Hydrocarbon-based PCM Applications

Thermal Performance of the Exterior Envelopes of Whole Buildings XI International Conference:

Thermal Mass VI Workshop

Joseph A. King Jr., PhD

DuPont Building Innovations

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The miracles of science™

Increase thermal comfort

- Play as a buffer to absorb excessive solar gains
- Reduce influence from outside weather conditions changes.
- Reduce temperature fluctuations inside building

Decrease the energy bill, and the environmental footprint

- Reduce the energy consumption in summer (air conditioning)
- Reduce the energy consumption in winter, spring, and autumn (heating)
- Contribute to system solution to avoid air conditioning.
- Release energy gained during the day, at night. (in spring, autumn, and winter)

Contribute to satisfy building regulations

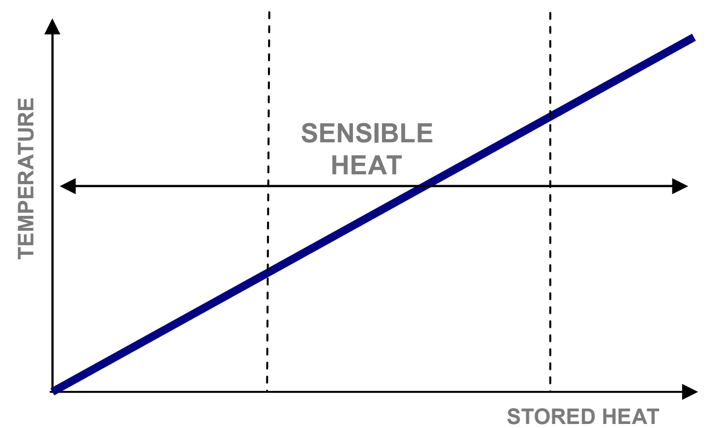
- Prevent overheating in summer
- Helps to achieve low energy rating

Helps reduce CO_2 emissions

PLUS

Passive solution
No maintenance costs

HEAT STORAGE AS SENSIBLE HEAT*

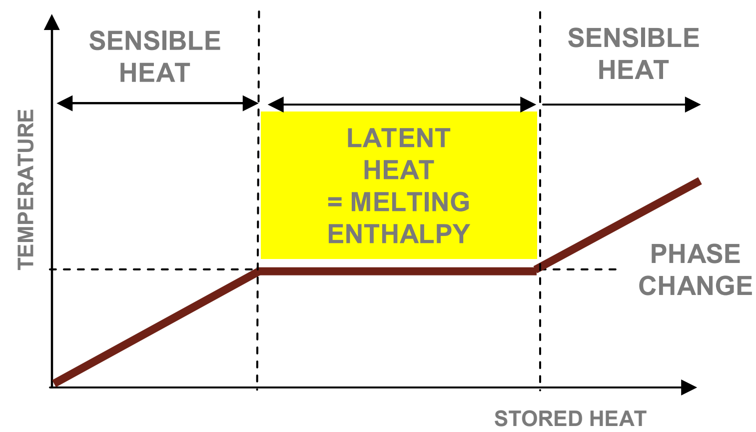


A temperature increase leads to a temperature increase of the storage medium (blue curve)

Heat capacity of the medium:
Stored heat/temperature increase

Examples: STONE, BRICK, CONCRETE

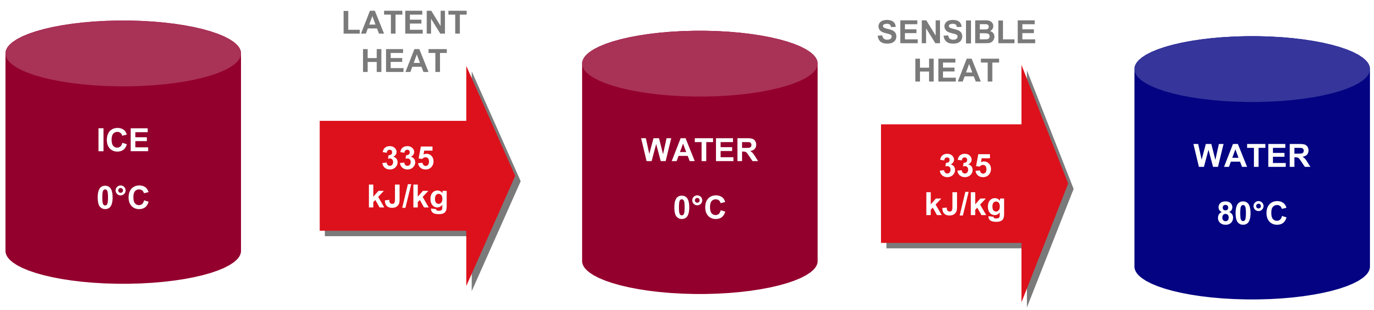
LATENT HEAT/LATENT HEAT OF FUSION STORAGE



The material absorbs sensible heat and starts to melt when reaching the temperature of the phase change. Until melting is completed, the material maintains a constant temperature. Once complete, any further heat transfer results in sensible heat storage.
The heat stored during the melting process (melting enthalpy) is called the latent heat as the material doesn't show a temperature increase.

