Storepet – European Project of an Innovative Thermal and Acoustic Insulation Solution for Construction Materials

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Short Summary

The Construction Cluster „DUNDJER“ participates together with number of distinguished research and development organizations in EU, in the 7th FP European project entitled STOREPET (FP7-SME-2011-2, Proposal 286730). STOREPET is a project which goal is develop an innovative thermal and acoustic insulation solution based on phase change materials in building sector. StorePET will be especially designed for lightweight and low thermal mass building envelope structures, as well as for any other residential/commercial/governmental new or refurbishing building projects, with extra insulation and heat storage capacities needs. With a project budget of € 2.4 million, it has been estimated that the new product will produce new streams of revenue worth € 170 million in the materials and energy savings worth above € 300 million. The research is at a moment in progress. One of closing meetings, with presentation of final research results will take place in Niš, Serbia, in the year 2013. The Construction Cluster „DUNDJER“ will have all rights and royalties, including regional production and merchendise.

Key words: building materials, thermal insulation, acoustic insulation, light building constructions, energy efficiency, sustainable building.

1. INTRODUCTION

New building strategies addressing climate change effects and reduction of heating/cooling energy are two fundamental issues at EU level. Figures as the 35,000 excess deaths attributed to the last heat wave in the continent in 2003, or 10% of the world’s energy being used just for heating of buildings support European citizen’s concerns and new EU legislation. New national and communitarian stringent directives, together with the economic slump of the construction sector (showing two digit shrinkage rates) have set extremely high challenges to the already weakened companies in the construction sector, especially the SMEs. A market need and a new opportunity for them is researching competitive solutions for thermal and acoustic insulation of light-weighted constructions, a broadly recognized market driver for the next decade. Lightweight constructions represent an economical alternative to traditional buildings, one of whose main drawbacks is the very high energy load needed to keep internal comfort conditions, as they are unable to curb rapid swings of temperature. When compared to heavier weight materials buildings, it’s estimated that to maintain a thermally comfortable temperature range of 18-24°C, low weight materials use between 2 and 3 times the heating and cooling energy needed by a heavy weight material construction.

2. PROJECT DESCRIPTION

The project concept is based upon the fact that outdoor/indoor heat exchanges (which play a significant part of lightweight buildings cooling and heating loads) can be potentially controlled by a new fibre insulation that possesses a thermally active heat storage capacity. During the day, when temperature rises, the peak loads can be largely absorbed by a PCM-enhanced fiber insulation layer, only to be slowly discharged back to the environment later (during the night time, when outside temperature drops), without affecting the interior building energy balance, as it is aided by the presence of an standard low heat transfer fiber insulation layer. This approach will provide a much slower response of the building envelope to daily temperature fluctuations, helping maintaining inside temperature in a comfortable range and thus avoiding the need for extra energy consumptions to accomplish it. Effective levels of indoor comfort will be also guaranteed by the well known fiber materials excellence, when it comes to reduce airborne noise transmission and its superior performance upon controlling the sound resonance in construction cavities.

3. ENVIRONMENTAL CONTEXT

Currently buildings account for 40% of the world‘s energy and almost half of the today‘s Green House gas emissions. This means that buildings contribute more greenhouse gases than traffic, which is estimated at 31%, and industry, estimated at 28%. When we breakdown and analyze buildings‘ energy consumption, the most worrying aspect is that most of this energy used for heating, cooling or ventilation is needlessly wasted or resulting of poor insulation and all the recent projections claims that this consumption will rise considerably on the next years to come. Under this scope, the last Intergovernmental Panel on Climate Change (IPCC) recommendations has stated that worldwide governments, businesses and individuals must aggressively start to reduce energy use in new and existing buildings, in order to reduce the planet‘s energy-related carbon footprint by 77% (against the predicted 2050 baseline), and stabilize CO_2 levels to reach the level called by IPCC. To reach this objective it‘s estimated that global building sector needs to cut energy consumption in buildings 60% by 2050, in order to meet the global climate change targets.

