Projet cofinancé par le Fonds Européen de Développement Régional (FEDER)
Project cofinanced by the European Regional Development Fund (ERDF)

Identified Technologies for the Glassolating pilot plant (ES)

PROJECT TITLE: Enhancing Mediterranean Initiatives Leading SMEs to innovation in building energy efficiency technologies

AXIS: Strengthening innovation capacities

OBJECTIVE: Dissemination of innovative technologies and know-how

INTERNAL MED CODE: 1C-MED12-19

Deliverable number: D4.1.1

Work Package: WP4

Action: 4.1

Responsible partner: CIRCE

Authors: Miguel MARCO

Status: V1

Distribution: Public

Date: 07/12/2013

Table of contents

List of abbreviations and terms – if applicable

CIRCE	Stands for Centro de investigación de recursos y consumos energéticos, headquartered in Zaragoza, Aragón region, Spain
Glassolating	is the short name of the pilot action implemented in Spain, Aragón region, dealing with *Phase Change Material technology in glass envelopes*
HVAC	means Heating, Ventilating and Air Conditioning
LHS	stands for Latent Heat Storage
PCM	stands for Phase Change Material, designating a material which stores and releases latent energy depending on the temperature of its ambiance.
R&D+I	means Research, Development and Innovation

1 Introduction

This report is the Aragón (Spain) fold of Deliverable D4.1.1., which aims at detailing the technologies that will be implemented within the pilot actions of the EMILIE project. This report refers particularly to the Glassolating pilot plant, in the Aragon region, Spain, under the lead of CIRCE.

This pilot activity is focused on demonstrating new possibilities for tertiary sector to become more energy efficient using already available technologies. It includes two different experimental set ups that will be adapted or developed to test the energy performance of glass windows doped with an innovative technology known as Phase Change Materials (PCM).

On the one hand, commercial PCM glass will be added to a part of CIRCE buildings by substitution of/ adaptation to conventional windows. On the other hand, an experimental space will be specifically designed to test this technology under a controlled environment and varying conditions.

In both cases, the aim is to compare the effect of PCM-glasses (composed of tempered safety glass + gap with PCM-plate + tempered safety glass) with standard glasses without PCM (composed of tempered safety glass + air gap + tempered safety glass).

The effect of low-e coated glasses, solar-control window films, thermochromic glasses, PV-glasses, etc. is not intended to be analyzed.

The objective of the pilot plant, therefore, is to test the degree of energy efficiency gained through an innovative system of isolation which can be easily adapted to most of the residential and commercial sector.

For that matter, two sorts of data will be needed:

1. Real data of energy efficiency gained in spaces which are being normally used along the whole year (with different weather and irradiance conditions)

2. Precise and accurate data of energy efficiency potential from the PCM technology along the year (with different weather and irradiance conditions). Therefore, this test requires a controlled and fully monitored site, where conditions can be closely determined and modified, if needed.

A whole year of measuring and monitoring will be needed, in order to test the technology in all possible conditions in what regards temperature, irradiance, wind, etc. Furthermore, for the controlled experimental site, different positions for facades and walls will be tried so factors such as the orientation or the number of sun hours.

2 Presentation of the demonstration site

2.1 Location

CIRCE's head office is a model of bioconstruction and sustainability, and a monument to state the art technology and progress in the field of eco-efficiency and energy saving. Constructed using building materials of low ecological impact, it is a Zero Emissions building throughout its Life Cycle, is environmentally friendly and a good example for future buildings.

The building itself is a R&D+I lab aiming to lay out the most advanced scientific-technological foundations worldwide in the development of Zero Emissions Constructions. It integrates techniques involving bioconstruction, energy savings, water, renewable energy and materials, thus obtaining the greatest possible efficiency with the resources available, without compromising thermal comfort.

