Grant agreement no.: 260056

D7.5 Refurbishment of a real apartment and office

Author(s):

	Ignacio del Val	**ACCIONA**
	Jesús Dueñas	**ACCIONA**
	Ángel Cerviño	**ACCIONA**
	Mónica García	**ACCIONA**

Issue Date	August 2012 (M26)
Deliverable Number	D7.5
WP Number	WP7: Demonstration of developed Phase Change Nanomaterials
Status	Approved by Steering Committee

Document history			
V	Date	Author	Description
1	August 2012	Ignacio del Val	Draft version
2	August 2012	M Garcia	Draft version

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Summary

The overall objective of NanoPCM project is the development, implementation, production and demonstration of a novel PCM to use in insulation of buildings.

At this point, numerous PCMs materials were refined in WP2 and WP3. Later, they were used in WP6 to construct different prototypes inserting these PCMs in PU foam or external composite wall layers.

As conclusion from these activities, it was extracted that the encapsulation (with different technologies) is the best option for the PCM insertion in panels for buildings.

Regarding the melting point of each material, there were chosen three kind of PCM: octadecane, fatty acids and RT-27 (Rubitherm).

The two first materials were encapsulated in SiO_2 microcapsules, while the last one was confined in LDPE-EVA microcapsules.

The last step is the behavior evaluation through real demonstration. For this, it was chosen two different demo-parks placed in Madrid (Spain) and Warsaw (Poland) to use them in cold and warm atmospheres.

Every PCM was inserted in foam insulation panels to be installed on buildings.

As combination of both aspects, as melting points as temperature profile of each location, it was chosen the materials used in each mock-up.

For these reasons, RT-27 was used in the panels installed on the walls of both demo-parks, octadecane on the roof of the Spanish one and fatty acids on the roof of the Polish mock-up.

In this deliverable it is described both the demo-park construction and the panels installation.

Abbreviations

OSB	Oriented strand board

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1. INTRODUCCIÓN

According to NANOPCM DOW task 7.4, a refurbishment of two real scale buildings was foreseen as demonstration activity for testing and energy performance behavior of developed PCM nanomaterials within the project.

Due to requirements from EC, suggesting common demonstration activities within the recently created "Nano-E2B-Cluster" (described in deliverables D8.7 and D8.8), it was decided to design and build a common demonstration strategy for testing and evaluating energy performance of the different developed nano-materials within each involved research project.

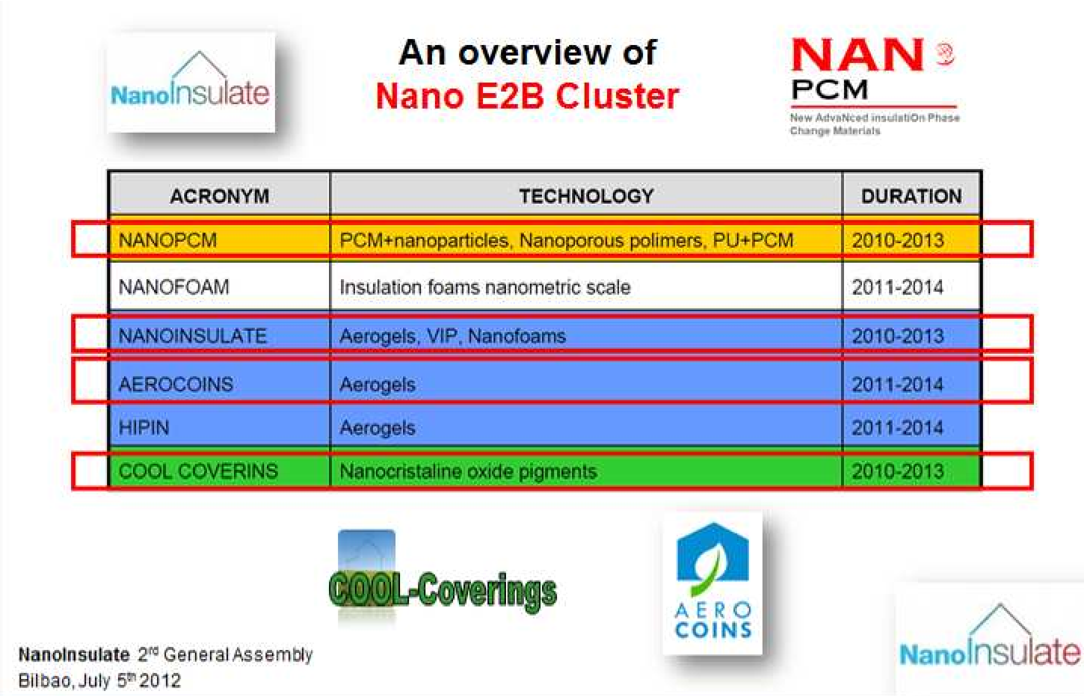
After several technical meetings (described in deliverable D8.7) about design, location and construction of a real scale building, it was decide to build up several mock-ups in two different climatic conditions (Spain and Poland). Following is described work carried out in design and build of mentioned structures.

1.1 E2B CLUSTER DEMO PARKS AT MADRID AND WARSAW

E2B Cluster Demo Park is a facility that integrates the demonstration tasks of several research projects within the Seventh Framework Program of the European Commission under the theme EeB.NMP.2010-1 *"New nanotechnology based high performance insulation systems for energy efficiency"*. At August 2012 four R&D projects form EeB PPP are involved: NANOPCM, NANOINSULATE, COOL COVERINGS AND AEROCOINS.

The integration of these demonstrations activities comes naturally after going over the technologies developed by the different projects within the cluster framework, summed up in **Figure 1**.

To prove materials performance successfully, two main aspects have to be justified: energy consumption reduction and indoor comfort improvement. So, regardless of technology type, parameters related to temperature, heat fluxes and humidity conditions must be taken into account in all the projects and sensor installation, and data logging procedures can be shared within the cluster members to a large extent, despite of small differences in the measurement strategy itself, due to material's nature (foams, cool paintings, phase change materials, etc.).



ACRONYM	TECHNOLOGY	DURATION
NANOPCM	PCM+nanoparticles, Nanoporous polimers, PU+PCM	2010-2013
NANOFOAM	Insulation foams nanometric scale	2011-2014
NANOINSULATE	Aerogels, VIP, Nanofoams	2010-2013
AEROCOINS	Aerogels	2011-2014
HIPIN	Aerogels	2011-2014
COOL COVERINS	Nanocristaline oxide pigments	2010-2013

Figure 1: Members integrated in Demo Cluster activities. Current members highlighted.

One important thing is testing the materials in different climate zones, so as to have a better idea of their performance in different scenarios.

In order to do this, two different Demo Parks were planned to be built: one in an European warm zone (Madrid (Spain), now fully operative) and another one located in a colder zone (Warsaw (Poland), planned to be finished by late September 2012). With this strategy, a more accurate amount of data can be analyzed and conclusions are expected to be sounder.

Four projects have already joined the cluster: NANOPCM, NANOINSULATE, AEROCOINS and COOL COVERINGS. Two more members (HIPIN and NANOFOAM) are foreseen to be included in a near future. Cluster talks are ongoing about this issue.

From now on description is going to be focused on NANOPCM project. But because considerations about the constructive process are critical to understand and justify the demonstration tasks and procedures - it is understandable that shadowing considerations, physical mock-up distribution, ground composition and power and data installation are critical for data interpretation -, a general overview of the constructive process of the site is going to be given in the next points.

1.1.1 LOCATION

1.1.1.1 Madrid Demo Park

The chosen place (40°35’34”, 3°34’49”) is located close to the village of Algete, at 20 km north of the city of Madrid. One of the main assets of this location is that it is perfectly communicated with the city. It is by the A1 National Highway (100 m) and Barajas Airport is only at 14 km. There also exists a complete railway net around, so train transport is also possible.

Besides, it must be pointed out that the land owner is ACCIONA INFRAESTRUCTURAS S.A itself, so deals and contracts will be done within the company without dealing with external lessors.

Another valuable quality is that weather reports can be directly looked up from the Barajas Airport Meteorological Station (40°27’59”, 3°33’19”) only at 14 km of the Demo Installation Site. Meteorological data as temperature, dew point, wind speed, relative humidity, atmospheric pressure, rain level and global radiation can be founded up-to-date, and historic series are also available.

Figure 2 shows geographic details of the location.

Figure 3 shows a satellite view of ACCIONA INFRAESTRUCTURAS industrial park (Talleres Torrejón) in which E2B Cluster Demo Park is housed (highlighted in pink). Total area reserved is about 900 m².

