windows help reduce peak heating and cooling loads. This allows homeowners to install smaller heating and cooling systems, which cost less.

There are many high performance fenestration products on the market today with regard to glazing. The majority are triple or double glazed products with low-e layer coatings and g-values, but other solutions such as vacuum glazing, aerogel based solutions, electrochromic dynamic solar control glazings, solar cell glazing, etc. are growing and producing new glazing with competitive U-values and solar gain factors.

6.2 Identified subcategories

In the present point, different identified subcategories have been developed. For each one, its innovativeness, identified constraints or drawbacks, and current technological/market situation will be analysed. Finally, a list of products will be displayed.

6.2.1 Low-E layer coatings

Description and innovativeness

Low-Emissivity (Low-E) glass is specially treated with a microscopically thin, transparent coating. The coating reflects heat back into the building, thereby reducing the heat loss through the window. It also reduces the heat transfer from the warm (inner) pane of glass to the cooler (outer) pane, thus further lowering the amount of heat that escapes from the window. These properties thus reduce the demand for energy in order to heat the building.

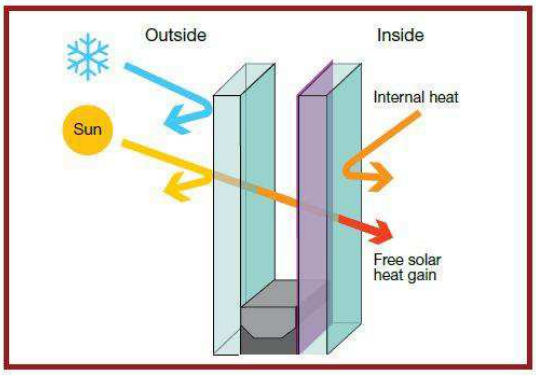

Figure 9: Brief summary of the effect of low-e glasses. Courtesy of **www.glassforeurope.com**.

In addition, the coating allows large amounts of free solar energy to enter the building, thereby heating it passively. Besides, it limits the amount of ultraviolet (UV) rays that come through the fenestration. UV rays can be harmful to the skin and can damage fabric by causing it to fade.

Double-glazing units now readily available in European markets are equipped with coating, such as Low-Emissivity coatings and/or Solar-control coatings. These coatings increase considerably the insulation performance of the double-glazed units but they also allow free solar-heat gains. Buildings equipped with early uncoated double glazed windows or glazed facades can therefore be upgraded with low-E glazing, which can be between 2.5 to 5 times more efficient.

Other innovations such as triple glazing products can offer additional improvements in the window's insulating properties while the use of low-iron glass can increase light transmittance and free solar-heat gain. Triple-glazing is even more efficient and helps achieve extra energy savings. The 'U value' of coated triple glazing units usually reaches 0.7, which is over 8 times more efficient than single glazing (U value of 5.8) and nearly 4 times more efficient than early basic double glazing; (the lower the U value, the better the insulation)[13].

In general terms, coated triple glazing is an essential component of 'nearly-zero energy buildings', which is to become the standard for all new buildings in the EU by 2020. High performance triple glazing has become the 'rule' in Scandinavian countries in recent years, and it is now enjoying rapid growth in Germany, where it now represents nearly 40% of the glass market[14].

Identified constraints or drawbacks

It is obvious that low-e glass is more expensive than regular glass. Windows that are designed to block out UV rays and infrared light are generally going to be more costly than traditional windows. This means a larger initial investment to deal with.

Another potential disadvantage is the formation of slight hazes in the window. This can make it more difficult to see clearly through the window.

[13] Energy saving glazing solutions and a low carbon economy. http://www.glassforeurope.com/en/issues/faq.php

[14] Energy saving glazing solutions and a low carbon economy. http://www.glassforeurope.com/en/issues/faq.php

In addition, since Low-E glass reflects more sunlight, it has been observed that the extra reflectivity combined with any concavity in the glass would effectively turn the glass into a concave mirror, concentrating sunlight onto other objects such as adjacent houses, cars, and increasing the island heat effect at certain points. This problem is exacerbated by dual pane windows filled with Argon gas.

Finally, low-E windows also block mobile telephone signals so it would make necessary to intensify the signal of the antenna system of the city/area, a measure that could be unpopular between the residents.

Current technological/market situation

Widely used in windows, doors and sunrooms for residential segment and in glazing for commercial segment, Low-e glass market accounts for approximately two-fifth of insulating glass market. The global production of low-e glass has been increasing on the back of growing demand from both the residential and commercial sectors. Residential sector accounts for a maximum share in low-E glass market which doors and windows hold almost equal shares.

Globally utilization rate of low-E glass is highest in the US followed by Europe. From 1990 to 2009, the window industry saw major shifts in glazing and framing materials. In the residential USA market, vinyl frames took a quarter of the market from wood frames, while double-pane sealed insulated glass units took market share from single-pane and unsealed double-pane windows. In the commercial market, tinted and reflective glazing, which together accounted for 47% of the market in 1995, accounted for only 13% in 2009. Low-e coatings increased their share from 17% to 54%, and clear glazing held on to about one-third of the market[15]

	Existing U.S Stock	**Vision Area of New Windows (Million Square Feet)**			
Type	Existing U.S Stock 2009 (% of buildings)	1995	2001	2005	2009
Single Pane	53%	56	57	56	48
Insulating Glass *(1)*	47%	294	415	407	389
Total	**100%**	**350**	**472**	**463**	**437**
Clear	65%	36%	49%	44%	33%
Tinted	28%	40%	24%	15%	10%
Reflective	7%	7%	8%	4%	3%
Low-e	*(2)*	17%	19%	37%	54%
Total	**100%**	**100%**	**100%**	**100%**	**100%**

(1) Includes double- and triple-pane sealed units and stock glazing with storm windows
(2) Included as part of the Tinted category

Table 4: Non-residential Window Stock and Sales, by Glass Type.

In Europe, low-e glass market has almost doubled in terms of volume over the period 2005-2009 due to compulsory energy efficiency regulations and standards. The utilization rate of low-E glass in 2009 was highest in Germany followed by the UK, France and Italy. Most of the Asian regions are untapped; therefore the Asian market provides tremendous growth opportunities. South Korea is the most developed market among the Asian countries in terms of consumption of low-E glass. Low-E glass manufacturers are

[15] Buildings energy data book. U.S. Department of Energy. Energy Efficiency & Renewable Energy. http://www.buildingsdatabook.eren.doe.gov/ChapterIntro5.aspx

fragmented with major players operating in this industry include Guardian Industries, Saint-Gobain and Asahi Group.

Triple glazing is also gaining importance in construction due to recent regulatory changes in many countries. As a result of its wider use in these countries, prices of triple glazing have decreased. Studies also show that significant additional energy savings can be achieved in the central parts of Europe with cold winters such as the UK, Poland, France, Benelux, etc. thanks to the installation of triple glazing on the most exposed orientations of buildings, in combination with Low-E double glazing on the south facades.

Proposed materials, technologies or systems catalogue

- ENERsign. Pazen Fenstertechnik
- Optitherm. *Pilkington*
- K-Glass. Pilkington
- Plus-Valor. *Finstral*
- Solar Protection Glass. *Guardian Sunguard*
- AislaGlass. Guardian Sunguard
- Sun-Lite. Solar Components Company
- SGG Xtreme. *Saint Gobain*
- SGG Climalit Plus. *Saint Gobain*
- SGG Planitherm. *Saint Gobain*
- Sunbalance. *Asahi Glass*
- VidurGlass. *Vidur*
- Termo Max Plus. *Minusdrei GmbH*
- Infrashade. Flachglas Markenkreis
- Infrareflect. Flachglas Markenkreis

6.2.2 Vacuum glazing

Description and innovativeness

Vacuum glazing or Vacuum Insulated Glass (VIG) consists of an outer pane of low-emissivity glass and an inner pane of clear float, with a vacuum rather than air or another gas in between. The result is excellent thermal performance from a unit only fractionally as thick as a standard one.