The building consists of a net floor area of 1,743 m2 with a gross floor area of 1,990 m2 and a total built volume of 9,550 m3. The building has a compact shape and is divided into two floors. It clearly shows three elements: a round vestibule with a dome, the offices clustered around it and the laboratories. The laboratories constitute a rectangular building at 36º to the east-west axis, which acts as a barrier to the prevailing wind (North wind). This avoids the considerable temperature drops in the winter months. At the same time, there is a 13-metre high solar chimney, which acts as passive cooling system.

The heating and cooling demand of the building, calculated using the hourly-based Spanish simulation tool Leader, are 38.5 and 11.8 kWh/m2 year (the ratio is expressed in useful, air conditioned square meter) respectively.

In synthesis, this location offers all kind of benefits to the project:

- Logistically: Being nearby CIRCE researchers, it becomes much easier to monitor and experiment with different possibilities
- Technologically: Being in the Engineering campus premises, all sort of infrastructures and ancillary equipment is available
- For dissemination: Since CIRCE building is already a demonstration site, many more stakeholders will have the chance to visit the EMILIE project pilot plant.

2.2 Technology and principle of operation

Passive methods can manage the thermal energy exchanged in a building, which contributes to downsizing of the heating, ventilating and air conditioning (HVAC) equipment and reducing the energy demand. In this sense, the thermal storage approach plays an important role in the process, especially focusing on the incorporation of latent heat storage (LHS) systems by introducing phase change materials (PCMs) into construction structures [1].

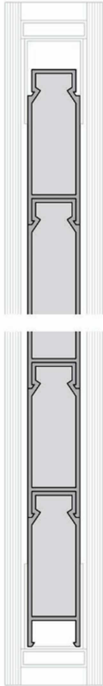
PCMs can passively cool and heat a living area without including heavy mass or high extra space typically required by sensible heat storage systems [2]. These materials foster the thermal inertia of the construction elements leading to lower temperature peaks.

PCM added to construction materials can be based on organic (paraffin, fatty acids and polyethylene glycol) or inorganic (salt hydrates) compounds. In comparison to inorganic PCMs, the organic compounds show congruent phase changes, they are not dangerous because of their chemical stability, they can be recyclable and they have a good nucleation rate. On the other hand, although salt hydrates present high volume change and supercooling and segregation phenomena, their main advantages are the high volumetric LHS capacity, high thermal conductivity and the sharp phase change [3]. Moreover, inorganic compounds as sulphates are indeed integrated in other building materials [4].

Phase Change material inside the double glazing window.

Additionall [illegible] into the walls, ceiling and floor of buildings for further thermal energy storage. In this pilot activity, the PCM will be added to glazing elements to be used as windows. Selecting the appropriate PCM for the climate condition is essential to improve the heat transfer mechanism in the building. In this case, where the main goal is the incorporation of this material in tertiary buildings, the selected PCM glass should manage the temperature within the comfort range, 21-24°C.

Glass 1	Tempered safety glass
Gap between panes (GBP 1)	Gap between panes with PCM plate
Glass 2	Tempered safety glass



Element thickness	~ 38 mm
Thickness tolerance	-1/+2 mm
Min. fold width	~ 44 mm
Weight	max. 58 kg/m²
Max. surface area	4,2 m²
Max. height	280 cm
Max. width	150 cm
Light transmission for crystalline PCM	0 - 38 %
Light transmission for liquid PCM	4 - 55 %
Storage capacity1	1185 Wh/m²
Storage temperature	26 - 30 °C

3 Description of the pilot plant

3.1 Characteristics of the pilot plant setup and implementation of improvements

Taking into account the building configuration and the glazed surfaces, different potential alternatives have been proposed and analyzed to implement the new glass technology. These options are shown in Table 1 in bold.