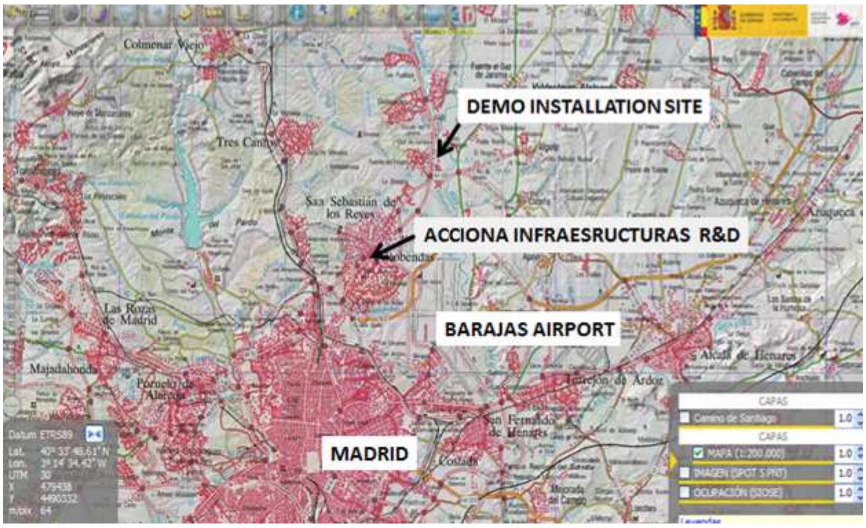


Figure 2 Madrid Demo installation site and general view of Madrid and its surroundings.

Figure 3 Satellite view of ACCIONA INFRAESTRUCTURAS industrial park in Algete (Madrid). *E2B Cluster Demo Park* facilities highlighted in pink.

1.1.1.2 Warsaw Demo Park

The chosen place (52°08'01", 21°01'09") is located close to the town of Piaseczno, at 17 km south of the city of Warsaw. This location is by Pulawska Street that is one of the main streets of the city of Warsaw. It links the southern city center with the suburb of Piaseczno and is 10 km away from Warsaw Chopin Airport.

Figure 4 shows geographic details of the location.

Figure 5 shows a satellite view of Warsaw place of demonstration, reserved area squared in red.

Figure 4 Demo installation site and general view of Warsaw and its surroundings.

Figure 5 Satellite view of Warsaw demo installation place. *E2B Cluster Demo Park* facilities squared in red.

1.1.2 DEMO PARK STRUCTURE

Madrid and Warsaw Demo Parks are identical in form and philosophy. In a nutshell, Demo Park is basically a group of cubic buildings that are scale models of a single room (called from now on mock-up) monitoring using assorted sensors and refurbished with different insulating nano-materials depending on the project involved. All the data is collected in an office (from now on called Shelter) with Internet connection that allows engineers to access and manage data.

Madrid Demo Park (currently operative) consists of seven mock ups (actually nine positions have been equipped, but at present just seven mock-ups have been installed, see **Figure 12** for project distribution). One of these mock-ups is a reference one, this is, a naked mock-up (not refurbished) with which the rest are going to be compared. Another reference mock-up is expected to be built, this one refurbished with standard insulation materials.

Warsaw Demo Park (now ongoing) consists of just two mock-ups, one of them for reference purposes. It is going to be used by NANOPCM project for one year and after this period it is expected to be used by NANOINSULATE project.

1.2 Constructive process

Because Madrid and Warsaw parks are identical (despite regarding the number of mock-ups), from now on no distinction is going to be made among Madrid and Warsaw sites.

Next points are about the full constructive process of a standard park. Because of Madrid one is accomplished and Warsaw is ongoing, the most of the photos depicts Madrid facilities.

1.2.1 Ground leveling

Initial terrain was treated step by step to turn it into a flat base capable of holding up the mock-ups structure. First of these steps was to fill the terrain with a gravel–base layer to enhance the stability and consistency of the floor. 150 tons of gravel (made of non-crushed aggregates) were deposited on the ground and distributed using a road roller machine for rough leveling.

Second ground flatting was carried out using excavators. Finally, a flat base was obtained by means of compacting with water and road rolling pressure combined with manual leveling.


Figure 6 Ground preparation works.

1.2.2 Shadow study and simulation

Figure 5 shows the schematic demo installation site layout including the main obstacles that were taken into account to fix the mock-ups positions. The main adjoining buildings to be studied are an abandoned "*pelota*" court (East), storage vessels with 15m-high silo towers (North) and a security fence surrounding the perimeter (West). These elements are important because the mock-ups area must evade any external shadow that could affect their performance ratio.

A second thing to be considered is the distribution and distances between the single mock-ups, in order to prevent shadows between each other through the whole year (overlaps). According to previous designs, a grid distribution of nine mock-ups has been chosen, so as to minimize the space and therefore the renting costs.

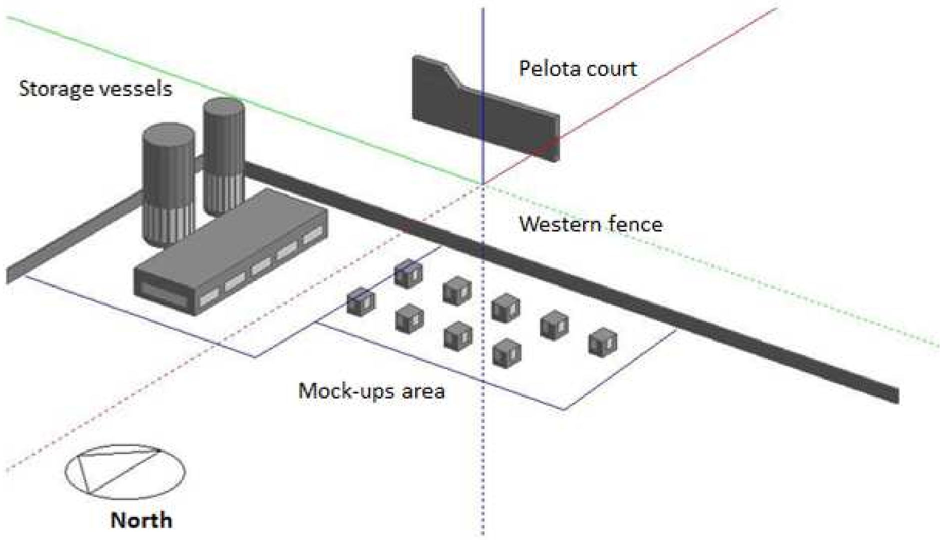


Figure 7 Layout basic scheme using Design Builder simulation tool.

Distribution optimization has been carried out using DESIGN BUILDER simulation tool. Shadow effects have been run for four representative days in the year, the two solstices and two equinoxes at sunrise, midday and sunset, selecting specific times depending on the season.

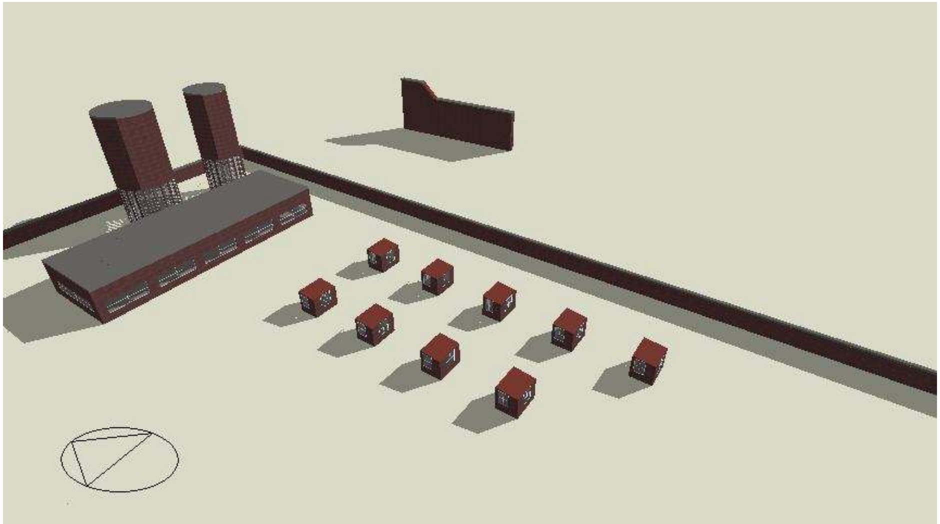


Figure 8 Example of shadow simulation using Design Builder Software (March 21th at 9:00 am)

According to Design Builder simulations, if mock-ups area is set up 25 m away from the "*pelota*" court, 10 m away from the storage vessels (that do not interfere with the mock-ups in any case because of their orientation) and 10 m away from the eastern fence, direct shadows are avoided for any day in the whole year, apart from some punctual moments mainly at sunset. However, this occurs for a few minutes and by that time irradiation level is very low.