* Sensible heat is the energy exchanged by a thermodynamic system during a change in temperature. The sensible heat of a thermodynamic process may be calculated as the product of the body's mass with its specific heat and its change in temperature: $Q_{Sensible} = mc\Delta T$ where m is the mass, c is the specific heat capacity of the body at the appropriate temperature and pressure range, and ΔT is the change in temperature of the body.

Water Example:



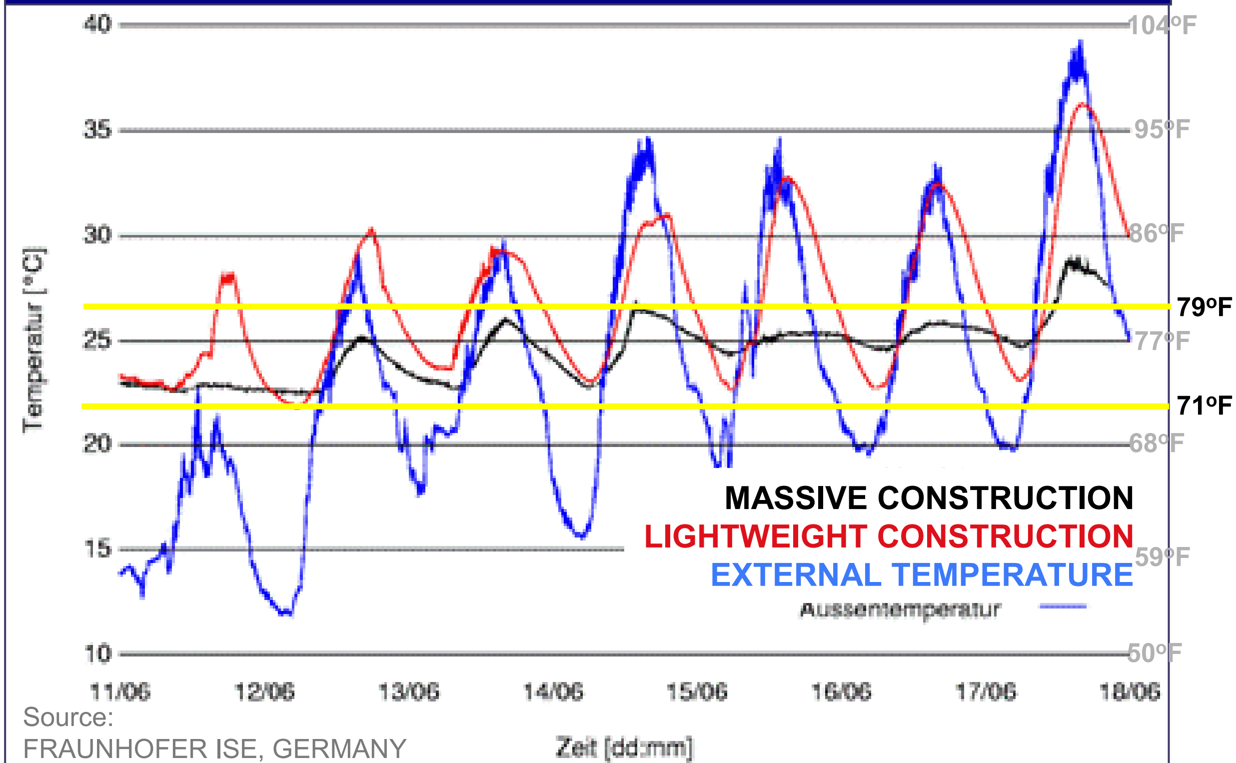
SENSIBLE vs. LATENT HEAT STORAGE

	kJ/l	kJ/kg	Comment
Sensible heat			
Granite	50	17	$\Delta T = 20°C$
Water	84	84	$\Delta T = 20°C$
Latent heat of melting			
Water	330	330	0 °C
Paraffin	180	200	5–130 °C
Salthydrate	300	200	5–130 °C
Salt	600–1,500	300–700	300–800 °C

Source: Harald Mehling, Luis Cabeza Bavarian Center for Applied Energy Research, ZAE Bayern, Germany

PCM CAN STORE 3-4 TIMES MORE ENERGY PER VOLUME AS IS STORED AS SENSIBLE HEAT STORAGE IN SOLIDS OR LIQUIDS FOR A TEMPERATURE INTERVAL OF 20 °C.