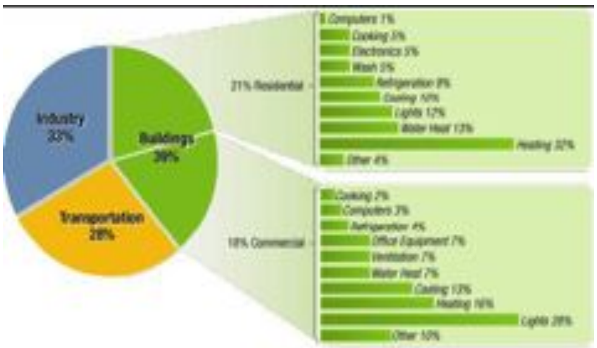

Fig. 1. : Distribution of world energy consumption

With such high levels of energy consumption clouded by severe climate change estimations, the European Community (EC) has triggered a significant number of regulatory and legislative actions. In March 2007, the European Council set clear goals for a reduction of 20% by 2020 in the total energy consumption (below 2005 levels), with a 20% contribution of renewable energies to total energy use and a 20% reduction of greenhouse gas emissions with respect to 1990 figures. In this context, the building sector must assume very ambitious objectives on energy consumption cuts of around 165 Mtoe (millions of tons of oil equivalent) and contribute with 50 Mtoe from renewable energies by 2020. To underline the magnitude of the task, these figures are equivalent to the total joint energy consumption of Spain, Portugal, Greece and Ireland in 2004.
In May of 2010, the new *Energy Performance of Buildings (EPB)* Directive was finally adopted as Directive 2010/31/EU. It calls for improved national regulations upon new and renovated houses energy efficiency, with very ambitious standards and mandatory goals. It also includes a framework for national requirements, related with **heating/cooling** and ventilation systems. In July 2012, the

new directive shall be implemented, though many elements including the regulation of building systems will only be fully enforced by July 2013. By the end of 2020, new buildings in the EU must consume “nearly zero” energy.
With a current stock of around 160 million buildings in the EU, the latest EPB Directive also tack the retrofit of existing buildings, including historic ones towards an effective action against climate change. As for the new buildings, universal trends now show a movement towards lightweight and modular timber or steel constructions (with less site wastes involved and lower embedded energy materials), with global demand for prefabricated housing and elements growing at 3.4 % per year, for a market valued at €51 billion in 2004 for complete buildings alone.

4. THE CONSTRUCTION SECTOR CONTEXT

The construction sector is the one that has suffered most the yet present downturn, partly related to several significant construction bubbles, but also hardly affected by the financial institutions‘ credit crisis.
In particular, focusing on the segment of lightweight prefabricated housing of the building industry, consisting of wood or light steel frame (LSF) and panelized pre-cut structures is expected to show in the next decade the largest growth in terms of novel solutions and production worldwide. Within this segment one of the most important subjects related with building‘s energy efficiency is the use of appropriate insulation materials, both for warm and cold climates (air conditioning is no longer considered an energy-efficient alternative as it accounts for almost 15% of the total energy consumed in Europe). Boosted by present and provisional needs, worldwide consumption of insulation materials is projected to expand 3.8% per year through 2012.. Maintaining the last decade trend, foamed plastic insulation will continue to account for the largest portion of total demand through 2012. Economic expansion in the developing countries of Asia will raise the demand, preferably for foamed plastic, both in building construction and in the production of household appliances. Fiberglass insulation is expected to expand its presence outside of North America (mainly Europe, Asia and all the BRIC - Brazil, Russia, India, and China), while mineral wool will see its share of the market shrink due to the competition of glass wool. Other fiber alternative materials mostly made from recycled materials, like nonwoven technical insulations, will continue to be niche products if they don‘t endorse and push forward their performance.
The increasing demand for energy-saving technologies has contributed to a renewed research for thermal materials that can actively control heat flux environment variations - Phase Change Materials (PCM). The global PCM market is expected to grow from $300.8 million in 2009 to $1,488.1 million in 2015, at an estimated CAGR of 31.7% from 2010 to 2015. The paraffin-based PCM market commands the largest share of the overall PCM market in terms of value, while salt hydrate-based PCMs lead the market in terms of volume. Building and construction currently forms its largest application market, due to the globally increasing demands for indoor temperature control.
European companies in the increasingly knowledge-intensive construction sector need to react quickly to this situation and develop more protectable innovative solutions to remain innovative. In particular, the requirement of higher energy efficiency for buildings has been identified as the primary driver for the construction materials industry. StorePET will provide this EU sector and particularly to the SMEs an excellent knowledge-based competitive tool to ease the recovery and face the near future challenges of our Construction Sector.