Different grid separations were tested. **Figure 9** shows the final distribution optimization. In conclusion, if mock-ups are set up in two rows separated 6.5 m, and the separation between mock-ups of the same row is 6 m, shadow overlap is avoided at 90%.

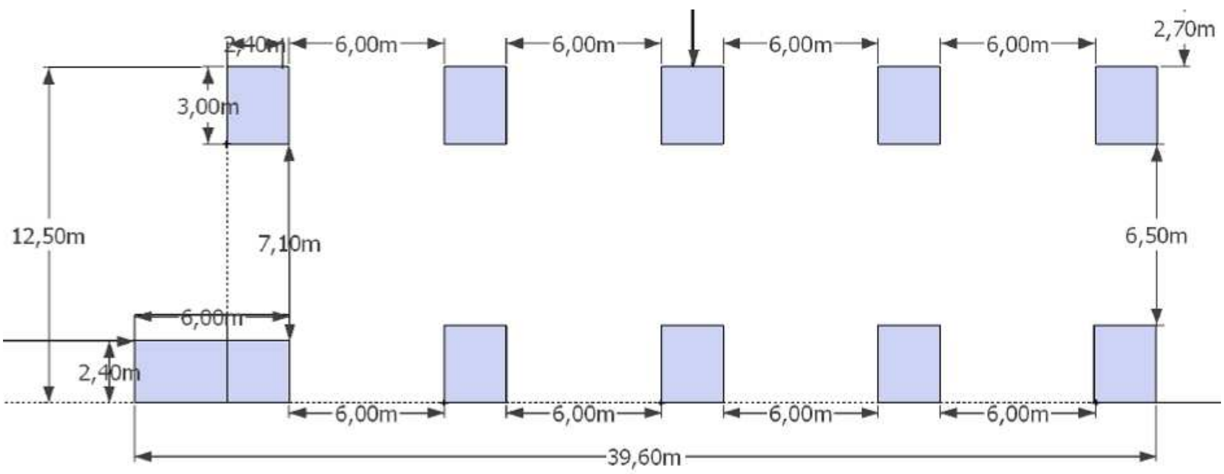


Figure 9 Madrid Demo Park Mock-ups distribution.

1.2.3 Power and data needs

This point deals with technical details about the electrical and data installation that makes it possible to back up the monitoring system and all the sensors and devices explained in deliverable D6.2.

Power is taken from the general three-phasic electric power source at ACCIONA INFRAESTRUCTURAS industrial park, about 250 meters away from the zone that houses the E2B Cluster Demo Park installations. As it can be seen in **Figure 8**, power is conducted from park's general panel (still three-phase) by means of a 6 mm² cable to Demo Park's general panel (housed in the Shelter), in which three-phase electric power is turned into single-phase electric power (220 V, 50 Hz) using a standard transformer.

A 2 mm² wire distributes the current from Demo Park general panel to each mock-up. Each single mock-up has its own electric panel with an electronic differential (25 A) and two magneto-thermal switches (16 and 10 A) so as to prevent the mock-ups devices from possible current overloads that could take place in the industrial park. All the electric installation is buried.

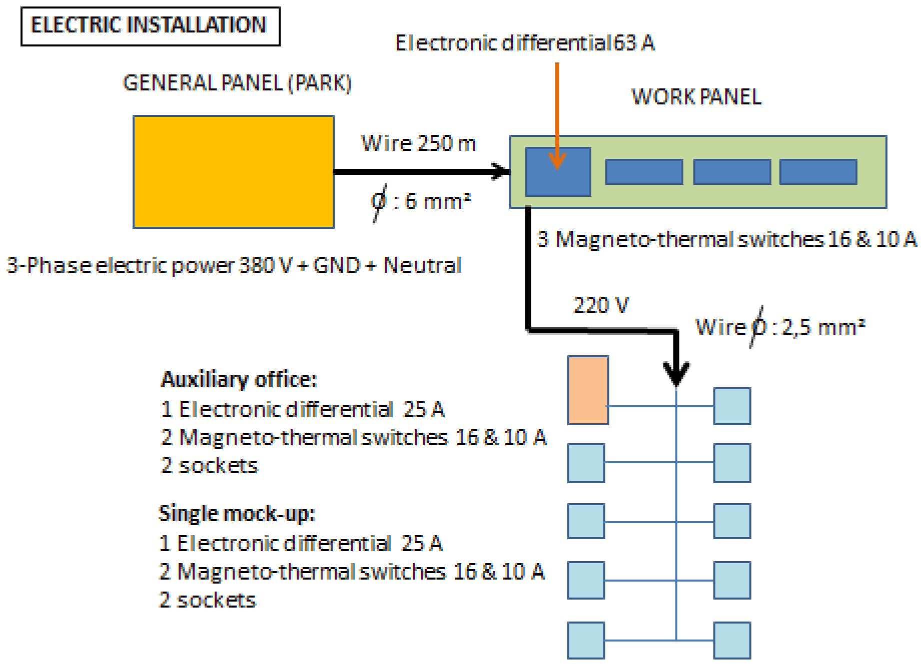


Figure 10 Electric installation of Madrid Demo Park.

Figure 11 estimates Demo Park power needs taking into account not only current devices installed in the mock-ups but also foreseeing possible future devices as for example HVAC systems, so power needs have been over dimensioned on purpose. To sum up, each mock-up can support around 1 kW,

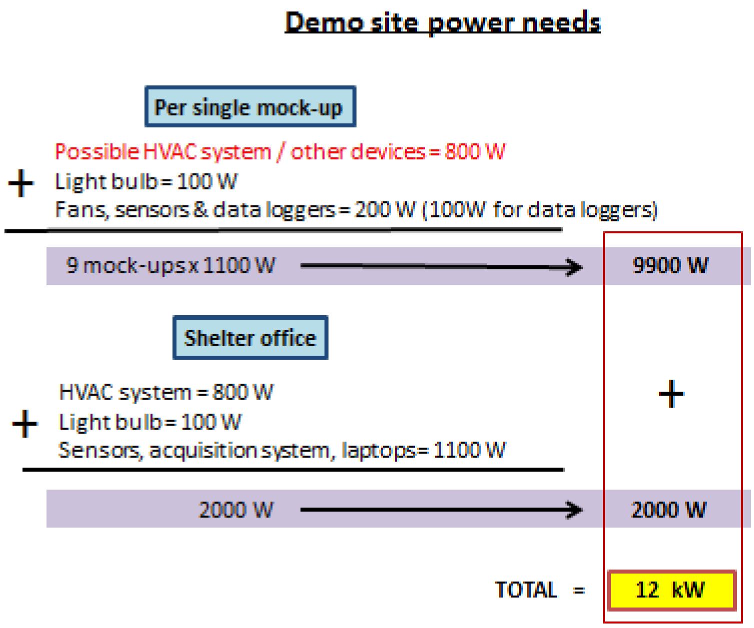


Figure 11 Madrid Demo Park power needs.

and because 9 mock-ups are expected to be built (now Demo Park has just 7), mock-ups power needs add up to approximately 10 kW. If we take into account Shelter needs, it is found out that the whole design has to support around 12 kW. Finally, Shelter has been dimensioned to hold an HVAC system, the Central Data Logger and the PC (around 2 KW).

Figure 12 shows a general diagram of data installation. As it is fully explained in D6.2 (*Monitoring plan and simulation model design and validation*), each mock-up has its own multiplexer that collects data from thermal sensors each five minutes (sampling rate). This data is sent through registered jack RJ45 lines to the general Data Logger housed in the Shelter, that registers the data in the PC memory. With specific software developed by TNO (COOL COVERINGS project), data can be managed and plotted. 3G connection using USB modem makes it possible to take over the Operative System using Virtual Private Network (dynamic IP) and gives access to the full data collection.

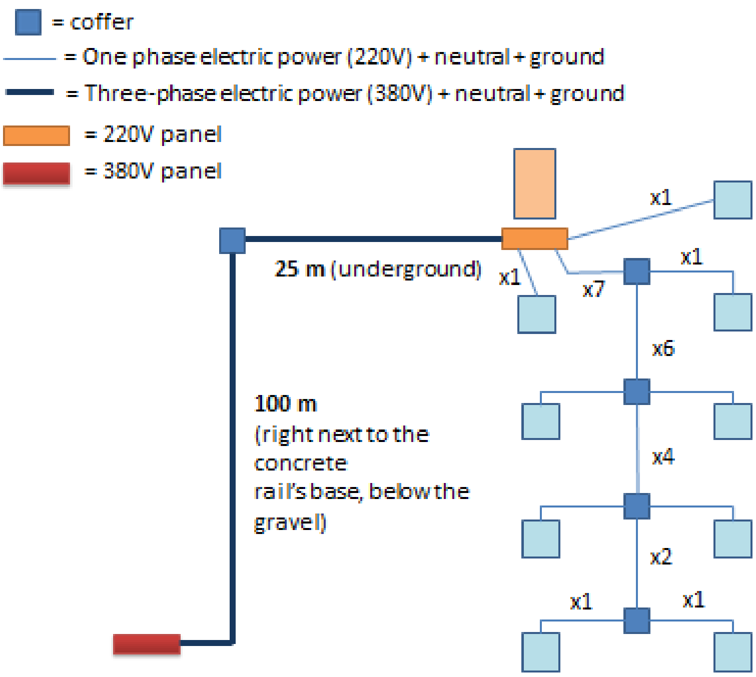


Figure 12 Data installation of Madrid Demo Park (Madrid).