THERMAL MASS IS CRITICAL TO "LEVELING" ROOM TEMPERATURES WITHIN BUILDING

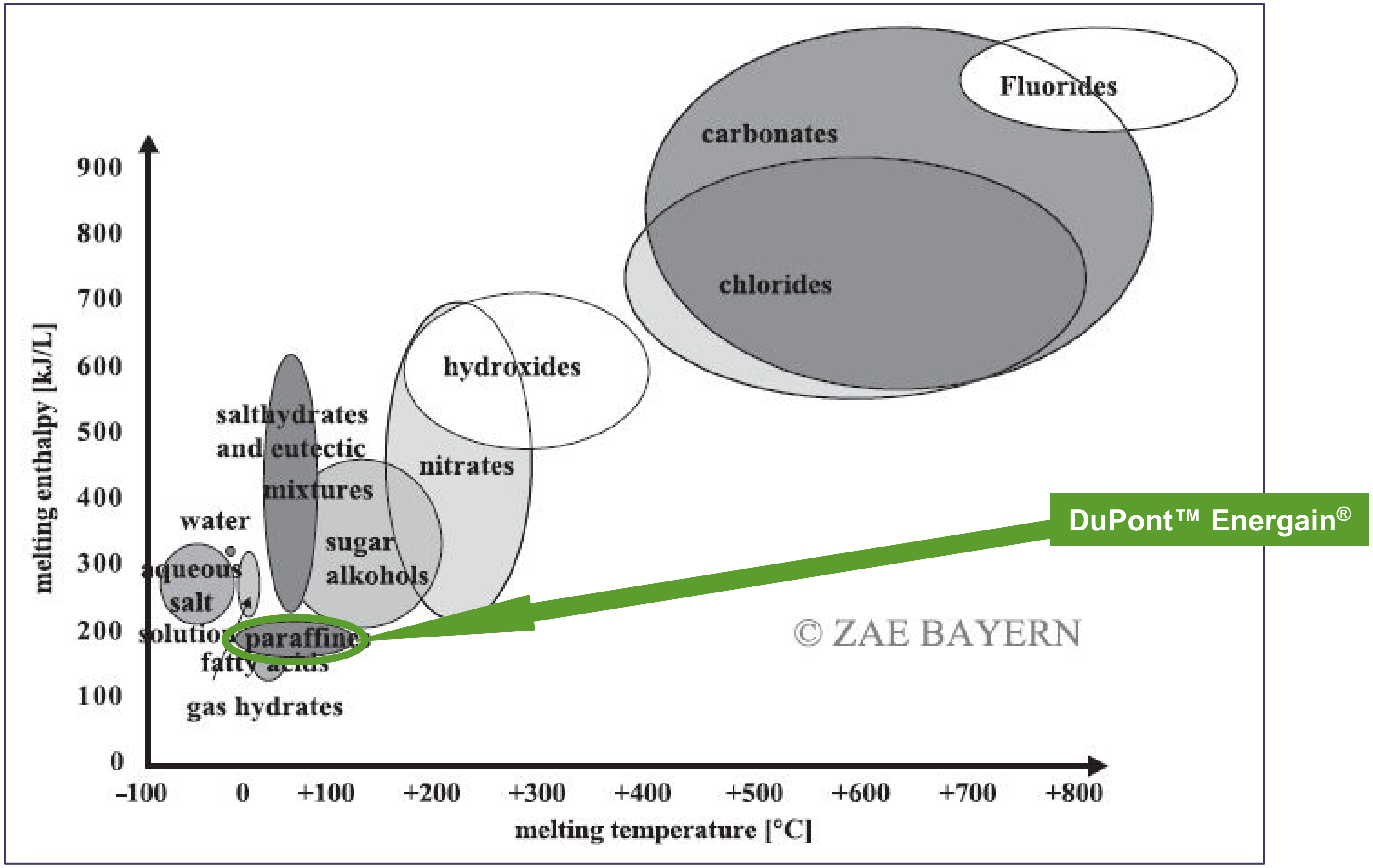


Source:
FRAUNHOFER ISE, GERMANY

THERMAL MASS EFFECT = THERMAL INERTIA

Thermal mass is the ability of a material to absorb and store heat. The thermal mass performance is determined by thermal conductivity and high specific heat capacity to maximize the heat that can be stored per kg of material.

A Lack of Thermal Mass Leads to Larger Interior Temperature Swings in The Building Resulting in Higher Energy Demands (Especially in Summer)



Source: Harald Mehling, Luis Cabeza
Bavarian Center for Applied Energy Research, ZAE Bayern, Germany

WHAT IS A Phase Change Material (PCM)?

PCM's such as water, paraffin, salt hydrates, *etc.* are able to absorb, store and release large amounts of thermal energy within comparatively small, defined temperature ranges by changing their physical state: *e.g.* Solid-to-liquid, liquid-to-solid, solid-to-solid or through evaporation of the storage material. The heat stored is called latent heat, therefore materials are also referred to as "LATENT HEAT STORAGE MATERIAL".

DuPont™ Energain®: Phase Change Material

DESIGNED TO

- Add ‘effective thermal mass’ to structures
- Store more energy than concrete with less mass & thickness

TECHNOLOGY

- Paraffin wax in a polymer matrix
- Dimensions: 1.0 m x 1.2 m x 5.26 mm

PERFORMANCE

- System melting point 22 °C (71°F)
- Solid at / or below ~ 18 °C (65°F)
- Once the room temperature increases, the paraffin starts liquefying and absorbs thermal energy (515 kJ/m^2) at 18-24°C
- Once the room temperature drops, the paraffin starts solidifying and releases the absorbed energy back into the room
- Net effect of the absorption/de-absorption of the thermal energy is a ‘leveling of the temperature swings’ within the room and, hence, a lower demand on the HVAC system