Standard double-glazing window 4/16/4 in CIRCE building

Type	Location	Surface	
Float glass 4 mm	Indoor: doors and windows	22.02	m^2
Float glass 6 mm	Laboratories	13.66	m^2
Double glazing 4/16/4	**Outdoor: doors and windows**	**83.11**	$\mathbf{m^2}$
Double glazing 4/14/4	Laboratories	5.60	m^2
Single glazing (greenhouse) 6 mm	**Greenhouse vertical windows**	**44.33**	$\mathbf{m^2}$
Laminated Safety glass 6+6	**Greenhouse roof windows**	**51.88**	$\mathbf{m^2}$
Laminated Safety glass 10+10	Laboratories	3.84	m^2
Laminated Safety glass 6/12/4+4	**Roof windows in corridors**	**35.30**	$\mathbf{m^2}$
	Total glazing surface	259.57	m^2
Possible surface to implement the PCM glass		**214.6**	$\mathbf{m^2}$

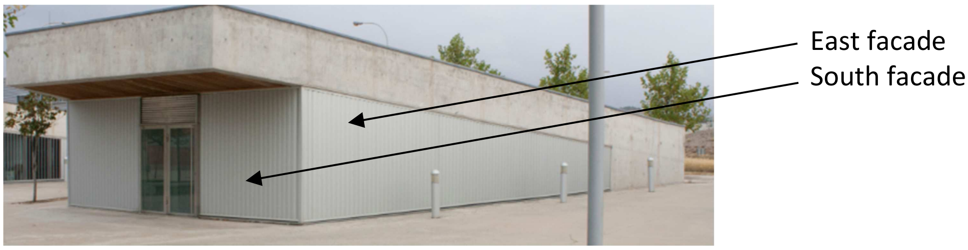
Glazing surfaces in CIRCE main building

The main problems detected for this particular site will be related to the sort of use given to every specific location. In order to have relevant and objective data, it is of the utmost importance to determine the number of people, present equipment and type of use related to the locations where the PCM have been installed. Furthermore, we should find to similar locations with parallel activities and conditions, so the test of PCM can be performed in comparison to an equal location with standard glazing.

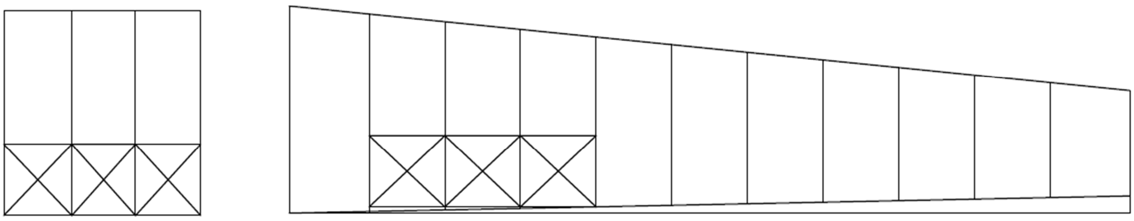
For that purpose, another interesting possibility was detected, referring to the use of two identical buildings besides CIRCE building, always in the campus premises and still owned by the University of Zaragoza (as CIRCE Building itself). The conditions in all regards remain the same (technologically, legally, etc.), but their potential to host an experiment is much higher, since the two buildings are absolutely identical, with the same level and type of use, and same orientation to the sun. The authorization to use them was achieved and therefore, this option was finally selected.

Image of one the selected buildings
(in the picture, the glass walls are covered by a protector due to the bad weather)