1.2.4 RUNWAYS

Runways have been installed in order to make access easier. Innovative design has been made to take advantage of ACCIONA INFRAESTRUCTURAS own innovative materials. In this particular case, a sand base merged with natural adhesive has been crowned with a red rubber covering (grinded recycled tires from wheels mixed with epoxy resin).

Figure 11 shows the schematic design. In **Figure 13** final design after works can be appreciated.

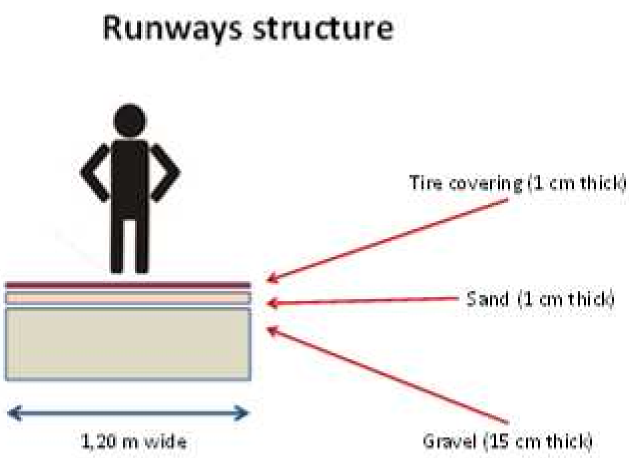


Figure 13 Runways structure.

1.2.5 OVERVIEW OF THE SITE

Works ended up on 11th June 2012. COOL COVERINGS, put its materials (cool ceramic tiles, cool paintings and cool asphalt roofs on 4 mock-ups) and they have informed the cluster they are monitoring thermal behavior successfully. Reference mock-up (that is going to be described in 1.3.1) is also operative and sending data to the PC. COOL COVERINGS engineers are analyzing this data and have also confirmed that the measuring system and the weather station works properly. This warm-up gives valuable background for NANOPCM demonstration task.

Two vacancies are also foreseen for AEROCOINS, HIPIN and NANOFOAM projects, not overlapped in time.

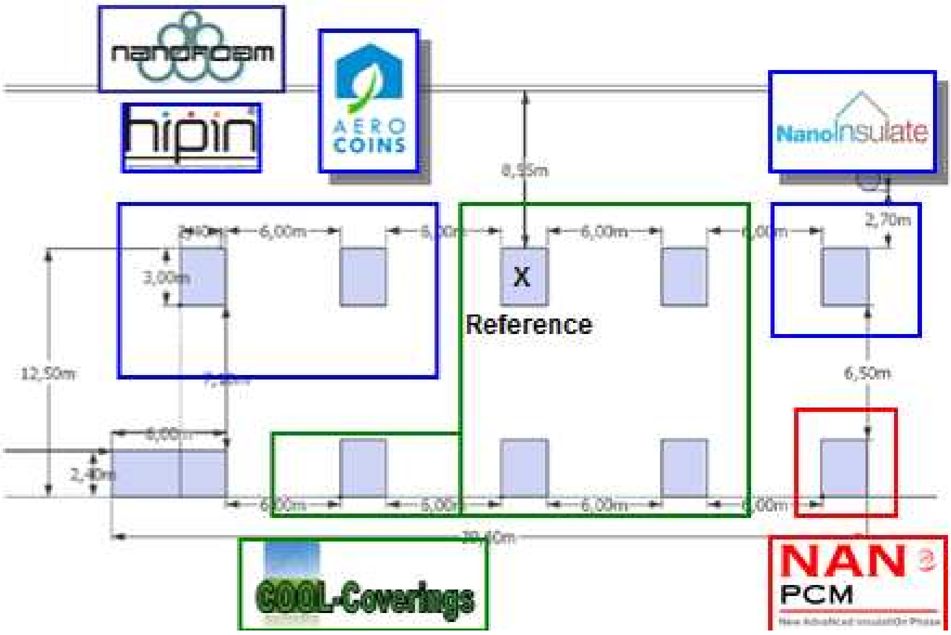


Figure 14 *E2B Cluster Madrid Demo Park* layout.

Figure 15 General view of Madrid Demo Park (June 11th 2012)

Figure 16 General view of Warsaw Demo Park (August 30th 2012)

2. NANOPCM FACILITIES AT DEMO PARK

NANOPCM demo strategy needs of two mock-ups to be consistent: first of them (from now on labeled NANOPCM Mock-up) refurbished with NANOPCM panels on the walls and the roofs, and another labeled REFERENCE Mock-up, with which thermal data is going to be compared and analyzed.

NANOPCM mock-up materials are going to be minutely explained in Point 3, so this description is put off until that point.

REFERENCE Mock-up is a standard mock-up that is shared between all members present in both demo-parks. The idea is compare thermal data (for example outdoor and indoor temperatures, heat flows through the walls) from refurbished mock-ups with data from REFERENCE Mock-up and draw conclusions about the performance of the specific developed materials.

REFERENCE Mock-up has the same sensor distribution than the rest but the main difference is that it is naked, so it does not present any insulation material or system. This issue has been discussed and agreed within the cluster members. In the near future it has been planned to refurbish it with standard insulation materials, but for the moment it is going to remain naked and demo tasks will carry out taking this into account.

Figure 17 specifies the position of both mock-ups at Demo Park. Thermal testing indicates that all the mock-ups present identical irradiation conditions regardless of the position (ΔT≈1ºC in the worst-case scenario between the colder and the hottest mock-up according to thermal imaging and data acquisition system pre-tests carried out by technicians), so mock-up position in the matrix really does not matter and all the projects have the same initial conditions regarding their position.

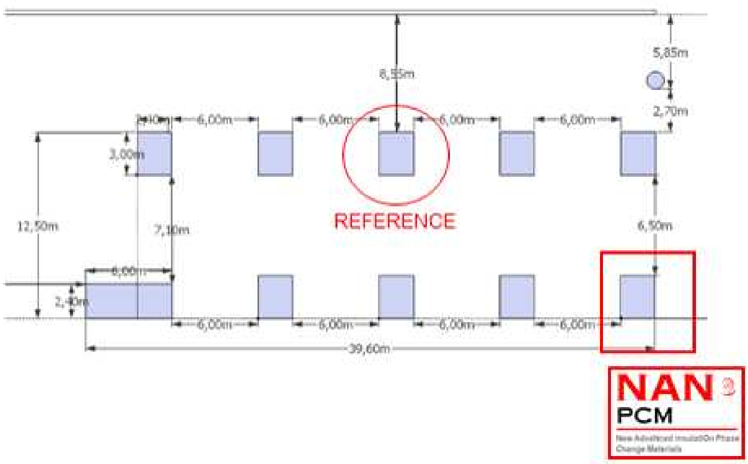


Figure 17 NANOPCM facilities at Spanish Demo Park.

2.1 Mock-up design

2.1.1 Architectural design

NANOPCM and REFERENCE mock-ups have the same structure. The base is a rectangle of 3m x 2.4 m and the height is 2.55 m (north façade) and 2.60 m (south façade) respectively, because the roof is slightly sloping (1.2º) in order to evacuate water when it rains.

Figure 18 details mock-up distribution of windows and doors.

Façade	Door	Window
N	X	
S		X
E		X
W		

Figure 18 Mock-up windows and door location.

Mock-up base consist of a 10 cm-thick concrete slab. In order to avoid possible foods a pedestal was built. This additional base elevates the mock-up around 20 cm from the ground and acts as an extra insulation system not only for but also for thermal purposes. Some simulations were carried out using TRNSYS software to check air drafts effects in the mock-up. Despite it was found out that drafts did not affect inner temperature significantly (ΔT around1ºC), cluster members agreed to seal base sides creating an air chamber that could be seen as an extra insulation system, as it can be seen in **Figure 19**.