VIG samples have most of the air removed from the space between the panes, leaving a nearly-complete vacuum. However, at 10 Tn/m2, the atmospheric pressure on evacuated flat glazing is very high and requires the use of spacers in the cavity between the panes. They are hermetically sealed along their perimeter with solder glass, that is, a glass frit having a reduced melting point. Such a rigid glass seal will experience increasing stress with increasing temperature differential across the unit, so it is no recommended to use vacuum glazing when the temperature differential could be great.

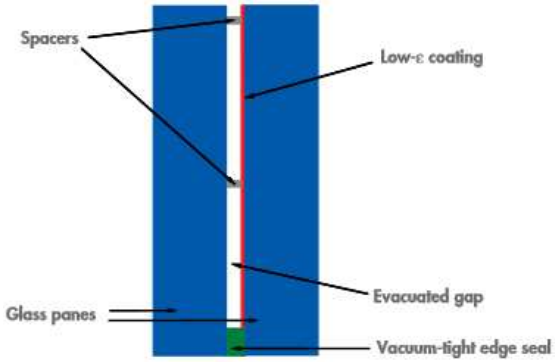

Figure 10: Composition of vacuum glazing.

Identified constraints or drawbacks

As there is a vacuum in the gap between panes, spacers must be provided at short intervals. Those spacers impair transparency. Also, it is still very expensive to make the glazing-edge seals. Regarding of high manufacturing cost, this type of glazing is not competitive at present.

Current technological/market situation

Standard insulating glass products on the market use argon. The excellent U_g values of triple-glazed insulating glass units produced with krypton are achieved at a very high cost since the inert gas is very cost-intensive. In order to achieve an U_g value of 0.5 W/m2 K, it is necessary to have a 12-14 mm cavity between the panes, which means that the overall system is correspondingly thick[16]. The considerable weight can cause problems in terms of the hinges, fittings and frames. In contrast, double- glazed vacuum glass achieves U_g values of 0.5 W/m^{2}K with less weight and a slim construction. Since only one low-E coating is used, this has a relatively high g value compared to triple-glazed insulating glass and therefore, in terms of the energy balance, it has greater solar heat gain.

Proposed materials, technologies or systems catalogue

- Spacia. Pilkington

6.2.3 Aerogel based solutions

Description and innovativeness

As mentioned previously, aerogels are synthetic low-density materials with especial physical properties. They are manufactured by removing the liquid from a gel under special drying conditions, bypassing the shrinkage and cracking experienced during ambient evaporation. This process creates a solid three-dimensional nanoporous structure containing 80-99% air. Due to their high porosity, aerogels exhibit very

[16] Kerstin Corradi. Vacuum glazing: When inert gas is replaced by a vacuum. BINE Projecktinfo 01/08. 2008. http://www.bine.info/fileadmin/content/Publikationen/Englische_Infos/projekt_0108_engl_internetx.pdf

low thermal conductivity, whilst being transparent to light and solar radiation. For these reasons, aerogels are often cited as a promising material for translucent insulation applications. They can be made from several materials, although the most common form is silica aerogel which can be produced as granules or in solid tiles.

In this document, aerogel has been presented as a suitable material for opaque envelope thermal retrofitting; transparent monolithic silica aerogel achieves U-values as low as 0.1 W/m^2K[17]. At this point it will be considered for the two following products.

- Glazing units and cladding systems containing granular aerogel.
- Translucent and opaque insulation boards, blankets and tensile roof membranes embedded with aerogel particles.

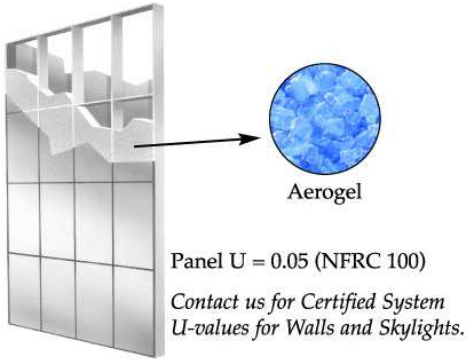

Figure 11: Sketch of a panel filled with granular aerogel. Courtesy of www.kallwall.com

The amount of radiative heat transfer through aerogel is dependent on the intensity and wavelength of the thermal radiation, the optical properties of the material, the size and shape of its pores and its overall thickness. At ambient temperature, the nanosized pores and particles provide effective attenuation of infrared thermal radiation due to high levels of absorption and reflection. Silica aerogels can be considered transparent insulation materials that effectively transmit solar light, but block thermal infrared radiation.

The material exhibits high translucency, often accompanied by a slight bluish haze. This can be attributed to 'Rayleigh scattering', an optical phenomenon that occurs when light scatters off particles smaller than the wavelength of light, where shorter wavelengths in the blue spectrum are most easily scattered.

Figure 12: Two applications of panels filled with granular aerogel (Xtralite and Lumira).

[17] Mark Dowson. Novel retrofit technologies incorporating silica aerogel for lower energy buildings. Doctoral thesis. Brunel University. 2012. http://bura.brunel.ac.uk/bitstream/2438/7075/3/FulltextThesis.pdf

Identified constraints or drawbacks

The research and development of aerogel into monolithic glazing is limited due to the high cost of production, long processing time and the difficulty of creating large uniform samples with complete transparency[18].

The major problem of aerogel, with respect to a general application in windows, is the optical quality of the vision through the material, the so-called image blur. This effect has been reduced during the last years, although not to the same level as the one of ordinary glass panes.

Current technological/market situation

The main target is to achieve "complete" transparent samples. Nowadays, this solution is still under development with big perspectives in the future. However, due to this situation this aerogel based solutions are not cost-competitive yet.

Proposed materials, technologies or systems catalogue

- Profilit. *Pilkington*
- Xtralite Nanogel. *Cabot*
- Lumira. Brett Martin
- Kalwall Lumira. *Kalwall*
- Wasco Skylights with Lumira Aerogel. *Wasco Skylights*
- Nano Insugel/Lumira. *Bristolite*

6.2.4 Electrochromic dynamic solar control glazing

Description and innovativeness

Electrochromic glazing is an electronically tintable and programmable glass that allows the highest possible dynamic control of solar heat and light through windows, while preserving the natural light and views to the outside that are essential to human health and performance.

Lighting, heating and cooling consume at least 65% of the energy used in a typical building, and effectively controlling solar heat gain has a major impact on all three factors. Electrochromic glazing works as a dynamic energy valve, to meter, regulate and make optimum use of solar energy coming into a building. Even many ambitious daylighting designs intended to bring natural light into spaces are undermined or even negated by occupants dealing with heat, glare and discomfort. Electrochromic glazing offers unique opportunities for creating a productive, sustainable space that responds dynamically to its occupants and to changing conditions, inside and outside, throughout the day, the year and the life of the building.

[18] Mark Dowson. Novel retrofit technologies incorporating silica aerogel for lower energy buildings. Doctoral thesis. Brunel University. 2012. http://bura.brunel.ac.uk/bitstream/2438/7075/3/FulltextThesis.pdf

Electrochromic devices change light transmission properties in response to voltage and thus allow control over the amount of light and heat passing through. In electrochromic windows, the material changes its opacity: it changes between a coloured, translucent state (usually blue) to a transparent state. A burst of electricity is required for changing its opacity, but once the change has been effected, no electricity is needed for maintaining the particular shade which has been reached. Darkening occurs from the edges, moving inward, and is a slow process, ranging from many seconds to several minutes depending on window size. Electrochromic glass provides visibility even in the darkened state and thus preserves visible contact with the outside environment. The selection of the chromatic state will depend of the outer conditions.

This technology presents the following features:

- Controllable
- Drives occupant comfort and energy efficiency
- Maintains view and connection to the outdoors
- Durable
- Energy Efficient
- Aligns with current insulation glass units installations

Figure 13: Four different states of the same electrochromic glazing (Extracted form View Dynamic Glass brochure).

Identified constraints or drawbacks

When a low-voltage electrical charge is passed across a microscopically-thin coating on the glass surface, it activates an electrochromic layer which changes colour from clear to dark. The electric current can be activated manually or by sensors which react to light intensity. Hence, electrochromic glazing, unlike the rest of the presented technologies in this point, is not a passive technology. It requires electric power to achieve the different states and this has to be taken into account. As has been pointed, this contribution is only necessary to change the light transmission of the fenestration, so the electric expenses cannot be considered as an important constraint. However, as all electric installation, it is susceptible to fail and it might require maintenance.