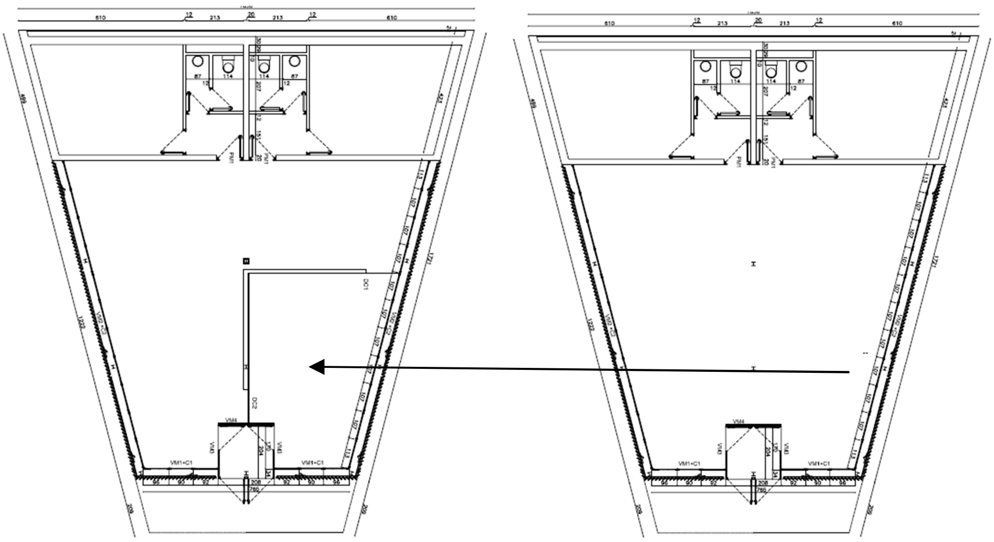
In order to improve the monitoring stage and obtain a higher representation of the PCM behaviour inside the selected room within the buildings, the PCM glass will have a high glazing ratio in relation to conventional walls. In this sense, the performance of the PCM will be optimized and the influence of other construction materials minimized. The South and East façade will be equipped with PCMs, as shown below:



Furthermore, aiming at testing the energy efficiency gained without really modifying the lighting characteristics of the building, it was decided to install the PCM material in the lower part of the windows, thus allowing the natural light to fill in with no interference.



The room within the building will be specifically designed in order to balance the floor square meters, air volume and glass square meters in the optimal way to perform the experiment. As can be seen from above, the result will be the left graph:



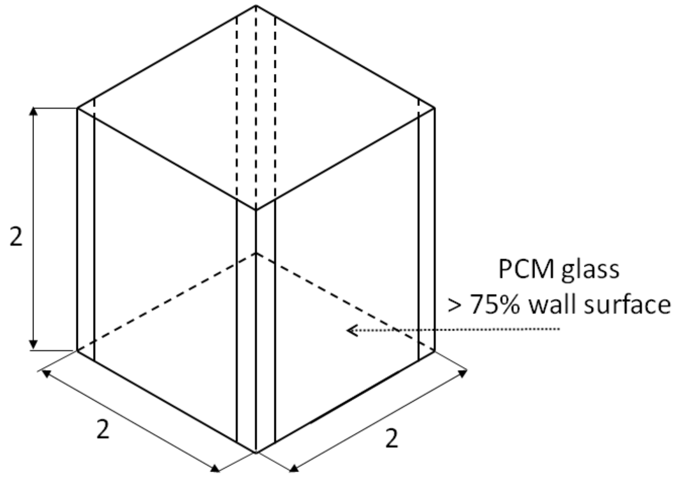
Both experimental buildings, from now on referred to as 'modules', will be equipped with AC devices, fan-coils, and a number of measuring and monitoring devices which will constantly inform the experts about the performance in both modules. An IT modem will also be installed so all data will automatically be recorded in a database for its later analysis and process.

CONTROLLED EXPERIMENTAL SET UP

As was already mentioned, besides the installing of the PCM glass in a real building, this pilot activity includes the development of a specific set up to test the behaviour of the PCM technology in controlled conditions with a higher glazing ratio of surface covered by the PCM glass. This experimental set up will be designed considering at least 75% of the wall surface available to implement the PCM glasses. In this sense, the performance of the PCM will be maximized because other influences in the walls would be highly avoided. If the glazing surface is very small compared to other material surfaces in the walls that interact with the outside/inside, it is possible that the thermal influence of the PCM would not be significant enough.

The core idea, therefore, is to obtain accurate and precise data on how the PCM materials increase the energy efficiency in varying conditions of sun, temperature and orientation.

As a preliminary approach, this experimental facility described below would be a square room of approximately 2x2x2m to maintain the symmetry and monitoring equally the four wall orientations (North, South, East and West). The final value of the dimension could be changed if it is necessary depending on availability of PCM glass sizes and cubicles options in the market.