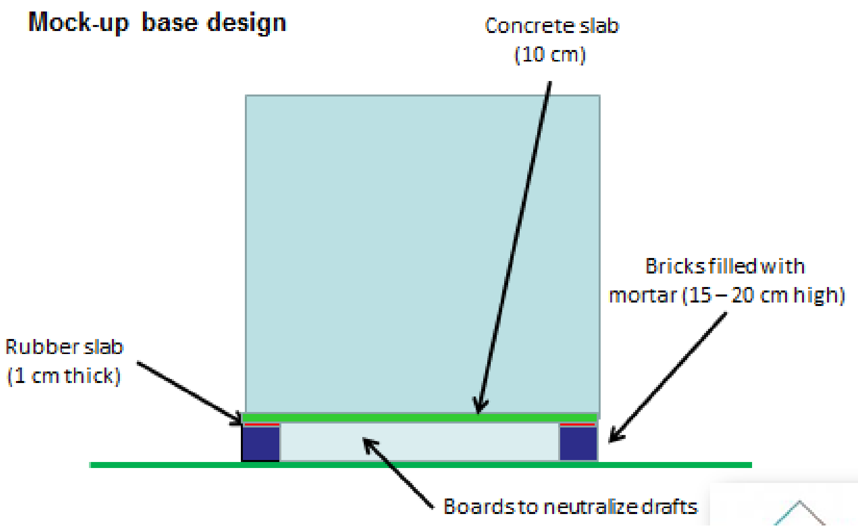


Figure 19 Mock-up base design.

Figure 20 Mock-up pedestals.

Figure 20 shows the pedestal structure. Each pedestal is made of bricks filled with mortar (15 to 20 m high depending on the ground level) crowned with a rubber slab to give concrete base mechanic stability.

Door (90 cm x 200 cm) is dark metallic and it has been painted with a standard white painting to reduce the overheating since thermal imaging shown it reached temperatures over 50ºC. With this coating temperature cools down in more than 10ºC. Windows are double glazed (90 x 60 cm).

Figure 21 Naked mock-up structure. In the left corner, NANOPCM Mock-up.

2.1.2 Façade Materials

The façade profile has three main parts, from inside to outside:
- An 1.25 cm thick plaster board.
- A 7.50 cm thick air gap.
- A 2.50 cm thick OSB board.

Physical characteristics detailed in **Figure 22**. All NANOPCM panels are going to be put and fixed on the plaster board.

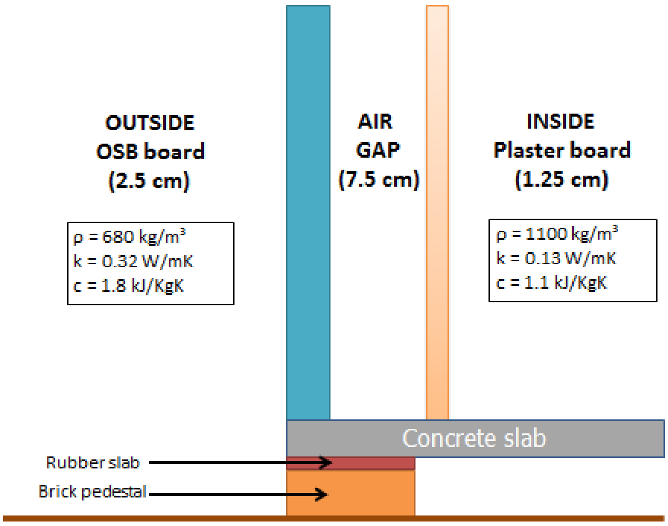


Figure 22 Façade profile

2.1.3 Roof

Roof structure is essentially identical to wall's, but slides are protected with metal rivets and the rooftop is crowned with a bituminous coating.

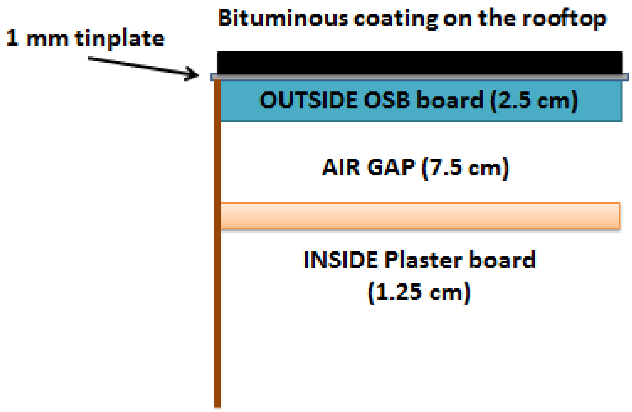


Figure 23 Roof profile

2.1.4 EXTRA ELEMENTS, SENSORS AND MONITORING SYSTEM

This point is fully and meticulously explained in D6.2 "Monitoring plan and simulation model design and validation".

3. NANOPCM MATERIALS AND PROTOTYPES

Following the aim of the development of the PCM with the best thermal properties, several novel PCMs were developed in the NanoPCM project within WP2 and WP3.

At the same time, it was studied the addition of different nanoparticles to improve the own characteristics of the PCM.

On the one hand, different methodologies to insert the PCM in the insulation material were used. This way, encapsulated and not encapsulated PCM were refined.

On the other hand, different places to insert the PCM in a sandwich panel were tested, as the core foam as external layers

Encapsulated PCM:

1. Fatty acids in SiO_2 microcapsules
2. Octadecane in SiO_2 microcapsules
3. Hexadecane in SiO_2 microcapsules
4. RT27 in LDPE-EVA microcapsules with CNF (2% wt)

Not encapsulated PCM

1. Eutectic mixture in epoxy resin with nano Al_2O_3 (0,5% wt)
2. SiO_2 impregnated with paraffin

Few prototypes were constructed and tested within WP6 to check the thermal properties and the feasibility to construct and install on the mock-ups. They have been described in the Deliverable 6.1.

Panel	Description
Panel1	PU foam laminated with 5 GF layers on the top and at the bottom
Panel2	PU foam+ masterbatch (50%PCM) laminated with 4 GF layers, laminated with 5 layers on the top and at the bottom
Panel3	PU foam+ masterbatch (50% PCM) laminated with 13 GF layers, laminated with 5 layers on the top and at the bottom
Panel4	PU foam+ masterbatch panel (40%PCM), laminated with 5 GF layers on the top and at the bottom
Panel5	PU foam with 5%PCM (SiO_2 impregnated with paraffin), laminated with 5 GF layers on the top and at the bottom

Table 1 Panels description. GF: glass fiber, PU: polyurethane

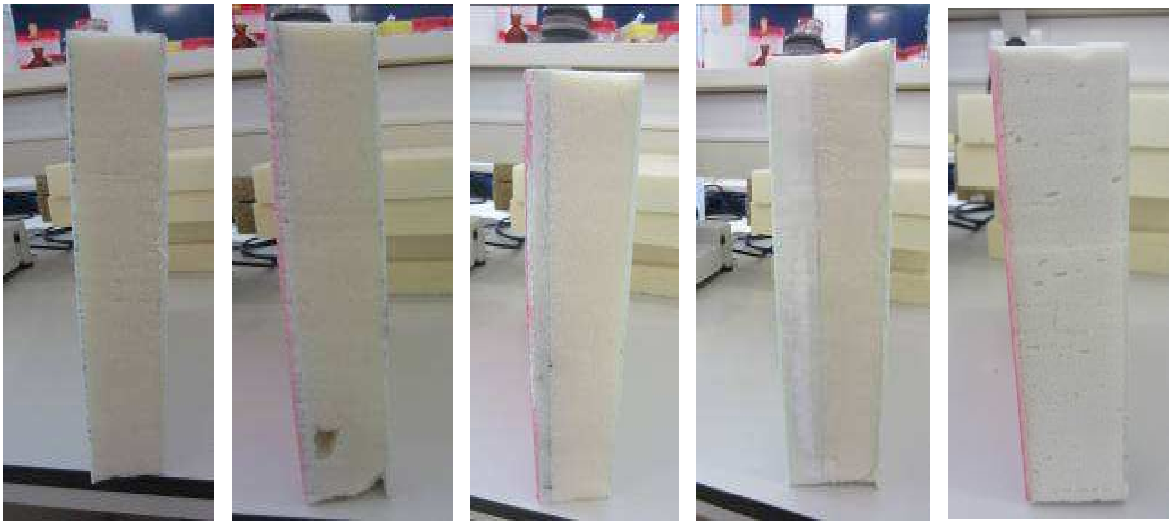


Figure 24 Prototypes constructed (from panel 1 to panel 5)

The results from the thermal conductivity measurement are shown in the next table:

		Layers properties				Panels properties			
PROTOTYPES	LAYERS	k (W/mK)	Thickness (cm)	Dimensions (cmxcm)	Density (Kg/m3)	k (W/mK)	Thickness (cm)	Dimensions (cmxcm)	Density (Kg/m3)
1	Epoxy resin laminated	259,63	0,3	30x30	154,17				
	PU foam	0,03	4	30x30	45				
	Epoxy resin laminated	259,63	0,3	30x30	154,17	0,03455-0,03817	4,6	30x30	281,98
2	Epoxy resin laminated	259,63	0,3	18x18	154,17				
	PU foam with 5% SiO2 porous	0,0345-0,03709	4	18x18	49				
	Epoxy resin laminated	259,63	0,3	18x18	154,17	0,0423-0,04369	4,6	18x18	269,79
3	Epoxy resin laminated	259,63	0,3	30x30	154,17				
	Masterbach panel(40%PCM)	ERROR	1	30x30	1951,00	ERROR			
	PU Foam	0,03	4	30x30	45				
	Epoxy resin laminated	259,63	0,3	30x30	154,17		5,6	30x30	525,3
4	Epoxy resin laminated	259,63	0,3	30x30	154,17				
	Masterbach (50%PCM) laminated with 5 layers of GF	0,1025-0,1136	0,3	30x30	578,78				
	PU foam	0,03	4	30x30	45				
	Epoxy resin laminated	259,63	0,3	30x30	154,17	0,034	5	30x30	383,56
5	Epoxy resin laminated	259,63	0,3	30x30	154,17				
	Masterbach (50%PCM) laminated with 13 layers of GF	ERROR	1	30x30		ERROR			
	PU foam	0,03	4	30x30	45				
	Epoxy resin laminated	259,63	0,3	30x30	154,17		5,6	30x30	489,17
6	Epoxy resin laminated (5GF)	259,63	0,3	30x30	154,17				
	PU foam with 12% PCM (UCLM)		4	30x30	49				
	Epoxy resin laminated (5GF)	259,63	0,3	30x30	154,17		5	30x30	
7	Epoxy resin laminated (5GF)	259,63	0,3	30x30	154,17				
	PU foam with 10% PCM (octadecane)		4	30x30	49				
	Epoxy resin laminated (5GF)	259,63	0,3	30x30	154,17		5	30x30	
8	Epoxy resin laminated (5GF)	259,63	0,3	30x30	154,17				
	PU foam with 10% PCM (fatty acids)		4	30x30	49				
	Epoxy resin laminated (5GF)	259,63	0,3	30x30	154,17		5	30x30	
9	Epoxy resin laminated (5GF)	259,63	0,3	30x30	154,17				
	PU foam with 10% PCM (hexadecane)		4	30x30	49				
	Epoxy resin laminated (5GF)	259,63	0,3	30x30	154,17		5	30x30	

Table 2 Thermal measurements of prototypes constructed. Yellow squares: prototypes of the panels that will be installed on the mock-ups. Red squares: Error in the measurement of the thermal conductivity. After trying several times, it was impossible the stabilization of the value because the PCM was in a continuous melting and solidification.

4. MATERIALS INSTALATION IN REAL BUILDING

4.1 SELECTED INSULATION MATERIALS

The decision of the insulation materials to use in the real buildings was taken into account the next characteristics:

1. PCM production
2. Cost of the developed panel
3. Feasibility to install
4. Current normative in construction

During the NanoPCM project, it was decided the use of encapsulated PCM (Deliverable 6.4). Few conclusions were extracted as follows:

1. Although the masterbatch developed in WP2 has good thermal results (Table 2 and Deliverables 2.3 and 2.4), the insertion of PCM in epoxy resin is not convenient for buildings attending to the current normative within the construction sector in relation to fire protection of materials used as elements in construction (normative 312/2005, 18th March; 1630/1992, 29th December, 89/106/CEE; 1328/1995, 28th July)

   Additionally, epoxy resin should be used on external layers of a sandwich panel and for this, it should be used a lamination process. Currently, the lamination process is a manual process what would mean an increase in the final cost of the product by increasing the personal and time costs.

   Regarding the final cost of the product, it would not be competitive in relation to the current products already present in the market.

   As NanoPCM project has the objective of developing a novel commercial product, this additional cost by using the lamination process would make this not possible.

2. The PCM production without encapsulation is currently in a really early stage. Nowadays this methodology cannot be scaled-up. In consequence, this method cannot be used in order to produce a commercial product.

   For this reason, although SiO_2 impregnated with paraffin has good thermal characteristics to be used as insulation material (Table 2 and Deliverable 3.3), it will not be tested in the demo-park

3. Insertion of encapsulated PCM in foam showed the best results in relation to the production process and the stability.

Regarding these conclusions, it was decided the use of encapsulated PCM to apply to real buildings.

Although the pilot plant was constructed to produce microcapsules of RT-27 covered by LDPE-EVA, it was concluded that a comparison of the behavior of different PCM would be better for proper conclusions.

Regarding the results from the tests, as thermal properties as feasibility to insert, it was chosen three different types of PCMs.

1. Encapsulated RT-27 in LDPE- EVA microcapsule with CNF as additive
2. Encapsulated fatty acids in SiO_2 microcapsule
3. Encapsulated octadecane in SiO_2 microcapsule

Experiences were carried out to study the thermal stability through 2880 cycles of melting and solidification. It was established an average of 100 cycles per year. This way, it could be concluded that the PCM insertion can be stable in buildings for 28 years.

Every PCM has been inserted by mixing with the typical components in the traditional production of PU foam.

It was inserted as maximum a 10% of PCM using SiO_2 microcapsules and 12% using LDPE-EVA.

The final properties of the new foam are:

Panel (kg)	Capsules (Kg)	Foam (Kg)	Panel (m^3)	% PCM	Panel Density (Kg/m^3)	PCM
1	0,1	0,9	0,02	10	49,4	Octadecane
1	0,1	0,9	0,02	10	49,3	Fatty acids
1	0,12	0,88		12	49	RT-27

Table 3 Properties of the novel panels with PCM inserted

Checking the temperature profile of both demo-parks, it was selected the best ones for each location. This way, in Spanish demo-park it was installed Encapsulated RT-27 on the walls and octadecane on the roof.

In the Polish demo-park it was installed encapsulated RT-27 on the walls and fatty acids on the roof.

In the next table it is shown the calculation of the needed materials

m^2 panel	m^3 panel	Amount PCM needed (Kg)	Capsules Density (Kg/m^3)	Kind of PCM	Place	Demo-Park	Total amount (Kg)
6,0109	0,300545	1,49	433,15	Octadecane	Roof	Madrid	1,49
6,0109	0,300545	1,48	372,7	fatty acids	Roof	Poland	1,48
20,47	1,0235	6,01818		RT-27	Walls	Both	12,04

Table 4 Amount of PCM necessary for panels construction

4.2 Panels production

Extracted from the experiences in Deliverable 6.1, it was chosen a basic panel system 50/32 B, characterized by low density what improves the insulating properties of foam.

Additionally, the system included some flame retardant and it was checked the interaction between PCM and commonly used components.

A	PARTS BY WEIGHT	COMPONENTS
1	100	POLYETHER POLYOLS
2	30	FLAME RETARDANT
3	20	BLOWING AGENT
4	3	WATER
5	0,6	BLOWING CATALIST
6	0,6	GELATION CATALIST
7	2	SURFACTANT STABILIZERS
B	110	PUROCYN B

Figure 25 Substances present in each component to do the foam.

Components A and B have to be mixed to produce the foam. The PCM addition is done just at the same time.

To get a proper shape, it is mixed in a mold. In this case, it was used a mold of 45 cmx 45 cmx 150 cm an later the panels were cutting from this block.

In relation to the lamination of the foam panel using glass fiber and epoxy resin, it was discarded regarding the construction normative and the state of art of this kind of process. The panels lamination would be a manual work that means an high added cost to the final product.