Other drawbacks are[19]:

- Electrochromic glass responds slowly.
- Limited cycle lifetime.
- The "iris effect" in which colour change begins at the outer edges of the window and trickles its way toward the centre.
- Costs relatively high.
- Needs over voltage and over voltage protection.

Current technological/market situation

The dynamic glass market will grow substantially over the next several years, with electrochromic glass revenues hitting the billion-dollar mark in 2017[20]. Cost, of course, is the main challenge that all dynamic glass manufacturers face. Yet, prices are coming down, materials are getting better, and companies are raising more money, opening up opportunities for greater commercialization of electrochromic technologies.

In the following table it is possible to see the situation of this market niche in 2011 and the previsions up to 2018.

	2011	2012	2013	2014	2015	2016	2017	2018
Electrochromic window glass volume (million sqm)	0,19	0,35	0,61	0,96	1,49	2,30	3,54	5,48
Average cost per square meter ($)	700	609	529	461	401	348	303	264
Electrochromic glass revenues ($ Million)	136	213	321	443	597	801	1075	1446

Table 4: Electrochromic market niche previsions, 2012-2018[20].

Proposed materials, technologies or systems catalogue

- Infraselect. Flachglas Markenkreis
- SageGlass. Sage Electrochromics
- View Dynamic Glass. *Solar innovations*

[19]] http://www.nbmcw.com/articles/glass/1432-glass-technologies-for-buildings.html

[20] Next-Generation Smart Windows: Materials and Markets. 2011. www.nanomarkets.net

6.2.5 Solar cell glazing

Description and innovativeness

Solar cell glazing generates clean electricity on see-through glass windows, by making use of the energy of natural sunlight and artificial sources such as fluorescent and LED lighting typically installed in offices, schools, and commercial buildings. Hence, the extensive glazing surface in tertiary building could be used for this purpose. Solar cell glazing is considered as a Building-Integrated Photovoltaic (BIPV), a material that is used to replace conventional building materials in parts of the building envelope such as the roof, skylights, or façades.

These kind of materials are being progressively incorporated into the construction of new buildings (and also in already existing buildings) as a principal or ancillary source of electrical power. The advantage of integrated photovoltaic (PV) over more common non-integrated systems is that the initial cost can be offset by reducing the amount spent on building materials and labor that would normally be used to construct the part of the building that the BIPV modules replace. These advantages make BIPV one of the fastest growing segments of the photovoltaic industry.

Figure 14: Two examples of the use of solar cell glazing. Extracted from VidurSolar Brochure.

Solar cell glazing must be designed to replace conventional constructive elements, assuming their functions in terms of solar protection, security and thermal insulation.

This technology can be purchased as already manufactured modules or as films that can be stuck into existing glazes.

Identified constraints or drawbacks

The main constraint at the moment is the “opacity” of the photovoltaic cells. This can limit their use in small surfaces. The development of transparent or more translucent cells will overcome this drawback.

On the other hand, the use of solar cells requires a considerable maintenance that is not necessary in regular glaze. The electric system also requires an important maintenance, thus, this additional cost should be considered during the project period.

Finally, it is possible that the solar cells could break during the life of the glaze. It is convenient to consider this fact in the manufacturing of these elements.

Current technological/market situation

Modules with different transparency rates and/or different technologies are available on the market. Most common they consist of transparent crystalline cells, very often are also modules with transparent back side and with standard crystalline cells. Another interesting solution is presented by thin film transparent amorphous modules. Transparent modules could also be used as window glazing in usual windows, sunspaces or they can be integrated into roofs. Quite often they are also a part of shading devices, whether movable or not. These systems are also known as shadow-voltaic systems.

Transparent modules can be also part of energy efficient glazing, where they are used instead of usual glass. With coloured back side interesting architectural visual effects can be obtained. Such solutions are often used in old architectural protected heritage buildings[21], for example heritage building renovation with photovoltaic roof tiles. Very attractive are also thin film modules because they offer some tailor made solutions - different shapes or patterns within modules are possible.

Figure 15: Solar panels for windows in various colours.

Solar cell glazing – replacing window glass with a semi-transparent photovoltaic panel – is a fast-growing industrial sector. As BIPV becomes a more usable and popular product, sub-markets such as glass will also experience growth. The BIPV glass market currently has revenues of €1.12 billion for 2012 and this should rise to €4.8 billion by 2016[22].

BIPV glass systems are expected to evolve from relatively crude systems with low levels of transparency to true integrations of PV and window glass. At the moment, the industry standard is to create BIPV glass panels by glazing together small opaque solar panels and window glass in a kind of mosaic. This only allows for uncovered areas of glass to remain truly transparent. Today's BIPV glass thus provides transparency that is well below 50 percent.

[21] Integration of photovoltaic panels. http://www.new4old.eu/guidelines/C7_Part1_H6.html

[22] Nicholas Stone. BIPV glass markets to rise rapidly. 2012. http://www.pv-magazine.com/opinion-analysis/publishers-comment/blogdetails/beitrag/bipv-glass-markets-to-rise-rapidly_100005859/

Proposed materials, technologies or systems catalogue

- VidurSolar. *Vidur*
- Transparent Sunways Solar Cell. *Sunways*
- VoltarLux. *Arnold Glas*
- EFL Glass-backsheet-module. *Ertex Solar*
- VSG Module, VSG-ISO, VSG-EVO. *Ertex Solar*
- Perform. *Schott*
- Optisol Screen, Skin, Shade and Sky. *Scheuten*
- See-Though. *Kaneka*
- Solar Power Glazing. *Oxford Photovoltaics*
- PowerGlaz. *Romag*
- Photovoltaic Transparent Glass. *Onyx Solar*
- Asi-Glass. Solar Constructions
- Volta-Glass. Solar Constructions
- Photovoltaic Sunshades. *Dams Incorporated*
- High-transmissivity Figured Glass. *Asahi Glass*

7 Technologies for the use of natural lighting

7.1 General description

Lighting is the second largest end use of energy in tertiary buildings and the third in the domestic sector with a total share of 18% within EU. Moreover, it has been classified as one of the most cost effective solutions to reduce energy consumption and CO_2 emissions in future years. Energy savings can be achieved either from the reduction of artificial (electric) lighting or from passive solar heating or cooling. The use of artificial lighting energy can be reduced by simply installing fewer electric lights due to daylight presence or by dimming/switching electric lights automatically in response to the presence of daylight, a process known as daylight harvesting. Nevertheless, this energy performance improvement has to warranty visual comfort for the users.

Sunlight represents one of the earth's primary sources of renewable energy and is a primary light source for hybrid solar lighting systems. Direct sunlight contributes approximately four-fifths of the total luminance at the earth's surface.

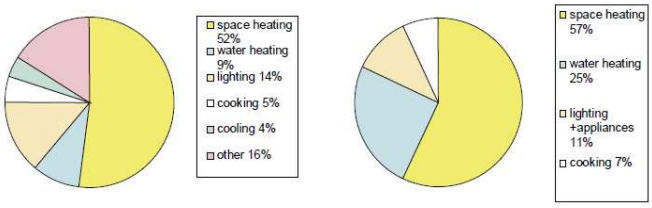

Figure 16: Energy consumption in tertiary (left) and domestic buildings (right).

A balance of light is important both for visual comfort and to perform visual tasks. Light levels for reading in the home or office range from 100 to 2000 luxes, and an overcast sky can provide outdoor levels of 5000 to 20000 lux.

Lighting quality is also a financial issue. Poor lighting conditions can easily result productivity losses of the employees and the resulting production costs of the employer can be much higher than the annual ownership cost of lighting. Therefore, solutions that guarantee good lighting with minimum energy consumption are needed.

Possible solutions to achieve good quality and sustainable lighting include solutions that take advantage of natural lighting can be

- Reflectors
- Tubular reflectors
- Optical fibre sunpipes
- Hybrid lighting systems
- Translucent Ceilings
- Shelves
- Devices that turn lights off through the use of photo sensors.

7.2 Identified subcategories

In this point, the different identified subcategories will be developed. For each one, its innovativeness, identified constraints or drawbacks, and current technological/market situation will be analysed. Finally, a list of products will be displayed.