Experimental set up preliminary design

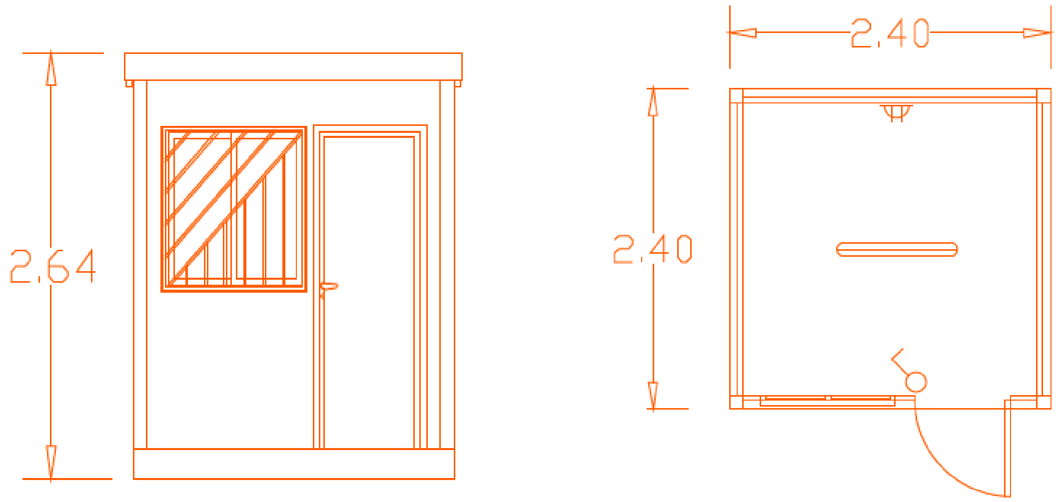
During the design and exploration period, several options were studied for this controlled experimental set up. A number of factors and variables were studied, such as size and volume of the cubicle, thickness of its walls, building materials used, etc. After analysing all the options as well as the best potential to render the due outcomes, it was decided to work with two equal cubicles with a standard size of 2,40 x 2,40 x 2,64 as presented in the graphs below:

Cubicles scheme

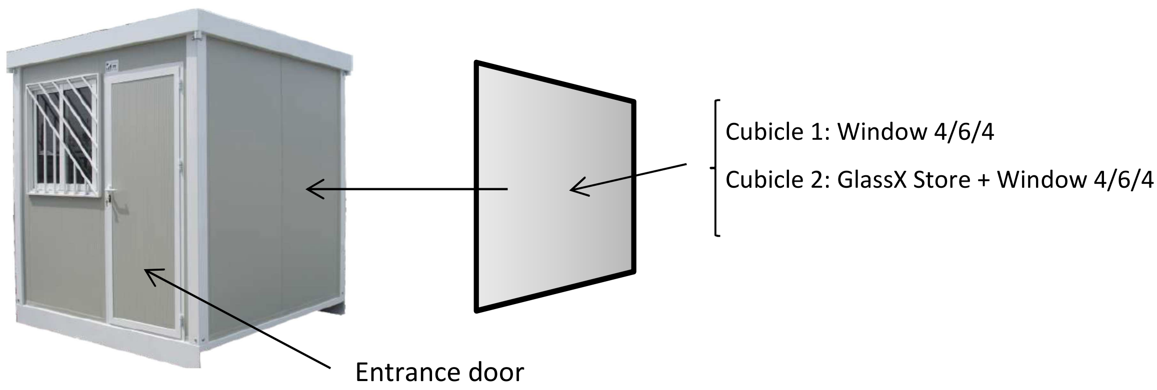
Cubicles specifications:

Structure: Electro-welded base and roof structure, with U200 beams running lengthwise.
FLOOR: CTB-H 19 mm. moisture-proof phenolic board. Electro-welded PVC coating (Overload 250 Kg/m2)
Wall Enclosure: 40 mm. sandwich panel with pre-lacquered paint finish on both sides (sides and roof)