4.3 Mock-ups characteristics

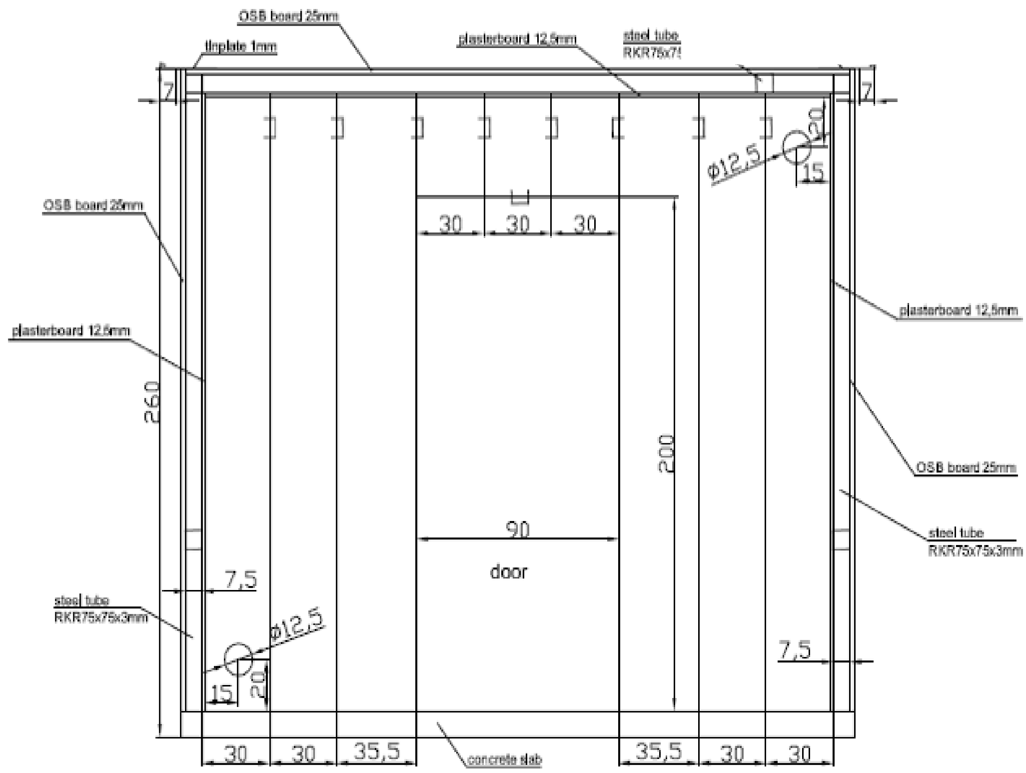
The dimensions of the final panel were 45cmx45cmx4cm (weigh x height x thickness)

In relation to the materials and the layers of the mock-ups walls, in the next table it is described the properties and sections of every one.

Mock up design		
<u>Cross section</u> **First layer – oriented strength board (OSB), (it is waterproof)** **Second layer – plasterboard (Fermicell)** **Air gap** **Third layer - plasterboard (Fermacell)**	<u>OSB:</u> Possible thicknesses of plasterboard wall. 15 mm, 25 mm Density - 680 kg/m3 Conductance - 0,32 W/mK Spec. Heat - 1,8 kJ/kgK	<u>Fermacell</u> Possible thicknesses of plasterboard wall. 10 mm, 12,5 mm, 22,5 mm, 25 mm Density - 1150 ± 50 kg/m3 Conductance - 0,13 W/m*K Spec. Heat - 1,1 kJ/kgK

Table 5 Material design for the mock-ups

Additionally, the next figures shown the mock-up structure



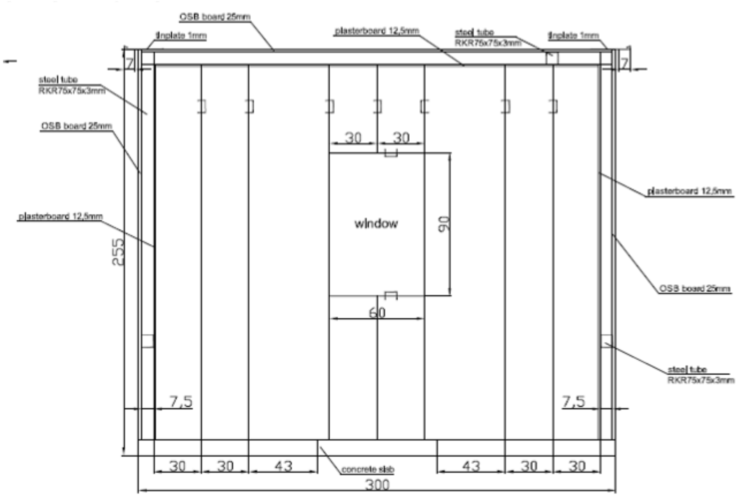


Figure 26 Internal structure of the mock-ups

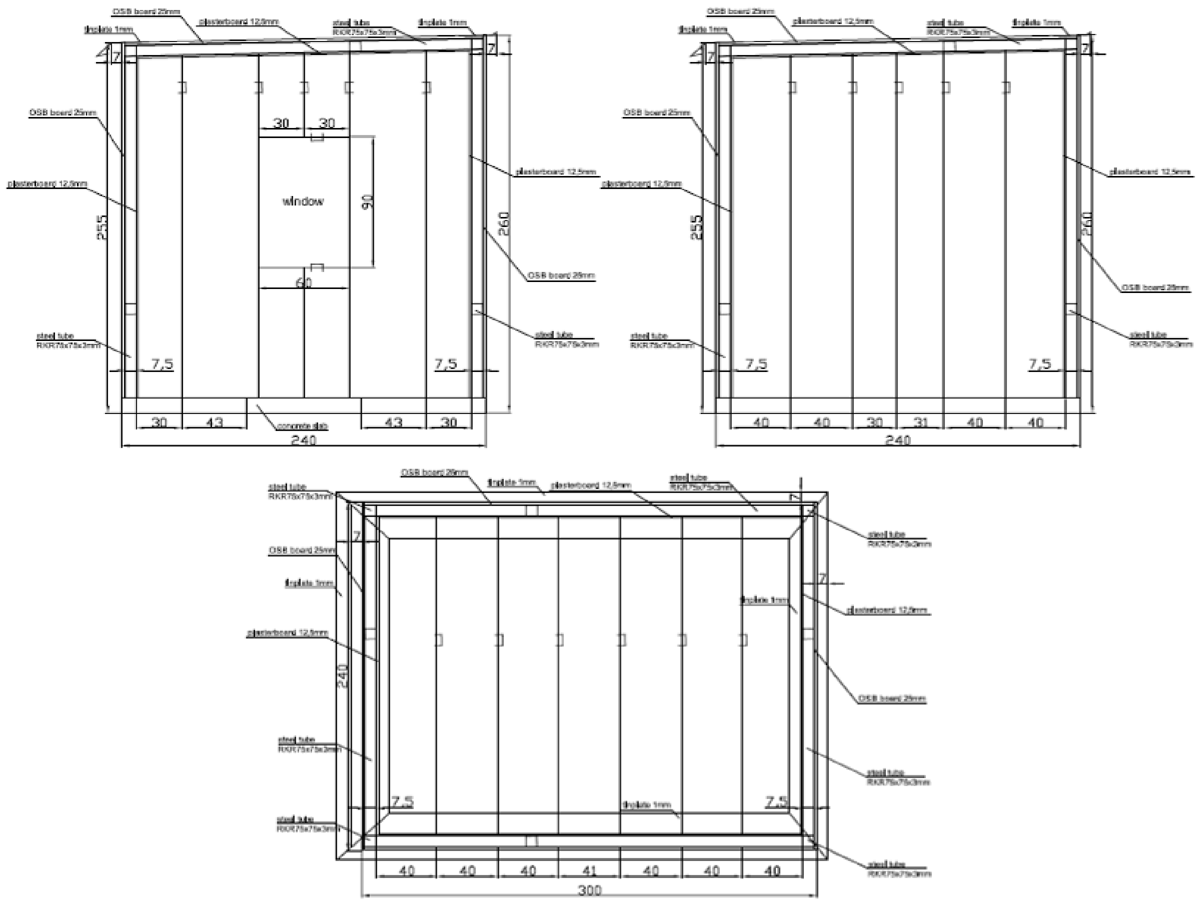


Figure 27 Internal structure of the mock-ups

Regarding the properties of phase change materials and the purpose of using them, it was decided to install the panels inside of the mock-ups, to take the most energy storage to conserve the comfort temperature.

It was done a proper plan to install the panels on the walls and roof as it is shown in the next figures. The dimensions are the internal ones.

This way, it was calculated how many panels were necessary for the novel insulation of the mock-ups and how they had to be cut.