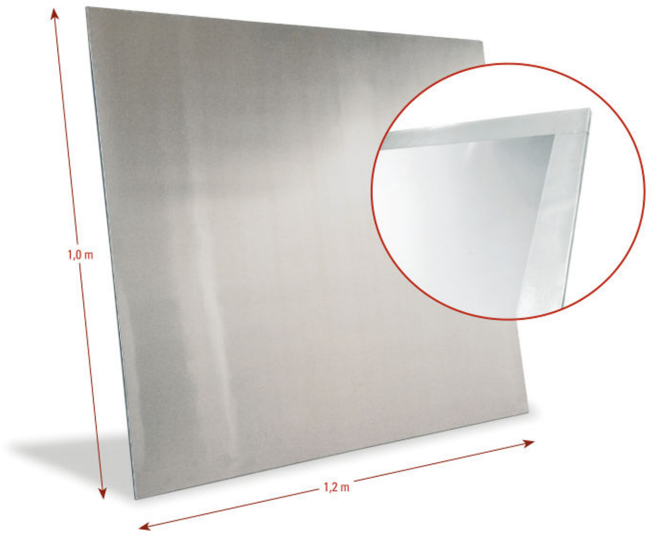
SPECIFICATION

- Model simulation of building installation requirements for design:
  - Number of square meters needed ~ 0.5-1m^2 per m^3 volume
  - Where best to install
  - Temperature reduction & energy savings estimates

VALIDATION

- Real life-experiment by EDF (Electricité de France), France

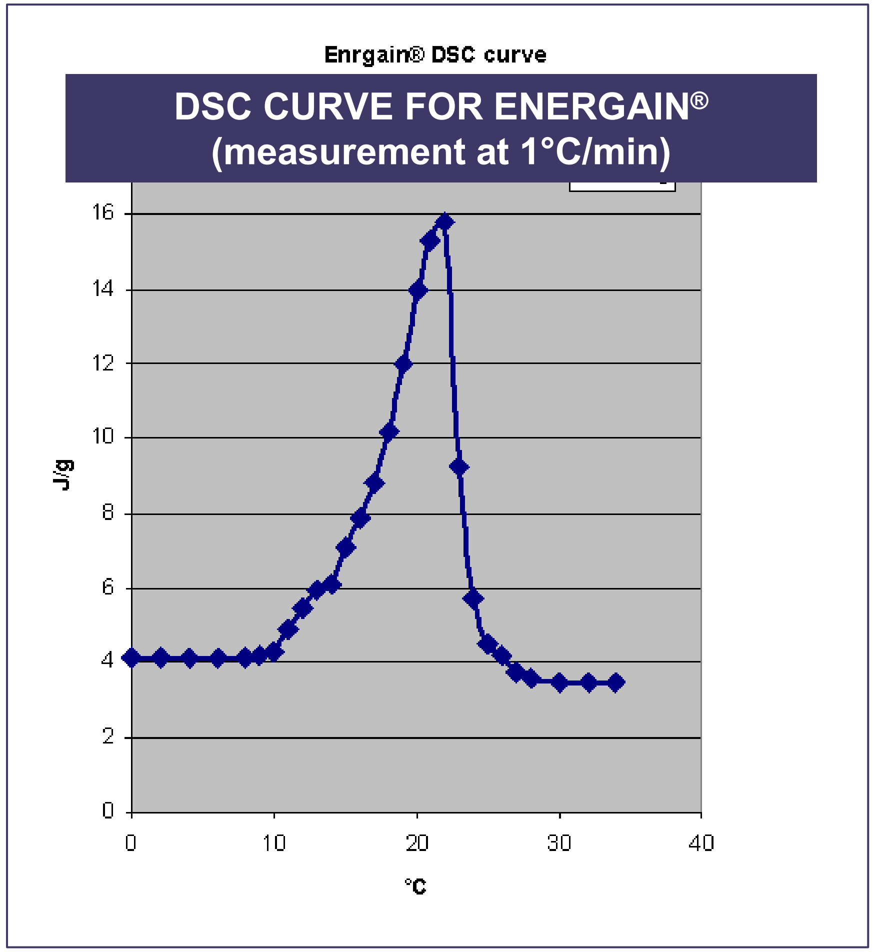
PASSIVE ROOM CLIMATE AND ENERGY MANAGEMENT



DuPont Innovation (PATENT)

ensures that the material (polymer compound / panel design) maintains its mechanical stability while the paraffin is in liquid state.

ENERGAIN®: PROPERTY	UNIT	VALUE
Temperature window	°C	10-31
Peak temperature	°C	22
Weight	kg/m^2	4.05
Thickness	m	0.005
Vol (Mass)	kg/m^3	810
Total heat storage capacity across temperature window (10-31°C)	kJ/m^2	649
Theoretical Energy absorption	$Wh/m^2.d$	180



DSC CURVE FOR ENERGAIN®
(measurement at 1°C/min)

*DSC**:** Differential scanning calorimetry is a thermoanalytical technique that measures the amount of heat required to increase the temperature of a sample for a given time step.*