5. THE TECHNICAL PROBLEM

Lightweight constructions represent an economical alternative to traditional buildings, one of whose main drawbacks is the very high energy load needed to keep internal comfort conditions, as they are unable to curb rapid swings of temperature. When compared to heavier weight materials buildings, it‘s estimated that to maintain a thermally comfortable temperature range of 18-24°C, low weight materials use between 2 and 3 times the heating and cooling energy needed by a heavy weight material construction.

When comparing the two types of constructions, studies have showed the heavyweight construction could suppress more easily the effects of possible climate change scenario, by maintaining a lower internal temperature than the lightweight construction for most of the time period, with peak temperatures up to 4.5°C cooler. Other studies have revealed that the difference between the peak external and internal temperatures can reach 8º C, when comparing both structures and that a peak temperature delay up to 6 hours can be observed, these delay and amplitude being a complex function of the wall thermal conductivity, the specific heat and several local temperature gradients around wall surfaces. The reason for this huge difference lies on the different thermal mass presented by the two types of constructions. In the case of dwellings for instance, the heat storage and thermal mass properties can vary significantly from 55kJ/m2K for a lightweight timber frame construction to 500kJ/m2K for a solid masonry construction. Thus, thermal mass can be hugely helpful to maintain indoor thermal comfort. Lightweight buildings have a “quick thermal response” and will heat up and cool down over a shorter period than heavyweight building that have a “slow response” (see Fig. 2).

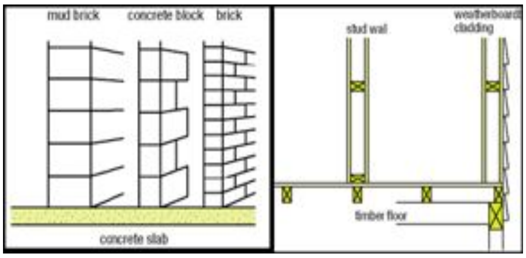

Fig. 2. Materials with high (left) and low (right) thermal mass capacity

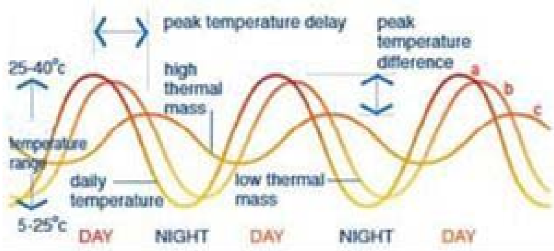

Fig 3. Daily temperature range fluctuations

Thermal mass is most effective in places and in seasons with large daily temperature fluctuations above and below the balance point temperature -BPT- of the building (BPT is the outdoor temperature below which heating will be required in the building because internal heat gains are less than heat loss through envelope and ventilation). In such cases substantially energy is saved by avoiding a significant portion of heat flux being transferred through the envelop backward and forward. Often, the benefits are greatest during summer and fall, when fluctuations above and below the comfort temperature occur. Nevertheless, the same concept can theoretically be used to moderate heat flux under either extreme cold conditions or extreme warm conditions, where outer temperature ranges are well above or below the comfort temperature.

When outdoor temperatures are at their high peak in warm climates, the inside of the building remains cool because the heat penetration through the mass is delayed. If the heat that is stored during the day hours could be evacuated selectively to the exterior at night, the effect of the thermal mass would be very similar to a high performance insulator.

In cold climates requiring intensive heating, thermal mass can be used to effectively collect and store solar gains and to store internal excess heat during the day and selectively release it back inwards. Buildings using electric heating/cooling can simultaneously use off-peak hours enjoying cheaper supply tariffs as daily storing phase. The result will be a substantial net reduction in energy consumption and additional bill cuts due to cheaper electricity.

New European states‘ regulations are more and more concerned about energy efficiency of existent and future buildings and finally looking at **thermal capacity** as a key element for it. For instance, the new UK‘s Building Regulations, recently implemented on the 1st October 2010 refers that thermal capacity of all the internal and external construction elements must play a decisive role on this goal, and used to reduce the heating and cooling demands of a building. Onwards, it will not be enough to consider only the overall heat transfer coefficient (U-Value) of the building elements (level of insulation), but also their related effective thermal capacity per unit area - Thermal Mass Parameter (TMP).