Exterior Joinery: (1) Two-panel sliding window with 4mm. glazing, in white lacquered aluminum 1.00 x 1.00 m.
(1) Steel safety irons 1.00 x 1.00 m. (1) Iron exterior door 0.80 x 2.00 m. panel-lined
Electricity: (1) Exterior connection box, protector panel
(1) 2x36W lamp (1) SCHUKO type electrical outlet base (1) Light switch
Outside installation hidden by PVC UNEX type conduits



Both cubicles will be equipped with AC devices, electricity plugs, light and door. Besides, one of the facades will be entirely made out of double glazing window, thus having a high percentage of window compared to the volume of the cubicle. In one of the cubicles, 90% of the window will host PCM glass, so the experiment can bring in clear and solid data.



3.2 Monitoring, collection and evaluation of feedback/results

All experiment locations, CIRCE buildings (modules) and experimental cubicles, will be monitored over long time periods to analyze the thermal performance inside the room and the elements including sunlight hours and night hours to cover the charges and discharges of the PCM behaviour. Since PCM performance depends on the outside climate as has been concluded in other studies [5], it will also be interesting to obtain data in different climate seasons to compare the results.

Temperature will be measured continuously on the surfaces of the glazing with PCM and without PCM, subject to the same physical conditions, as well as the inside and outside temperature. To do this, temperature sensors (pt100 or K type) will be used. Additionally, other point in the room or materials could be subjected to be monitored depends on the results obtained and the best option to improve the monitoring stage.

Additionally, other techniques such as heat flux sensors or thermography will be considered to be used in the monitoring to characterize deeply the glass PCM performance.

4 Expected impacts

Considering its thermal properties, PCM glasses can reduce the building's heating and cooling load by 30% approximately. This theoretical figure depends strongly on the glazing surface, facade orientation and shutter geometry. Impact on work conditions and other socioeconomic impacts associated to the use of PCM technology for windows will be assessed.

The main outcome expected from the experiment is the real and practical assessment of the PCM glass in day a day conditions. For that matter, two different sets of data are needed:

1. Scientific data, assessing the best potential which can be associated to the use of PCM in real structures (experiment performed with the cubicles). This data, accurate, precise and reliable, will therefore demonstrate whether the theoretical savings proposed are achievable or not (about 30% more efficient).
2. Field work data, assessing the savings and efficiency gained in a building which is actually being used, and which has a conventional and more restrict number of PCM glasses installed. Beyond the theoretical savings demonstration, a real conditions test must be conducted, to assess to what point those savings can be replicated in existing tertiary buildings.

The results of both experiments will be the essential base to analyze the cost-benefit ratio linked to the use of PCM in standard tertiary buildings, and design accordingly the most suitable actions for its promotion and use, thus increasing energy efficiency in our buildings and cities throughout Europe.

5 References

1. Pasupathy, A., R. Velraj, and R.V. Seeniraj, Phase change material-based building architecture for thermal management in residential and commercial establishments. Renewable and Sustainable Energy Reviews, 2008. 12(1): p. 39-64.

2. Zhang, Y., et al., Application of latent heat thermal energy storage in buildings: State-of-the-art and outlook. Building and Environment, 2007. 42(6): p. 2197-2209.

3. Kuznik, F., et al., A review on phase change materials integrated in building walls. Renewable and Sustainable Energy Reviews, 2011. 15(1): p. 379-391.

4. Kloppmann, W., et al., Building materials as intrinsic sources of sulphate: A hidden face of salt weathering of historical monuments investigated through multi-isotope tracing (B, O, S). Science of The Total Environment, 2011. 409(9): p. 1658-1669.

5. Aranda-Usón, A., et al., Phase change material applications in buildings: An environmental assessment for some Spanish climate severities. Science of The Total Environment, 2013. 444(0): p. 16-25.