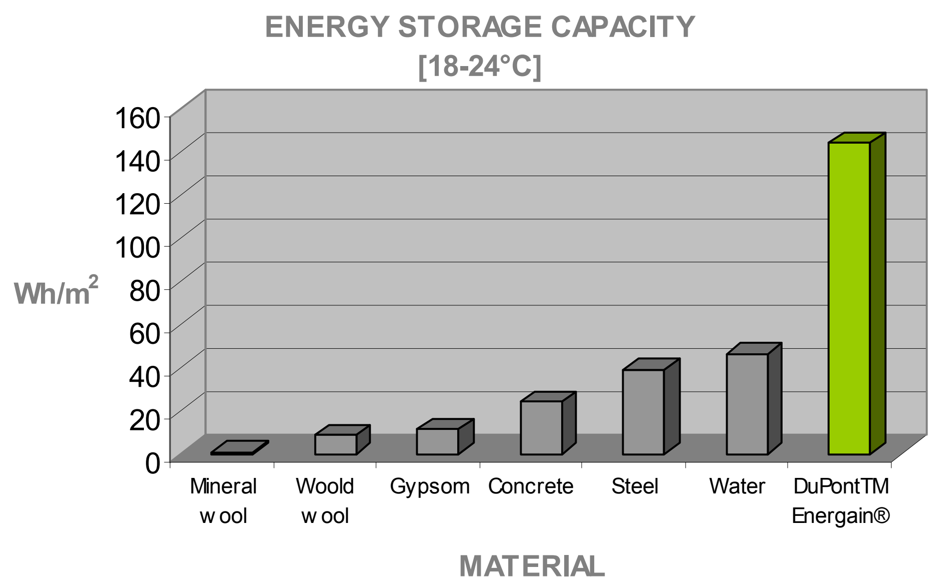
PCM: 'EQUIVALENT' THERMAL MASS COMPARISON

CONCRETE VS ENERGAIN®
(Effective Mass Equivalents)

10 mm of DuPont™ Energain® is equivalent to 80 mm of concrete.

Source: Joseph Virgone, Lyon University, France

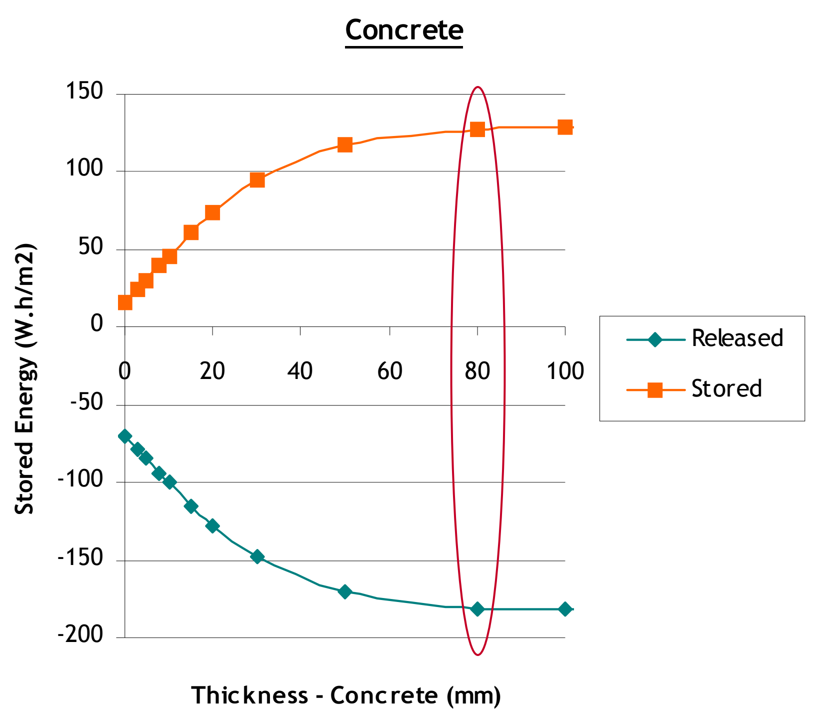
BUILDING MATERIALS (5 MM PANELS)