Generally, highly insulated structures cannot efficiently substitute a lack of thermal mass. Thermal mass stores and re-radiates heat, while insulation stops heat flowing into or out of the building. A high thermal mass material is not generally a good thermal insulator and the best insulation material has almost no thermal mass. Thus, in harsh hot climate conditions, the only way to

maintain a comfortable temperature inside a lightweight building on a summer day without installing active air conditioning is to somehow increase its thermal mass. You can do it in traditionally manner with heavy building materials, or by introducing latent heat storage materials in its construction.
Up to now the only solution it‘s to combine different materials separately for maximum performance. While it is reasonably easy for the heavyweight masonry sector to do this, the quest for thermal mass by lightweight construction builders (that rely almost exclusively upon insulation), it‘s still seen as a battle that needs urgently to be won in order to stay competitive for the years to come. Although there have been a great deal of resources invested on research (mainly on the US), worldwide construction market is still waiting for economical products that can effectively combine the best of the two worlds (thermal insulation and thermal storage properties), without forgetting the noise insulation ability on a **single, affordable and easy to work product**.
The goal of this project is the development of a new thermally enhanced fiber insulation product solution with the help of phase change materials (PCMs). PCMs are substances with high heat of fusion (high latent heat storage) which, by melting and solidifying at a certain temperature, are **capable of storing and releasing large amounts of energy**. Heat is absorbed or released when the material changes from solid to liquid and vice versa. PCMs are been used for several years as thermal mass components in buildings with some degree of effectiveness upon building energy performance. Today, there are many commercial PCM products available in the market, either in the form of a single material, or in the form of integrated products placed on the interior surfaces of walls, ceilings or floors (such as PCM integrated gypsum wallboards, concrete, plasters, etc). These products are generally used to reduce indoor space day/night temperature swings, due mainly to diurnal solar gains through glazing, by storing autonomously the heat during the day and release it back during the night, providing an extra heat source to keep the inside comfort. To understand the extent of PCM technology upon energy saving possibilities, studies have found that an area of approx. 120 m² using an enhanced plaster with a microencapsulated (thin polymer container) paraffin wax PCM (with a maximum heat storage of 110 J/g), could match up about 40,000 kJ, corresponding to more or less than 11 kWh. This energy consumption is equivalent to the cooling performance of an air-conditioning unit with an input power rating of 4 kW, used at full capacity for 1 hour a day. For a predicted PCM working process for five hours a day during 10 weeks of significant hot weather a year, that would have the same effect as using air conditioning unit for 300 hours, which corresponds to an average saving of 228 €/year, considering the initial equipment investment.
However, none of today‘s building materials incorporating PCMs in a stand-alone product are designed either to perform as heat flux blockers through the building envelope (external walls and roofs), or as a noise insulator. **The StorePET project intends to overcome this market gap** and act differently from any other PCM available product, **using PCMs fiber incorporation technology to excel the extra advantage of the conventional fiber insulation work**, regarding the large temperature fluctuations that take place in residential attics or at the exterior wall surfaces of lightweight building structures.

6. THE PROJECT CONCEPT

The project concept is based upon the fact that outdoor/indoor heat exchanges (which play a significant role in lightweight buildings cooling and heating loads) can be potentially controlled by a new fiber insulation that possesses a thermally active heat storage capacity. During the day, when temperature rises, the peak loads can be largely absorbed by a PCM-enhanced fiber insulation layer, only to be slowly discharged back to the environment later (during the night time, when outside temperature drops), without affecting the interior building energy balance, as it is aided by the presence of an standard low heat transfer fiber insulation layer. This approach will provide much slower response of the building envelope to daily temperature fluctuations, helping maintaining inside temperature in a comfortable range and thus avoiding the need for extra energy consumptions to accomplish it. Effective levels of indoor comfort will be also guaranteed by the well known fiber materials excellence, when it comes to reduce airborne noise transmission and its superior performance upon controlling the sound resonance in construction cavities.