7.2.1 Reflectors

Description and innovativeness

Reflectors are an already known solution that is constantly being improved. This system captures the sun rays in façades or in the upper parts of a building and redirection them inside, increasing dramatically daylight, transforming inner areas of the building (especially atria) into light boxes. The result is an amazing lighting level in comparison to the original situation: multiple sun rays bathing the walls and back yard. Even though the installation is static, the result is ray motion inside the atria, which introduce wellness.

This solution can be used both for tertiary and domestic buildings. In the case of residential blocks, reflectors help to recover dark and dirty atrias into new lively, brighten and dynamic areas where people could open windows and enjoy an open and fresh space.

Figure 17: Graphic scheme of the effect of reflectors in an atria (left). On the right, a real case (extracted from Deplosun – Espacio Solar brochure).

Reflectors are usually made of anodized aluminium with especial surface treatments and a reflection index of 98%. They should be installed in the upper part of the atria where they could catch sun rays and reflect them inside. Another common solution is to install them in façades, as shelves, in order to reflect the sun rays through windows or hollows, this option with be analysed afterwards, within this point *7. Technologies for the use of natural lighting*.

Their geometry will reflect sun rays all day, but it is convenient that it is optimized for winter and low sun rays when are more needed, usually sun heat will never be a problem in summer. Nevertheless, for certain configurations the use of motorised orientation could be necessary in order to improve the efficiency of the reflectors.

Identified constraints or drawbacks

This system could be impossible to use in already existing buildings. The atria must be accessible for the reflectors, small floor plans or very sloped roofs could influence negatively into the effectiveness of these devices.

It is also convenient to avoid the concentration of solar energy in small areas. Nevertheless, modern geometries and designs avoid this drawback.

Current technological/market situation

Currently this technology is already well-developed. However, its use is still very subsidiary. The future of this technology is to solve its integration in the existing buildings geometry. Besides, it would be necessary to improve the information related to this product among designers and architects.

Reflectors are also being considered for other aims. Related to the aim of this work is their use as a complement to improve the efficiency of solar panels. Flat-roofed urban buildings bake in the sun all day with no shade from trees, so they are the perfect place for solar panels. They can deliver power directly to where it's needed without significant transmission loss. But roof space is limited so efficiency is very important. Better efficiencies can be achieved by putting reflectors in the spaces between the solar panels as can be observed in the following picture. As can be observed, the scope of reflectors can be enlarged by using them with other technologies.

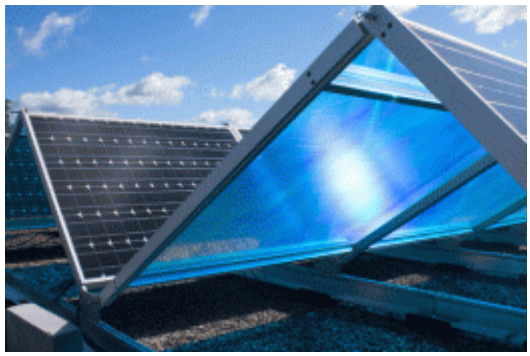

Figure 18: Reflectors between two rows of solar panels (courtesy of **http://www.f2e.es**).

Proposed materials, technologies or systems catalogue

- Bespoke Motorised Light Reflectors. *Levolux*
- Deplosun reflectors. *Espacio solar*
- Sunbender. Zomeworks Corporation
- Custom Formed Reflectors. 3M
- Sunportal DS, CS, RS. *Sunportal*
- LightTracker. *Solatube*

7.2.2 Tubular reflectors

Description and innovativeness

Tubular reflectors are ground-breaking line of tubular daylighting devices designed specifically for large volume spaces with high, open ceilings like airports, convention centres, lobbies, warehouses, manufacturing facilities, and retail centres.

They are a kind of solar reflectors. However, in this case, they are going to be use d as spot lights.

Figure 19: Solatube's skyvault composition and an application in a sport facility.

Identified constraints or drawbacks

The massive use of these devices requires a considerable budget. Besides, their use is more oriented for areas where the number of solar hours is high. Tubular reflectors can be combined with artificial lighting in those buildings or uses where minimum or constant light levels are required. However, this solution would increase the initial budget even more.

On the other hand, the installation of tubular reflectors in already existing buildings requires the execution of complex works. For example, joints should be sealed satisfactorily in order to avoid the infiltration of water and wind.

Current technological/market situation

This technology is being developed by few companies; although it is only a derivation of the use of solar reflectors. However, the current trends to reduce the dependence of non-renewable energy sources will promote the use of this kind of technologies. In the case of tubular reflectors, their use in sunny areas like Southern Europe or Africa can be a cost effective solution in few years.

Proposed materials, technologies or systems catalogue

- Skyvaults. *Solatube*
- Teclusol. *Solatube*
- Smart LED Systems. *Solatube*
- Metrodome Modular Rooflights. *Passivent*
- Sunscoop. Passivent
- Apollo Solar Light Pipe. *Orion Energy Systems*

- Deplosun glass tubular daylighting devices. *Espacio Solar*
- Pitched Roof Domed Skylight. *Huvco*
- High Performance Daylighting System. *Huvco*
- Tubysol. *Tubysol*
- SunTracker 400,800. *Ciralight*
- Solartube. *Chatron*
- Sunpipe. Monodraught
- Sky Tunnel XL2. *Sola Skylights*

7.2.3 Optical fibre sunpipes

Description and innovativeness

This technology supplies sunlight to buildings and makes indoor-sunbathing possible. The lighting system consists of three parts: a collector which tracks the sun and collects sunlight, optical fibre cable to transmit the sunlight and a cable terminal/light-fitting.

Figure 20: Optical fibre sunpipes general scheme (left) and details of the three components. Pictures extracted from Deplosun brochure.

Unlike tubular reflectors, which take up space and usually have to be installed during construction or disruptively later, the optical cables can be incorporated easily into existing buildings.

Identified constraints or drawbacks

The installation requires the use of optical cables through a considerable length. Thus, the execution process could be complicated and need a complex work.

On the other hand, light cannot be accumulated , so the sun inside is exactly as sun outside, so if there is a cloud going through, the system will practically not work and sun inside will be almost zero, when the cloud disappears, there will be light again. Therefore, they should be combined with artificial lighting in those buildings or uses where minimum or constant light levels are required creating a hybrid lighting system. This solution would increase the complexity of the installation and its final cost.

Currently, there is a limit in length for the daylight transmission by means of optical fibre. According to some manufacturers and publications, this limit can be around 20 metres.

Current technological/market situation

Optical fibre sunpipes are still unknown to designers and architects. Besides, there are few manufacturers of this technology. More diffusion is needed. Besides, the length limits to transmit daylight should be overtaken in order to create a truly competitive solution.

Proposed materials, technologies or systems catalogue

- SP3 System. *Parans*
- SolarPoint. Sunlight Direct
- T6. Sunlight Direct
- Deplosun Fibra Óptica. *Espacio Solar*
- Himawari. La Foret Engineering Co.

7.2.4 Hybrid lighting systems

Description and innovativeness

In a remote-source lighting (RSL) system, light from a single source is carried over a distance to one or more light outlets, or is emitted evenly along the way. In the present study this light source is the sun. The sunlight is collected by specially designed devices and then is distributed into the inner of the building towards the luminaries. This technology is very useful for those buildings where constant light levels are required (offices, malls, schools). Nevertheless, it is necessary to remark that in absence of suitable weather conditions this system could be ineffective. Therefore, it would be necessary to complement the sunlight with artificial light; a hybrid lighting system is required, including five major elements: light sources (sunlight, also electric lamps), sunlight collection and tracking systems, light distribution systems, hybrid lighting control systems, and hybrid luminaires

Most of the components have been previously explained and detailed. Therefore, in this point the ambient light sensors and the hybrid luminaries are presented. The hybrid luminaries are formed by diffusors for natural lighting and LEDs for artificial lighting. In some products both elements, light sensors and hybrid luminaries, are integrated into one single device (see Figure 23).

Figure 21: Simple lighting control sensor of Lutron (left) and Passivent hybrid lighting control system where the sensor, the LED for artificial lighting and the diffusor for natural lighting are assembled in the same element (right).