CONCRETE OFFERS ONLY 17% OF THE ENERGY STORAGE CAPACITY IN THE 18-24°C TEMPERATURE RANGE AT 5MM

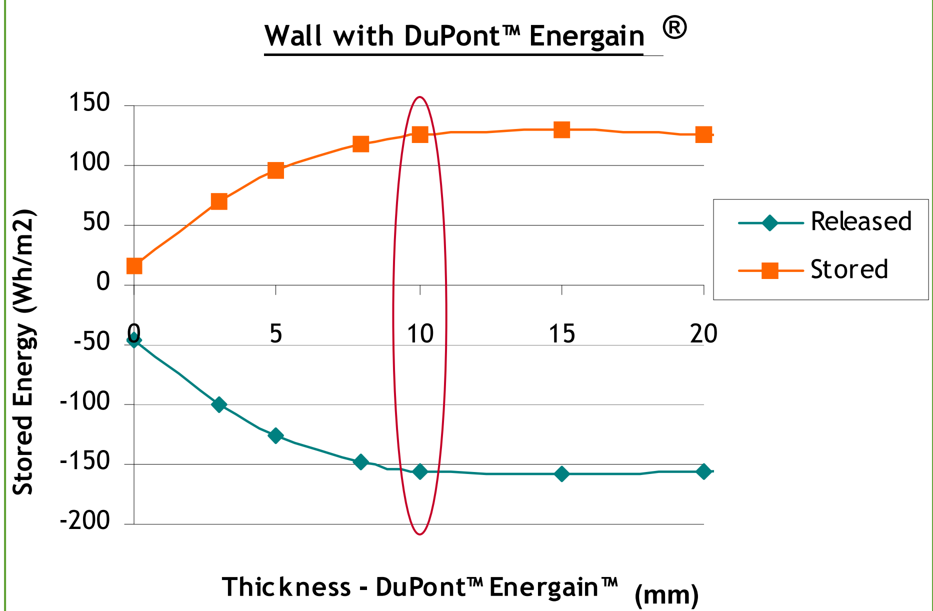
PCM: THERMAL MASS COMPARISON

CONCRETE



The optimum response is obtained with 8 cm of concrete with an energy of 130 Wh/m^2 with marginal additional gain between 25 and 80 mm of concrete.

ENERGAIN®



For DuPont™ Energain™, the optimum response is 10 mm, with a stored energy of 130 Wh/m^2. The further gain from a 5 mm vs 10 mm panel doesn't warrant the cost.

Source: Joseph Virgone, Lyon University, France

1

MEASURE

2

CUT

3

TAPE OR SEAL EDGES

4

INSTALL

4a

TAPE JOINTS IF USED AS A VAPOR CONTROL LAYER

5

PLASTERBOARD

The panel can be cut to any size and fitted in place by drilling and screwing, nailing and stapling. The panels are fitted behind ordinary dry lining plasterboards.

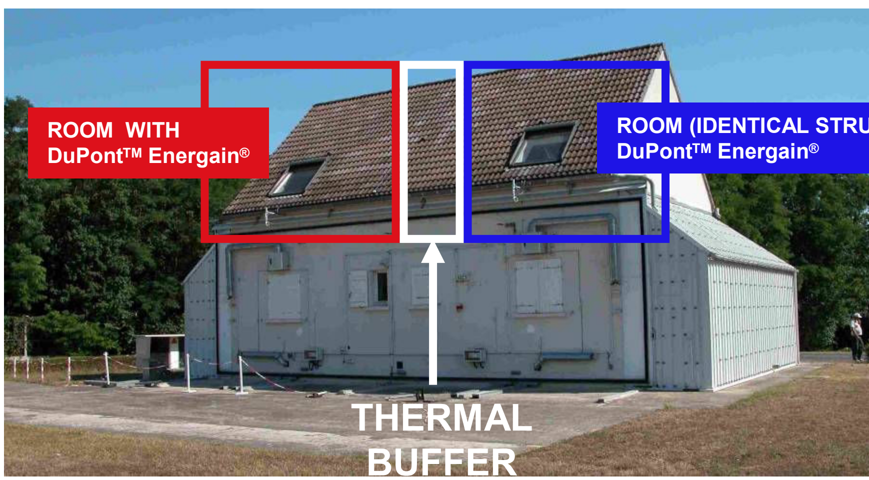
REAL-LIFE EXPERIMENT WITH EDF FRANCE

OBJECTIVE: Product performance validation under seasonal impact.
DuPont field test in cooperation with EDF (Electricité de France) **in the Paris region.**

Test duration: August 2006 – April 2007
DuPont™ Energain® - tested in the attic.

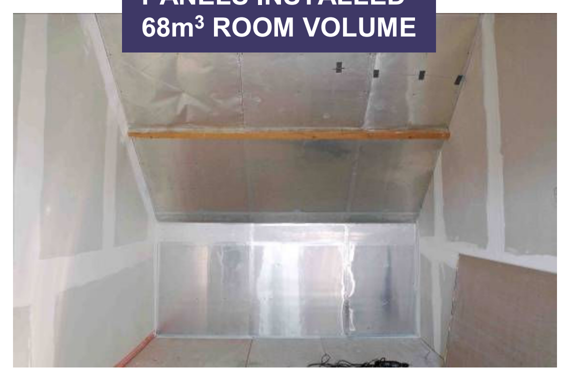
Insulation in attic:
R = 5 m²K / W (US R_{vaule} = 28)
Ventilation:
Summer : 0.5 vol/h (day), 2.4 vol/h (night) – free cooling
Winter : 0.5 vol/h (day & night)