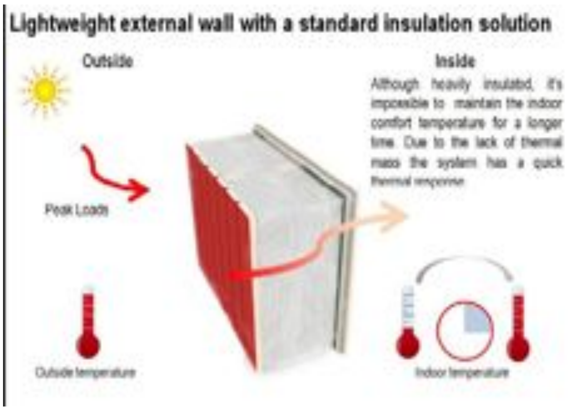

Fig. 4. Standard external insulation solution

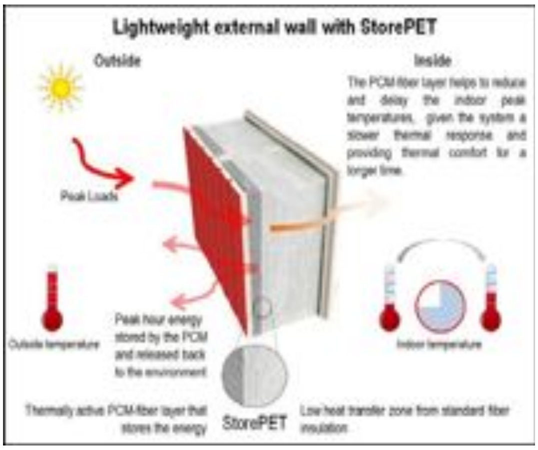

Fig. 5. External insulation with StorePET

From the point of view of energy efficiency design, the added value of the PCMs is its extra ability (on top of the thermal resistance) to reduce energy consumption in the building. The Fig.5. shows how StorePET solution would significantly reduce inside temperature fluctuation and therefore the needed heating/cooling load to keep temperature constant, in a scenario of high fluctuation of outside temperature.

The same conceptual solution when applied to extreme hot or cold temperatures would need different products (PCMs‘ fusion points, relative concentration and distribution along the matt cross section would be different to avoid external heat than to recover internal heat), and installation layouts (matt allocation, ventilation systems) would as well differ. Maybe the most notable difference is the convenience of an additional ventilation system to take full advantage of the thermal inertia provided by the PCMs.

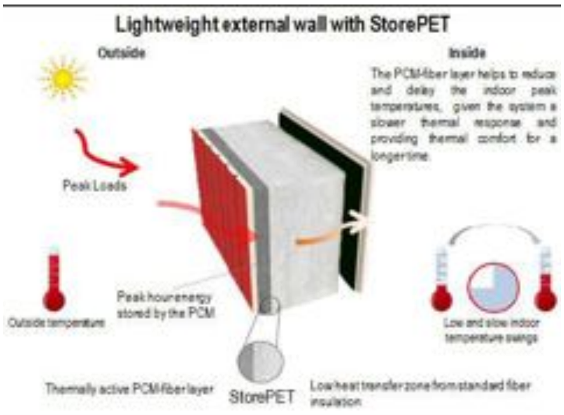

Fig. 6. Extreme high temperatures

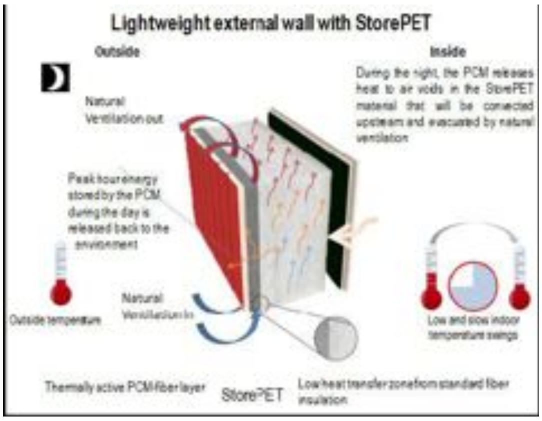

Fig. 7. StorePET with additional ventilation

The above figures (Fig. 6 and Fig. 7) intends to illustrate a scenario of extreme high temperatures. During the day, the PCM acts as a thermal barrier and only a fraction of heat reaches the inside, while the rest is stored in the PCM bat. When temperatures go down in the night (but yet above the comfort temperature), the bat warms up surrounding air. If properly ventilated, natural convection pushes warm air up and then out to the outside, refrigerating the PCM and avoiding storage heat to penetrate the building. An appropriate structure of the bat enabling air mobility in the plane of the facade and restricting the perpendicular direction will favor lateral convection for homogeneous refrigeration and vertical convection for evacuation. The design and manufacture of such a structure through a multilayered approach and other alternatives will be a relevant task of the non-woven panel research.

Although more suitable for warmer climates, while tailoring its composition with different phase change temperature materials and different installation layouts, StorePET will be able to respond to a broad range climate patterns. This will give it a unique and unmatchable versatility amongst other building insulation products. Out of each design temperature season, the product will just act like a normal fiber insulation material, keeping all other thermal and acoustic properties intact.