Hybrid luminaries' diffusors can be connected to tubular reflectors or optical fibre daylight, it will depend of the manufacturer and its developed technologies.

Identified constraints or drawbacks

The use of optical sensors and hybrid luminaries is the high point in the use of daylight at inner spaces; it is the solution for the problems derived of the normal discontinuity of the daylight in many areas of the world. However, the control of the hybrid luminaries by the sensors requires an additional intelligent light control system (ILC) to work satisfactorily. This system usually has to be designed for each application and it demands constant maintenance.

Current technological/market situation

Currently, light from core daylighting systems is usually directed into a space by large diffusers that descend below the ceiling. Smaller diffusers and hollow light guides that resemble ordinary luminaires are also available. It is reasonable to expect that these systems will have light distributions and glare control similar to those of standard luminaires. However, most manufacturing efforts have gone into producing systems which efficiently collect light and transmit it through the building. More development is needed to produce effective methods of directing light to the work surface.

Lighting control devices are easy to find. It is not a novel technology; their importance within this work is relevant due to its use in combination with hybrid luminaries. However, the presence of hybrid luminaries in the market is not broad.

New daylighting technologies are not likely to become common until their prices drop to reduce the payback period. In addition, the industry needs to seamlessly integrate component technologies into functional systems for optimal building performance. Daylighting systems, electric lighting systems, and controls need to be coordinated to optimize glare control, light balance, and energy savings. Backup electric lighting needs to be incorporated into the system so the changeover from day to night is continuous.

Proposed materials, technologies or systems catalogue

- Sunscoop Hybrid. *Passivent*
- Hybrid SolarTube. *Chatron*
- Himawari. La Foret Engineering Co.
- Radio Power Saver Daylight Sensor. *Lutron*
- WPS-5952 Indoor Photo Sensor. *Douglas Lighting Controls*

7.2.5 Translucent Ceilings

Description and innovativeness

Translucent ceilings are created with lay-in panels of reinforced acrylic or fiberglass, and they are backlit to illuminate the space below.

Figure 22: Translucent ceiling in an auditorium, product of Darlum.

Identified constraints or drawbacks

It is a non-industrialized solution. Normally, they cannot be applied in renovations unless they present a deep scope. The design for each situation is unique; therefore it is difficult to find industrialized solutions.

Many products are designed for inner applications with artificial lighting when the aim of this point is to use natural day lighting.

Moreover, some materials are prone to fire attack; this fact limits its broad application in buildings where the fire standards must be fulfilled.

Current technological/market situation

The technological advances are focused on the development of durable and light materials. On the other hand, the auxiliary structure to bear the translucent panels is also evolving towards more easy-to-install systems. Nevertheless, as has been commented, the main problem for this industry is the main range of situations, so the design of an industrialized solution is complicated.

Proposed materials, technologies or systems catalogue

- OpenSky. *Durlum*
- Trasluncents. *USG*
- Techstyle Translucent. *Hunter Douglas Contract*
- LightFrame. Decoustics (Saint Gobain)
- Barrisol Lumiére. *Barrisol*

7.2.6 Light Shelves

Description and innovativeness

A light shelf is a passive lighting strategy where a horizontal or angled or even slightly curved surface is placed over building openings higher than eye level to reflect daylight into the ceiling, thus, bringing light further into buildings.

Architectural light shelves have been proven to reduce the need for artificial lighting in buildings. Since they can reflect light deeper into a space, the use of incandescent and fluorescent lighting can be reduced or completely eliminated, depending on the space. Light shelves make it possible for daylight to penetrate the space up to 2.5 times the distance between the floor and the top of the window. Today, advanced light shelf technology makes it possible to increase the distance up to 4 times. In spaces such as classrooms and offices, light shelves have been proven to increase occupant comfort and productivity.

Light shelves have been featured in many buildings all around the world in many variants in term of surface material, size, angles of placement and adjustability. Some light shelves are non-adjustable fixtures while some are adjustable (usually automated) to create different angles of the reflecting surface to maximize the amount of daylight that enter the building throughout the day depending on the sun position. Light shelves can be installed alone, but they are often paired by external shading device that is placed at the same level of the internal shelves (Figure 23). The external shading reduces glares from the windows reducing the heat that is introduced in the building through radiation.

There are different varieties of surface options from matt perforated or even corrugated. The different texture gives a different level of total reflectance of the sunlight and also light diffusion intensity. The surface comes in different paint finishing too. Light shelves can be self-made as well using timber and gypsum board. However for a good performance, careful plan is necessary when choosing reflective surface material, (matt surface gives a more well distributed light in comparison with glossy surface), optimal size (height and width) and angles.

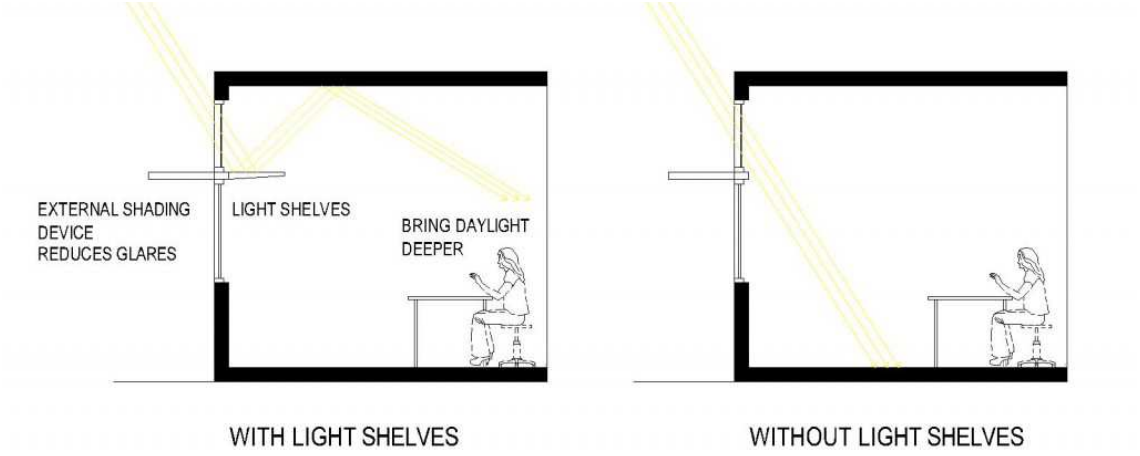

Figure 23: External Shading devices with light shelves (left) and without them (right). Courtesy of www.greenasiaforce.com

The main advantages of the use of those devices are[23]:

- They proved to increase the amount of daylight that enters the building, increasing visual comfort.
- They are relatively easy to install and sold as prefabricated units with own light weight support or bracketing system.
- Light shelves made of composite aluminium are the light and easy to handle.

[23] http://www2.buildinggreen.com/category/builder-categories/windows/outdoor-structures/light-shelves

The width of the daylighting zone along the exterior wall extends into the space 3 to 6 meters. This is translated to electricity savings of 30 to 120 watts per foot along the wall. In addition, the heat energy added to the space is not much different from what would be added by an equivalent amount of electric lighting. Shelves reduce the energy use by 30% compared to the baseline building performance rating per ASHRAE Standard 90.1. They also achieve a minimum day light factor of 2% in 75% of all space occupied for critical visual tasks. Moreover, they provide automatic dimming controls or accessible manual lighting controls, and appropriate glare control. Finally, as has been stated, light shelves can yield to a reduction in monthly demand charges due to reduced lighting energy during peak hours.

Identified constraints or drawbacks

Light shelves however, are not without any limitations. There are few things that we need to know before placing light shelves in our building[24]:

- In the tropical or desert context, the biggest concern about using light shelves is the obtained heat gain.
- Light shelves do not perform well during cloudy days; overall indoor illumination is reduced when sky is overcast.
- Light shelves are difficult to insert in existing window frames, this not always possible. Moreover, window coverings must be coordinated with light shelf design.
- Proper installation during construction is needed to ensure no thermal breaks are created. When sun shades are combined with light shelves on the interior, separation of these two elements by independently anchoring them to different framing and then isolating them using lapped insulation is an effective way to eliminate or limit thermal bridge at the anchor.
- Due to their position, they need constant maintenance. Dust can settle on a light shelf to degrade illumination; therefore, light shelves need to be cleaned on a regular basis.