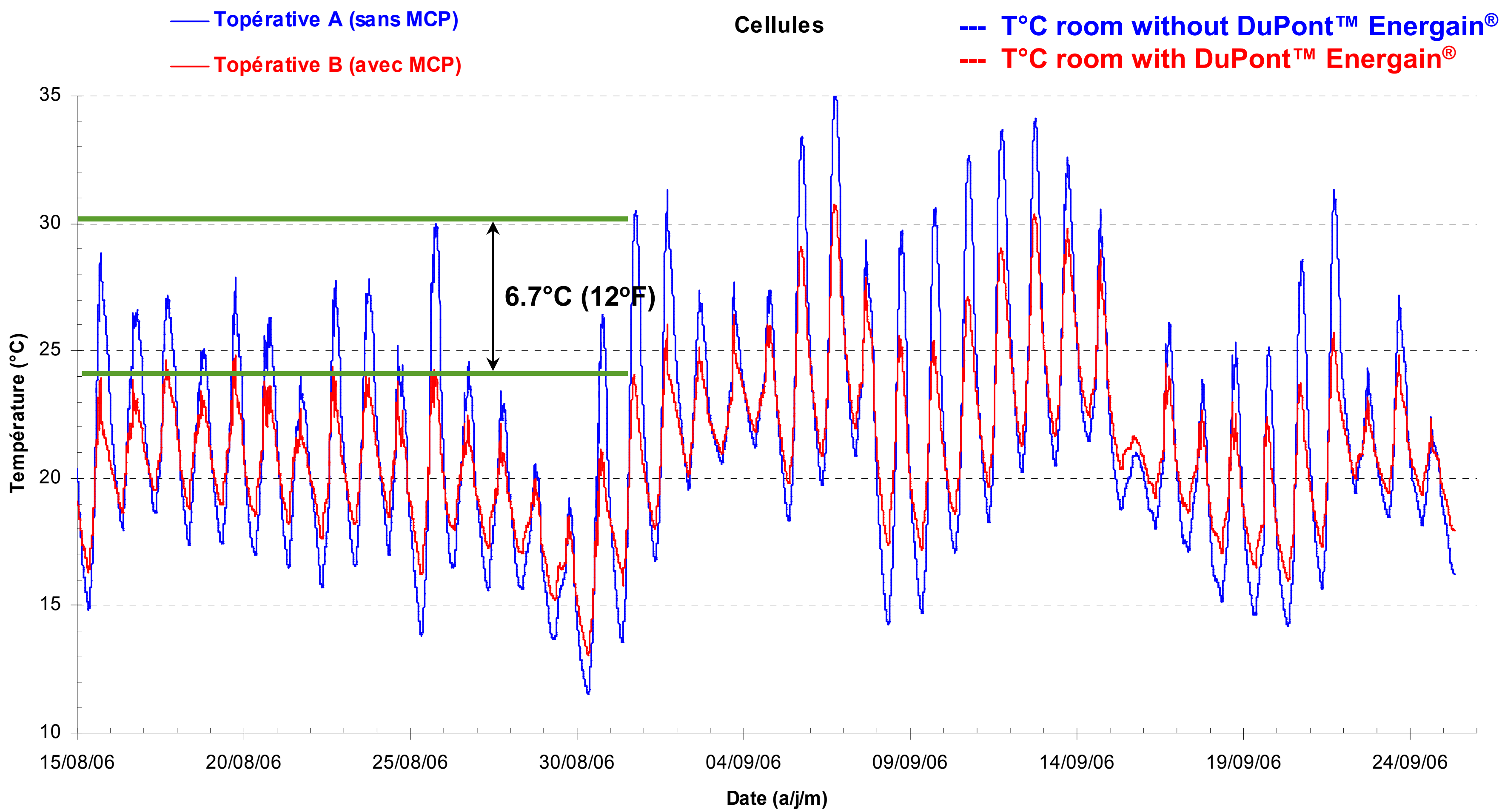
TEST BUILDING



ANALYTICAL INSTRUMENTS

PANELS INSTALLED 68m³ ROOM VOLUME





On Average, the PCM Room Peak Temperatures Were Reduced by 4.5°C (8°F) Relative to the Non-PCM Room During the Test Period

(Occasionally Observed Differences As High As 6.7°C)

BUILDING REFERENCES

HAMMOND HIGH SCHOOL, Swaffham, GB

Excessive internal temperature can have an adverse effect on both wellbeing and productivity – and for schoolchildren, it can prove a very unwelcome distraction.

UK Building Bulletin 101 - Ventilation of School Buildings:

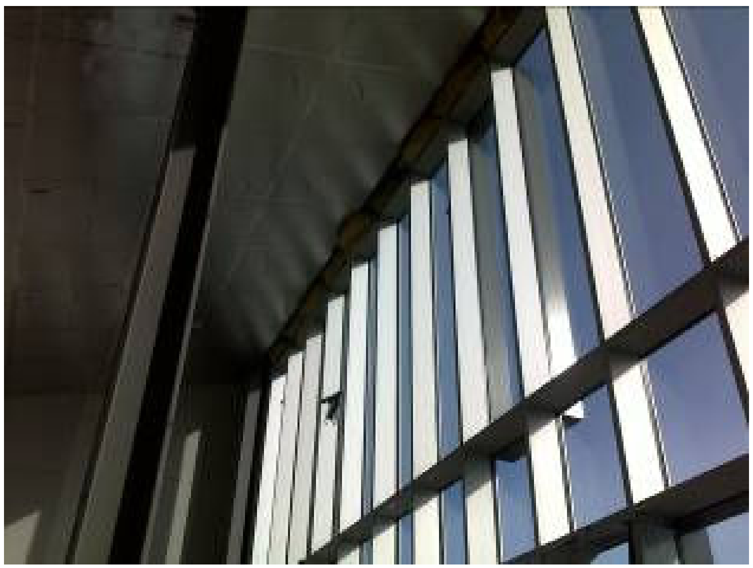
1. There should be no more than 120 hours per year when the air temperature in the classroom rises above 28°C (82°F)

2. The internal air temperature when the space is occupied should not exceed 32°C (90°F)

600 m² of DuPont™ Energain® installed into the ceilings of new classrooms.