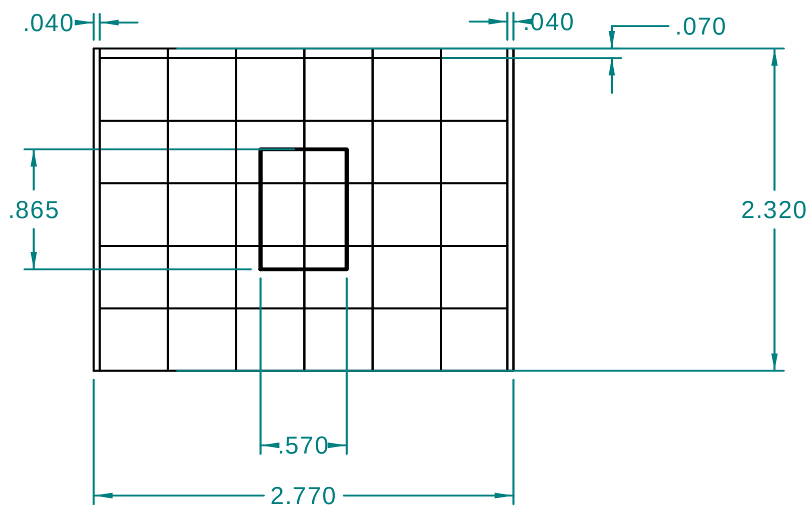


Figure 28 South façade

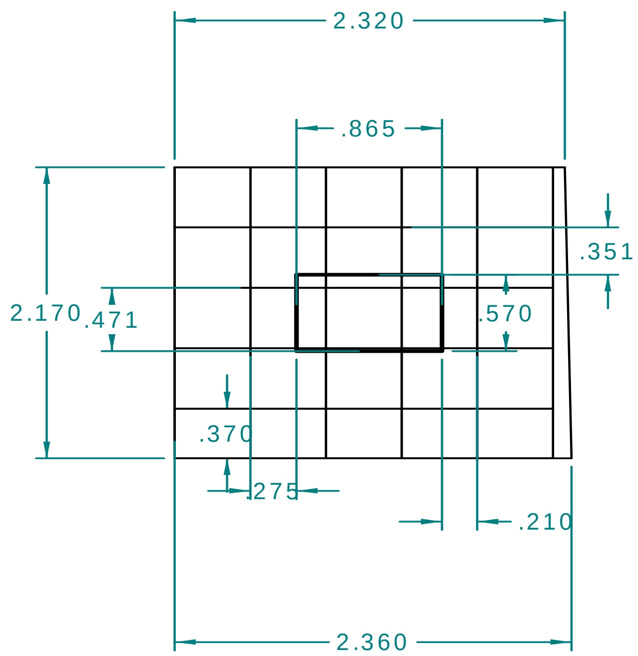


Figure 29 Western façade

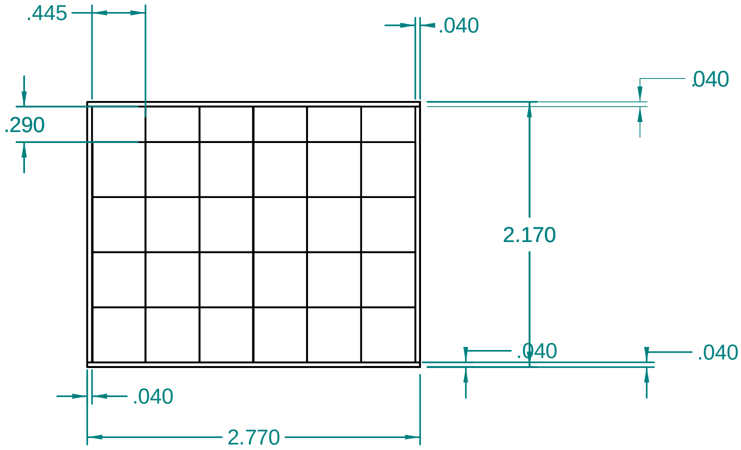


Figure 30 Roof

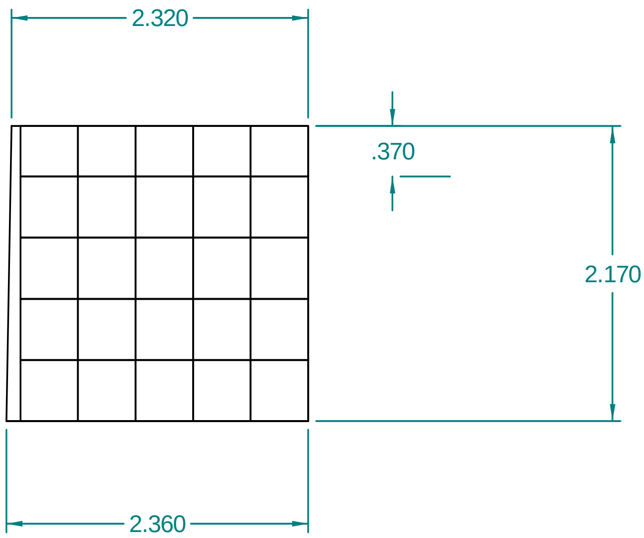


Figure 31 Eastern façade

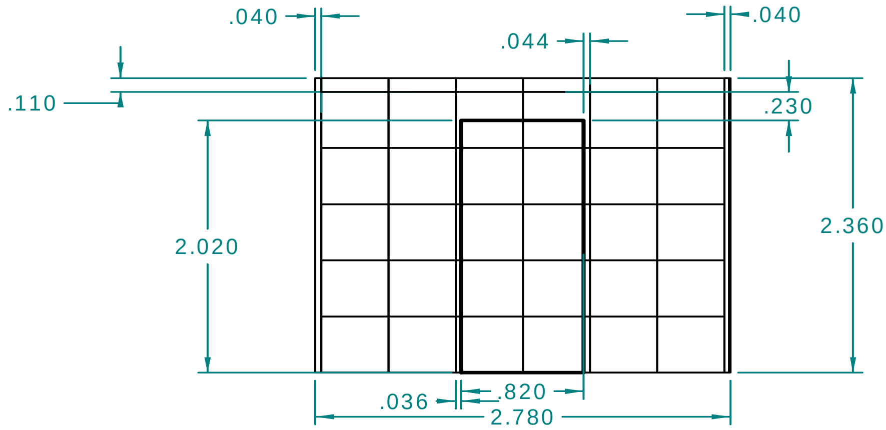


Figure 32 North façade

4.4 Materials Installation

Before installing the panels, they were cut in the lab to avoid possible problems in the demo-park.

The methodology to install them was by sticking on the walls and roof following the figures 28-32 and the next distribution:

1. On the walls they were installed the foam panels with 12% of R-27 encapsulated in LDPE microcapsules adding 2%(wt) of CNF.
2. On the roof, it was decided the use of two different materials
    a. In the Polish demo-park, it was installed the foam panels with 10% of fatty acids encapsulated in SiO_2 microcapsules with the addition of a mix of surfactants.
    b. In the Spanish demo-park, it was installed the foam panels with 10% of octadecane encapsulated in SiO_2 microcapsules with the addition of a mix of surfactants.

5. DISCUSSION

The NanoPCM project is already on the month 28, so it is in the last stage.

The different nano-materials have been developed in WP2 and WP3. Following the schedule, the prototypes were constructed on WP6. Their thermal properties were tested and the pilot plant was started-up on WP6 and WP7.

The final step is the evaluation in a real building. For this, two demo-parks were constructed in Spain and Poland.

On the other hand, the panels developed in the NanoPCM project were selected in relation to the melting points, temperature profile, feasibility to install and construction normative.

This way, although every developed material within NanoPCM project had good results, the selected PCMs to insert in PU foam were octadecane, fatty acids and RT-27. The first two materials were encapsulated in SiO2 microcapsules while the last one was confined in LDPE-EVA microcapsules.

This way, it will be tested a kind of PCM from a fuel source, a non-commercial PCM that can be obtained for example as by-products in biodiesel production, and commercial products that are cheaper and more focused to the market.

Finally, the panels were installed on both demo-parks. A proper plan was done to cut and sticky them.

The thermal behavior will be monitored until the end of the NanoPCM project and reported in WP7.

In parallel, a simulation model will be finished and validated within WP4.

The simulation macro-model from WP4 will be compared and validated with the real results from the demo-parks. This way, it will be used to predict the thermal behavior in other buildings, configurations or any required change.

6. ACKNOWLEDGEMENTS

The NANOPCM Consortium would like to acknowledge the financial support of the European Commission under the Seventh Framework Program.

7. REFFERENCES

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2. Deliverable 2.2 "Selection and characterization of suitable organic PCM", NanoPCM project
3. Deliverable 2.3 "Assessment of the dispersion of form-stable phase change nanomaterials in paraffin/polymers", NanoPCM project
4. Deliverable 2.4 "Assessment of the different processing techniques at lab scale of resultant form-stable nano material", NanoPCM project
5. Deliverable 2.5 "Assessment of the compatibility of the microencapsulating process with the use of additives", NanoPCM project
6. Deliverable 2.6 "Process optimization design of conductive nano materials incorporation to PCM microcapsules", NanoPCM project
7. Deliverable 3.3 " Hybrid Phase Change nano-Composites selected and prepared", NanoPCM project
8. Deliverable 6.1 "The prototypes of the developed materials designed and manufactured", NanoPCM project