Alternatives to light shelves for window daylighting include blinds and louver systems, both of which can be interior or exterior. Blinds reduce solar gain, but do little to redirect light into the interior space. Exterior louver systems often rely on adjustments from either complex servo motors or building occupants throughout the day to operate well. Both of these systems can be unreliable at times, reducing the overall benefit of having a daylighting system.

Current technological/market situation

Light shelves are products that can be manufactured by small enterprises. There are some companies that offer non-industrialized solutions as a complement of windows and fenestrations in specified projects. Therefore, it is not easy to find industrialized products.

Its use is more related to non-residential buildings, such as office buildings or schools. However, current trends are satisfactorily incorporating these solutions in residential buildings. The inclusion of light shelves as inherent part of windows and fenestrations is being also promoted by architects and designers.

As light shelves are formed by reflective materials there is no significant improvement in this way. Some trademarks are focused in the possibility to automate its functioning, i.e. to active electronically its position towards the sun.

[24] http://www.greenglobes.com/advancedbuildings/_frames/fr_t_lighting_light_shelves.htm

Proposed materials, technologies or systems catalogue

- Solar Shading. *Passivent*
- BrightShelf. Hunter Douglas Contract
- InLighten. *Kawneer*
- Sun Control Clear Story. *Wausau*
- aLuminate. *Tubelite*
- MaxBlock. *Tubelite*
- LS1 Light Shelf. *Firestone*
- Envolution Light Shelves. Doralco Architectural Metals
- Bristolite Light Shelves. *Bristolite*
- InLighten Light Shelf. *Alcoa*
- Light Shelves. Dams Incorporated

8 Materials and solutions for thermal energy storage

8.1 General description

One of the ways to reduce energy demand associated to space conditioning is the use of thermal energy storage. Traditional buildings store thermal energy in the massive materials used in buildings construction (i.e. concrete, ceramic tiles…). As new buildings become lighter or internal insulation is used as retrofitting solution, there is no longer thermal mass available in the buildings. This lack of thermal mass contributes to higher indoor air temperature's fluctuations leading to increased discomfort hours and higher power HVAC to compensate the non-stored energy, which turns in increased energy consumption.

The use of new light solutions with the capability of storing energy and releasing it when it is needed may help to improve this indoor air quality and reduce buildings energy consumption. New solutions with phase change materials (PCM) within building Tª range that contribute to stabilize indoor air temperature and that building's reduce energy demand in at least 20% are suggested.

These materials have the availability to change their state within the operation temperature ranges of buildings, releasing and storing high amounts of energy. Depending of the temperature in which this phase change takes, these solutions can be suitable for cooling or heating dominated climates. Moreover, thermal energy storage can be a promising solutions for off peak electricity energy storage as renewable electricity production can be forecasted and smart grids are introduced.

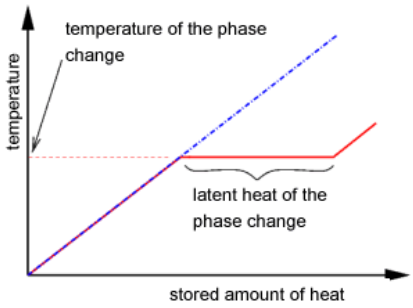

Figure 24: Comparison of the storage processes for sensible (blue) and latent (red) heat.

The temperature of the storage medium increases (blue line) when heat is stored in it. This form of thermal storage is thus also called storage of sensible heat. Storage of latent heat means storing heat in a material which undergoes a phase change, a so-called phase change material (abbreviation: PCM). The most commonly used phase change is between the liquid and solid states, but the phase change between two solid states can also be used in principle. However, the latter usually have a much lower storage density. When heat is fed into the storage material, the material begins to melt once the phase change temperature has been reached. Although further heat is applied, the temperature of the material does not increase until it has melted completely. Only then, the temperature rises again (red line). As no temperature increase can be observed over a long period of time, despite the application of heat, the heat stored during the phase transition is called "latent heat". For a solid-liquid phase transition, the latent heat is equal to the heat of melting or crystallisation of the storage material.

PCMs latent heat storage can be achieved through solid–solid, solid–liquid, solid–gas and liquid–gas phase change. However, the only phase change used for PCMs is the solid–liquid change. Liquid-gas phase changes are not practical for use as thermal storage due to the large volumes or high pressures required to store the materials when they are in gas phase. Liquid–gas transitions have a higher heat of transformation than solid–liquid transitions. Solid–solid phase changes are typically very slow and have a rather low heat of transformation.

PCMs can broadly be arranged into three categories: eutectics, salt hydrates, and organic materials[25].

- Eutectics tend to be solutions of salts in water that have a phase change temperature below 0°C.
- Salt hydrates are specific salts that are able to incorporate water of crystallisation during their freezing process and tend to change phase above 0°C.
- Organic materials used as PCMs tend to be polymers with long chain molecules composed primarily of carbon and hydrogen. They tend to exhibit high orders of crystallinity when freezing and mostly change phase above 0°C. Examples of materials used as positive temperature organic PCMs include waxes, paraffin, oils, fatty acids and polyglycols.

Some examples of this type of solutions that can be integrated in buildings:

- Plasters or wallboards with microencapsulated PCM in their matrix
- Tiles and light-weight panels with PCM
- Macro encapsulated PCM connected with buildings HVAC systems
- Windows with PCM

PCM materials thermal storage capacity, stability and durability that hampered their market penetration in the past, have been improved in recent years. Though PCM materials are produced by large multinationals like BASF, Rubitherm, DuPoint…etc. They can be easily integrated in different building products, which manufactures are local and generally SMEs. The enhanced performance of these traditional construction elements may suppose a market plus for these products' manufacturers or other products that compete with price.

With new buildings being lighter, these types of solutions may help to satisfy demanding comfort standards. On the other hand, as far as renewable energy power supply is increasing and smart grids are becoming more common, the thermal storage may represent a huge opportunity for peak load shifting and reducing procurers' energy bills.

8.2 Identified subcategories

In this point, different identified subcategories will be developed. For each one, its innovativeness, identified constraints or drawbacks, and current technological/market situation will be analysed. Finally, a list of products will be displayed.

[25] Phase Change Materials: Thermal Management Solutions. http://www.pcmproducts.net/

8.2.1 Plasters or wallboards with microencapsulated PCM in their matrix

Description and innovativeness

Construction applications use phase-change materials as they change between their solid and liquid states, rather than between a liquid and a gas state, as the volume change is far less. This presents the practical problem of containing the material in its liquid state. An effective solution here is microencapsulation.

The idea is that the PCM, in the form of a wax, is contained in an extremely hard plastic shell. Each capsule is tiny — for example, the BASF Micronal DS 5000 X microcapsules used in Armstrong's CoolZone products have a diameter of about 2-20 microns — or 0.002-0.02mm. The capsules have a very large surface-volume ratio, which allows a high level of heat transfer, while also protecting the paraffin to keep it in its pure form.

Pure paraffin is a suitable material for the wax because it undergoes less expansion than other PCMs, maintains its form in a liquid state and is highly durable — after 10,000 test cycles of the BASF Micronal DS 5000 X microcapsules (which use pure paraffin) there were no damaged capsules. The formulation of the paraffin wax can be adjusted to give a melting point of either 23°C or 26°C.

Figure 25: PCM in gypsum plaster. BASF.

Figure 26: Energain panels being installed.

Identified constraints or drawbacks

Currently this technology is not too developed. Thus, it is relatively complicated to find a considerable variety of products. Additionally, for this reason, the cost of this kind of products is still too high for deep renovations with modest budgets.

Minimal changes in volume are required; these substances expand or contract when they change state. Because PCMs in construction need to be contained within a cassette, large changes in volume could create problems.

Organic PCMs, such as paraffin, are flammable, even when it is encapsulated.

Current technological/market situation

There are two main manufacturers: DuPont with their Energain products and BASF with their Micronal PCM. Currently some local manufacturers are trying to integrate these materials into their products. Nevertheless the variety of this kind of system is still limited.