7. THE SCIENTIFIC, ECONOMIC, AND SOCIAL OBJECTIVES OF THE PROJECT

The main goal of the StorePET project is to develop a new nonwoven technical insulation product that integrates phase change materials for heat storage capacity skills. Maintaining the superior levels of thermal and noise insulation commonly recognized for fiber materials, StorePET will be especially designed for lightweight and low thermal mass building envelope structures, as well as for any other residential/commercial/governmental new or refurbishing building projects, with extra insulation and heat storage capacities needs. Although expected to be more effective in places and seasons with large daily temperature fluctuations, where it‘s possible to take full advantage of its performance abilities, this new product can also be used as standard insulation on any type of climates and a secure choice to counteract global warming rising temperatures.
To ensure that the project is a success we have defined clear objectives that are quantified, measurable and focused during the project‘s work package tasks program and continuing accounted on related deliverables reports.

7.1 SCIENTIFIC OBJECTIVES

- Achieve a clear and extensive understanding of the lightweight building systems currently available, their technical needs and most commonly thermal and noise insulation materials used, its relevant standards and building regulations dealing with the latest energy efficiency requirements;
- Clearly define the theoretical principles evolving thermal conductivity and heat storage and transfer behavior of PCM fiber composite materials, as well as the fundamentals ruling its acoustic absorption and insulation;
- Noticeably identify the best technical fiber characteristics and which PCMs materials and are most likely to be used, based on their thermodynamic, chemical and physics properties, production costs, and technological skills aiming the nonwoven PCM-fiber integration and its end using goals.

7.2 TECHNOLOGICAL OBJECTIVES

- Develop the product‘s design and the technology for its making by building a newly prototype line system for PCM-fiber integration and trial product manufacturing;
- Refine StorePET production technology, aiming to combine the best technical properties with the least embodied energy necessary for its production, using the most cost effective raw materials with the highest recycled content possible and least energy consuming production lines;
- Define the active ventilation systems that should accompany the installation of StorePET insulator, in areas of extreme absolute temperature but low fluctuation;
- Develop a software for thermal and acoustic properties evaluation aiming the design of the optimum StorePET product for a type of installation and a set of variables. It will bring an easy-to-use interface for professionals non highly qualified on the use of sophisticated simulation tools, but will relay on finite elements modeling, properties of raw materials, layer zone designs and climate patterns of the most plausible entrance markets.

7.3 PRODUCT TECHNICAL OBJECTIVES

- Achieve on a lab scale using a guarded hot box facility, reductions in heat flow of about 40% with the new PCM-fiber product, when compared on the equal conditions with the same fiber material produced without the PCM content;

- Achieve by field tests potential and significant cooling load reductions during a spring-summer season period. The fulfillment of this objective will be dependable on the location of these tests. For places with large daily temperature fluctuations during the hot season, peak-hour load reductions higher than 20% and cooling-dominated loads reductions up to 40%, shall be expected (representing real energy savings), when compared to regular fiber insulation materials (mineral wool, glass wool, etc.);
- Secure a thermal conductivity K (W/(mK)) not higher than 0,04 and preferably under this value;
- Accomplish a thermal resistance - RSI value (m^2K/W) not less than 2,5 for a nominal thickness of 100mm;
- Achieve a noise transmission insulation (Rw) not less than 55dB for StorePET, when placed between a wall partition made of a double drywall panel, with a 6cm cavity space;
- Guarantee all the other technical requirements to meet the national and communitarian building codes and regulations for each proposed entrance market. Special emphasis shall be given upon moisture and fire resistance, this last one with European fire classification stated not less than Class Bs2d0.

7.4 ECONOMIC OBJECTIVES

- Accomplish significant energy savings concerning the reduction of air-conditioning needs related with the walls/roofs heat exchanges, and a controlled and balanced price for this new product, aiming a reasonable payback time for its end users considering the energy saving possibilities (within a maximum of 5 years).

7.5 SOCIETAL OBJECTIVES

- Increase the consumer (building constructors and home-owners) knowledge and acceptance of this new thermally enhanced insulation product;
- Demonstrate the market demand for a new building insulation material like StorePET;
- Protect/increase the employment in related companies, from raw materials and technical non-woven producers, to PCM suppliers, up to the overall building construction market chain;
- Increase citizen‘s level of indoor comfort and reducing health problems related with thermal and acoustic insulation issues;
- Contribute for the reduction of global CO_2 emissions by joining the effort to effectively decrease the building sector account for energy usage.

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