BUILDING REFERENCES

NAPIER UNIVERSITY, in Edinburgh, GB 2010



Images courtesy of RMJM and ENU

650 m² of DuPont™ Energain® has been installed

BUILDING REFERENCES

PREBAT OFFICE BUILDING, Lyon, France

VENTILATION SYSTEM
(“Vide-Sanitaire”)

WALLS AND CEILINGS

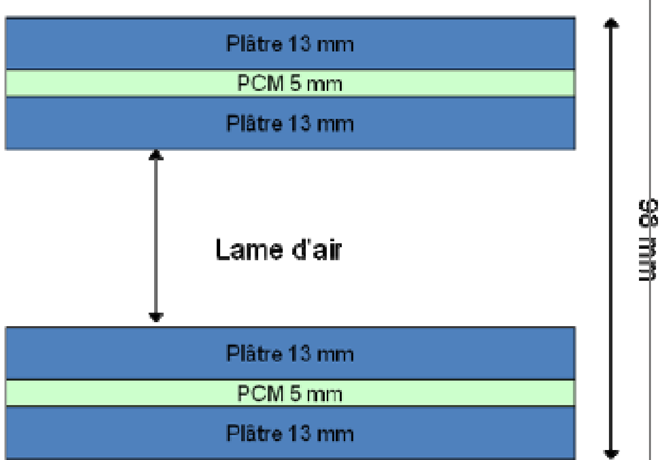
DuPont™ Energain® was selected to avoid installing an air conditioning system.

BUILDING REFERENCES

PREBAT OFFICE BUILDING, Lyon, France

WALLS AND CEILINGS

INSTALLATION SET-UP



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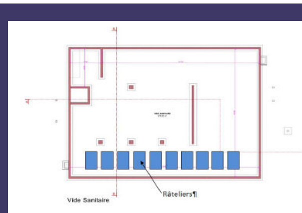

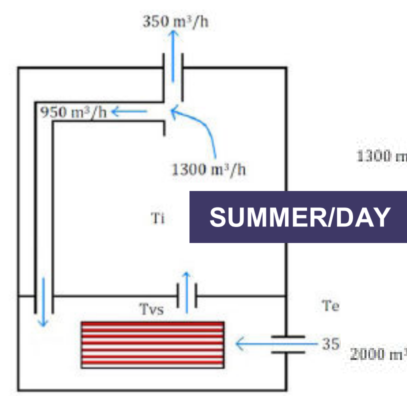

FIGURE 8: MODE DE VENTILATION "ETE", TE > 25,5 °C

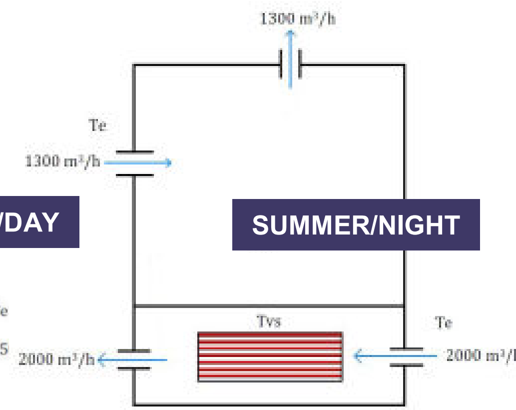

FIGURE 9: MODE DE VENTILATION EN PERIODE D'INOCCUPATION (NUIT)

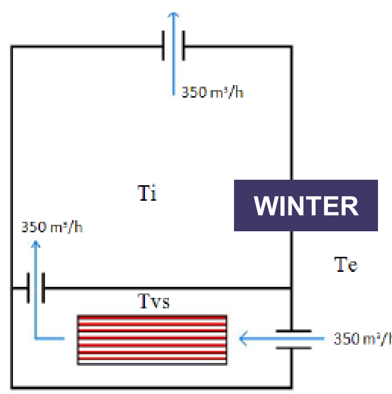

FIGURE 7: MODE DE VENTILATION "HIVER"

Surface of 275m², 10 shelves per rack with 10 layers (2m x 1.2m) of 2 Energain® panels each (1m x 1.20m)

BUILDING REFERENCES

BUSIPOLIS, Metz, France 2010

Photos © copyright SARL Busipolis de Metz

More than 500 m² of DuPont™ Energain® installed to improve room climate and reduce energy costs.

BUILDING REFERENCES

ZERO CARBON HOUSE, Kent, GB   2009

CROSSWAY HOUSE
BY RICHARD HAWKES

Finalist in Grand Designs Awards 2009.

Energain® installed to add thermal mass.

Photos: Courtesy of Richard Hawkes

BUILDING REFERENCES

PRIVATE VILLA, PRAGUE, CZECH REPUBLIC 2010

"Manipulation and installation of the DuPont™ Energain® panels were quick and easy, a perfect solution for this project", said Mr. Rychlý, sales manager of Kerilit (supplied and installed).

The miracles of science™