Proposed materials, technologies or systems catalogue

- Energain. *Dupont*
- Caparol. *DWA*
- EBB PCM Clay Board. *EBB*
- Enerciel. *Winco*
- AlbaBalance. Rigips (Saint Gobain)
- PCM Smartboard. *Knauf*
- RACUS PCM Wallboard. *Datum Phase Change*
- ThermalCore. National Gympsum
- Micronal PCM Gypsum Wallboards. *BASF*
- Maxit Clima. *BASF*
- Crystall Climate Wall Autarkis. *Orange Climate Group*
- Crystall Storage Panels Autarkis. *Orange Climate Group*
- Ilkatherm. *Ilkazell*

8.2.2 Tiles and light-weight panels with PCM

Description and innovativeness

These tiles incorporate tiny capsules of phase change material that absorb, stores and releases excess latent heat from within the building. In building applications, these processes occur within a narrow temperature range close to the human comfort temperature with large amounts of heat being absorbed and released.

During the transition phases, the core of the microcapsule will melt as the room temperature reaches the transition temperature and in doing so will absorb latent heat where it will be stored until such time that the room temperature cools whereby the heat is slowly released back into the room. With cooler night-time temperatures, the PCM will return to solid form, transferring the heat energy back into the room. This

means that the room is not too cool first thing in the morning but at a comfortable working temperature, and the PCM tiles are reset for another working day.

For example, ceiling tiles are installed into suspended ceiling systems. The heat is then absorbed from the room by means of radiation and convection, as long as the surface temperature of the ceiling tile remains lower than the room temperature.

Identified constraints or drawbacks

This subcategory presents the same constrains as those listed for the plasters or wallboards with microencapsulated PCM in their matrix:

- Technology is not too developed.
- High cost
- Flammability.

Current technological/market situation

Main manufacturers are the same as for plasters or wallboards with microencapsulated PCM in their matrix: DuPont and BASF.

Proposed materials, technologies or systems catalogue

- ThermaCool Ceiling Tile. *Datum Phase Change*
- ThermaCool Panel. *Datum Phase Change*
- RACUS Honeycomb PCM ceiling tile. *Datum Phase Change*
- Ceiling Fittings. *PCMproducts*
- CoolZone. *Armstrong*
- Energain. *Dupont*
- Crystall Comfort Ceiling Autarkis. *Orange Climate Group*
- Crystall Cooler Autarkis. *Orange Climate Group*

8.2.3 Macro encapsulated PCM connected with buildings HVAC systems

Description and innovativeness

PCMs have some other interesting applications in building construction such as heat/cold storage in HVAC (Heating, Ventilating, and Air Conditioning) systems. Thermal energy storage (TES) is very important to eradicate the discrepancy between energy supply and energy demand and to improve the energy efficiency of solar energy systems.

Two different types of PCM storage tank were considered. The first one is to use PCM in bulk, so the tank operates as a heat exchanger where the heat transfer fluid flows through the pipes and the rest of the tank is filled with the PCM. The other type of tank considered uses commercial PCM macroencapsulation, such as tubes, modules or balls. In this case the heat transfer fluid flows through the external surface of the modules and the PCM is contained inside the modules.

It is also possible to use PCM foils as a wall material. The resulting product is PCM encapsulated in bags. To ensure tightness of the bag regarding water, plastic foils are combined with metallic layers.

The necessity to encapsulate PCM has two main reasons: to hold the liquid phase of the PCM, and to avoid contact of the PCM with the environment, which might harm the environment and change the composition of the PCM. Furthermore, the surface of the encapsulation acts as heat transfer surface. In some cases, the encapsulation also serves as a construction element, adding mechanical stability.

The encapsulation materials used should fulfill some properties: First, the materials of the container wall must be compatible with the PCM. Secondly, taking into account the selected wall material, the container wall has to be thick enough to assure the necessary diffusion tightness. Finally, the encapsulation must be designed in a way that is able to cope with the mechanical stress on the container walls caused by the volume change of the PCM.

For latent heat storage, various phase change materials (PCM) for different temperature ranges have been investigated. Since these materials should be inexpensive, abundant, and safe, water or ice are the most attractive storage materials used in heating, ventilation, and air conditioning (HVAC). Water has a relatively high heat of fusion and a melting temperature that is suitable for cooling. The freezing point is suitable for comfort cooling, even though the low evaporation temperature of the refrigeration cycle decreases the efficiency of the machine.

Figure 27: Ice capsules for ice thermal storage in an air conditioning installation. Cryogel.

Since the tank volume is smaller than the water tank, heat losses from the tank are also smaller. Buildings with small space for water storage still can take advantage of TES through the use of ice storage tanks. Although ice storage tanks have been used successfully in commercial applications, their use is limited to cooling applications and lowers the efficiency of refrigeration machines due to the lower evaporative temperature associated with these tanks. Phase change materials other than ice have been studied for various purposes. Paraffin waxes, salt hydrates, and eutectic mixtures are also materials than can be selected for use in TES in HVAC systems. Compared to ice storage, these PCMs are used in a passive manner such as the stabilization of room temperature by means of the thermal inertia of phase change.

Identified constraints or drawbacks

To encapsulate salt hydrates, plastic containers are selected because of material compatibility. Plastics are not corroded by them; however, attention has to be paid to the water tightness of the material of the capsule wall. This is to make sure that the water content in the capsule and thus the composition of the salt hydrate does not change with time. Plastic encapsulations can also be used for organic PCM, but the

combination of PCM and encapsulation material has to be chosen very carefully because organic materials may soften plastics.

If good heat transfer is important, the low thermal conductivity of container walls made of plastic can be a problem. An option is to choose containers with metal walls. They also have the advantage of higher mechanical stability if a sufficient wall thickness is selected. It is nevertheless necessary to choose a suitable metal which is not corroded by the PCM. This selection should also take into account that depending on the different options of metals and restrictions for shaping, welding, etc exist.

Current technological/market situation

Currently PCM macroencapsulation market offers a wide range of products that allows PCM materials obtain a commercial level. Companies like PCM Products, Rubitherm Technologies GmbH, Climator, Dörken GmbH or PCP have found different ways to encapsulate their PCM like balls, tubes, plates, panels, etc. However, water is still the most used material within this field.

The use of this technology is more focused in the United States whilst in Europe its existence is not well-know.

Proposed materials, technologies or systems catalogue

- SavEnerg. *RGEES*
- Delta-Cool 24. *Dörken*
- Cool-Phase. *Monodraught*
- Thermusol k-Block. *Salca*
- Thermusol Thermupod. *Salca*
- Crystall Cooler Autarkis. *Orange Climate Group*
- PlusIce. PCM products
- IceBear. Ice Energy
- ExtraPak Ice Coils. *Evapco*
- IceBall. *Cryogel*
- Ice Harvesting. *Vogt*
- IceStor. *Fafco*

8.2.4 Windows with PCM

Description and innovativeness

These windows incorporate a phase-change material (PCM) between two of the panes of glass. PCMs store heat as they change phase from solid to liquid (melt) over a narrow temperature range, then they release that heat as they cool off. The salt hydrate used in this king of glaze melts and freezes in the temperature range of 26-30 ºC.

Figure 28: Windows with PCMs integrated in their panes (the translucent ones). Courtesy of GlassX.

PCM layer can be combined with low-E coatings and low-conductivity gases in the cavity, increasing the performance of the fenestration. Two separate low-emissivity (low-e) coatings and low-conductivity gas fill in the outer two sealed spaces glass help to push heat from the PCM inward while slowing outward heat loss. The U-factor is about 0.48 W/m^2K. The direct-beam light transmission (assuming the sunlight isn't blocked by the prism layer) is up to 45% when the PCM is liquid and up to 28% when the PCM has crystallized[26].

Identified constraints or drawbacks

If the previous elements that include PCM as a novel technology are not developed yet, PCM glaze is in even less developed. However, due to the current crisis, several companies are researching thoroughly this kind of materials. Thus, more models will appear soon in the market.

Current technological/market situation

Apparently there is a single PCM glaze manufacturer in Europe, GlassX.

Proposed materials, technologies or systems catalogue

- GlassX AG Crystal. *GlassX*
- GlassX AG Store. *GlassX*

[26] High-Tech Glazing With Phase-Change Material. http://greenspec.buildinggreen.com/blogs/high-tech-glazing-phase-change-material

9 Industrialized internal partition with low carbon footprint

9.1 General description

Internal partitions divide internal building zones, which may have different uses and therefore different thermal needs. For example an auditorium or meeting rooms may need punctual conditioning needs, and therefore acoustic and thermal insulation may be needed. On the other hand, the multiple uses of current buildings, request easily reconfigurable spaces that do not need to be demolish and build up new internal partitions again. These internal partitions must be able to satisfy the minimum aerial noise resistance levels of less than 70dB and higher impact noise resistance levels than 40dB. Thermal resistance should warranty energy fluxes lower than 0.5 W/m^2K for the expected temperature differences between interior spaces.

On the other hand the use of these types of panels in new buildings will reduce the on-site labour and residues. And allow end users to configure dwellings as they like, increasing their satisfaction perception.

Common internal partitions of buildings are usually made of simple hollow bricks or plasterboards. To reconfigure the space, this internal partitions, have to be demolished and a new one should be constructed. The use of offsite industrialized reconfigurable internal partition panels will reduce these impacts.

Description and innovativeness

Industrialized internal partitions with minimum thickness that allow high thermal and acoustic insulation and ensure low carbon footprint are suggested to turn interior spaces more reconfigurable and flexible. This type of solutions may represent an opportunity to build social housing dwellings that can be easily reconfigurable by the final tenants making their building more flexible and comfortable, and therefore increasing their satisfaction level with the building.

Construction and demolition residues can be used in their constructions, reducing thus the energy needs for new material fabrication. It represents at the same time a new application for the local construction and demolition residues, reducing landfill's occupation. On the other hand the used of plug and play prefabricated panel, that already include all the plugs, reduce on site labour time and therefore costs.

Light partitions can be built using wood or metal studs with gypsum board, lath and plaster finish or prefabricated panels. The studs may be full height (extending from floor-to-floor) or partial height, extending to the ceiling but not to the structural framing above. Partitions with partial height studs may be braced by the ceiling, but more commonly are braced with diagonal braces or wires independent of the ceiling, particularly at ceilings of lay-in acoustical tiles. The finish material may also run full height or stop at the ceiling, depending on fire or acoustical separation requirements.

Prefabricated panels can be made of several products. Porous cement-based materials (e.g. EPS foam cement panels), recycled demolition waste, natural fibres reinforced composites, phase change components (PCMs)… These materials are slim, present good thermal and acoustic performance, can be fire proof, and are easily manufactured. Glass is also an excellent choice for internal partitions in office and commercial premises. Not only does it allow more light into a building but it can reduce noise levels between areas, provide a security screen and can create smart looking glass corridors. You can use textured or laminated glass for tinted, white translucent and etched effects. The glass also allows for the addition of smart looking company logos or information signs. Glass also provides additional fire resistance.

Figure 29: EPS foam cement

Identified constraints or drawbacks

As light partitions do not present the same mechanical characteristics as conventional partitions, they can be easily damaged [27].

- In-plane (parallel with the wall) damage can occur to light partitions as a result of deformations of the structure (drift). Full-height partitions in flexible structures may be damaged in this way unless they are isolated from the building deformations. Typical damage consists of cracked or spalled finishes, deformed partition framing, and failed connections.

- Metal studs are often installed with a deflection track at the top that provides lateral support but also accommodates potential movement of the floor above due to changing gravity loading. In order for the deflection track to be effective in allowing vertical movement, neither the stud nor the finish material should be attached to the track. This lack of connection is often in conflict with fire or acoustical approvals of partitions systems.

- Out-of-plane (perpendicular to the wall) damage is due to inertial loading on the wall from the floor accelerations (shaking). This loading is proportional to partition weight, so partitions with heavy finishes or hung book or storage shelves are more susceptible. Typically, damage from this loading occurs at the top connection of the partition to the structure or ceiling and may include local connection damage or complete failure leading to overturning of the partition. Such partition failures may create falling hazards, block corridors, and endanger occupants attempting to exit from damaged buildings.

- Partitions are also used to provide lateral support for floor supported storage shelves, equipment or other non-structural items[27]. This additional loading was often not anticipated in the design of the partition and damage could occur at the equipment connection, in the studs themselves, or at the wall-to-structure connections. The supported item could also be damaged due to unanticipated sliding or overturning.

Current technological/market situation

[27] FEMA E-74 Reducing the Risks of Nonstructural Earthquake Damage. http://www.fema.gov/earthquake-publications/fema-e-74-reducing-risks-nonstructural-earthquake-damage-2

The number of materials suitable for this kind of elements is relatively high. Currently, the use of demolition waste is being researched by several institutions. Nevertheless, its implementation in the market is not very solid yet.

On the other hand, it is more frequent to find panels made of porous cement-based mixtures. There are several manufacturers in the Far East, but it is possible to find these products in Europe.

Proposed materials, technologies or systems catalogue

- Eko-Block. *LRC*
- Dendrolight. Dendrolight Lavitja
- LECA Blocks. *Leca*
- Ytong. *Xella*
- Hebel. *Xella*
- Fermacell. *Xella*
- Ductal. *Lafarge*
- Hess ACC Systems. *Hess*
- Litebuilt. Pan Pacific Group of Companies
- Acoustic Slab. *Rockwool*
- Prorox slabs. *Rockwool*
- Optifloat Opal. *Pilkington*
- Optilam I. *Pilkington*
- Viridian VLam Translucent. *Viridian*
- ViridianDecor. *Viridian*
- Knauf Partition Walls. *Knauf*
- Vboard. *Visaka*
- Vpanel.*Visaka*
- Promatect 100. *Promat*
- Styropanel. Building Constructions
- ThermaCool Panel. *Datum Phase Change*

10 Conclusions and recommendations

As a general conclusion, it can be stated that a considerable effort is being made by the industry to improve the performance of the solutions for efficient energy performance. The new trends, strongly promoted from the public institutions, push towards the development of highly effective technologies. Energy rehabilitation sector is a market niche in constant growth and many manufacturers want to take advantage of this situation.
It has been possible to study and analyse products of all the previously selected categories. In fact, within them, several subcategories has been identified and commented in relation to the aims of the PAPIRUS project.
The main conclusions derived from the work done in Task 2.2 and presented in the present deliverable are shown in the following bulleted sentences.

- Most of the used materials are very innovative. Aerogels, PCMs or transparent PV cells, for example, are not widely-used materials. Their price is still considerable and despite their optimum performance and being cost-effective, their use can destabilise projects with modest budgets.

- Moreover, some of these products are manufactured by few companies, usually powerful multinationals, well-assented in the market and with an important dissemination capacity. Unless, more and small manufactures will not start to produce these materials, prices will not decrease. In the Far East there are several manufacturers with competitive prices, especially in China. However, the trust in quality is a considerable drawback for them.

- Mentioned materials are also the base for many of the presented solutions. Hence, this fact affects also their price. It is true that some technologies are designed and manufactured by local or modest companies, but they have to use the materials above.

- All the technologies present drawbacks that have identified in the context of the project. Nevertheless, they are innovative solutions, so the existence of problems is inherent to them. Time, research and use would help to overcome them.

- There is a lack of knowledge towards these technologies. Therefore a suitable dissemination is required. As many manufactures are big companies and they have other profitable materials, this dissemination is not enough to stand out among the massive quantity of information that can be found in the current information sources, especially internet. The development of projects like PAPIRUS would help to improve and extend the knowledge of these materials.

- The market sometimes moves faster than reality. New materials are being researched by powerful research groups and companies. However, this progress needs to be supported by suitable policies promoted by administrations and companies.

- Users need also to be conscious of the importance of the issues presented in this work and be brave to use these products instead of cheap and easy alternatives that in few years might be obsolete and even counterproductive. Proper dissemination, again, would be a powerful tool to show the benefits of a deep renovation.

It has been stated that the market moves quickly. Therefore, it would be necessary to keep a constant vigilance in its evolution. The materials presented in this document will soon spread among small and local companies. Then, the range of products will increase and they will become more competitive. A suitable knowledge of the market would help to select the best possible option. On the other hand, new energy-effective materials and systems will be created. This is the current trend in the construction-materials sector, and the main companies do not want to fall behind.

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