Fraunhofer Center for Sustainable Energy Systems

Understanding Potential for Phase Change Material Applications in Residential Buildings

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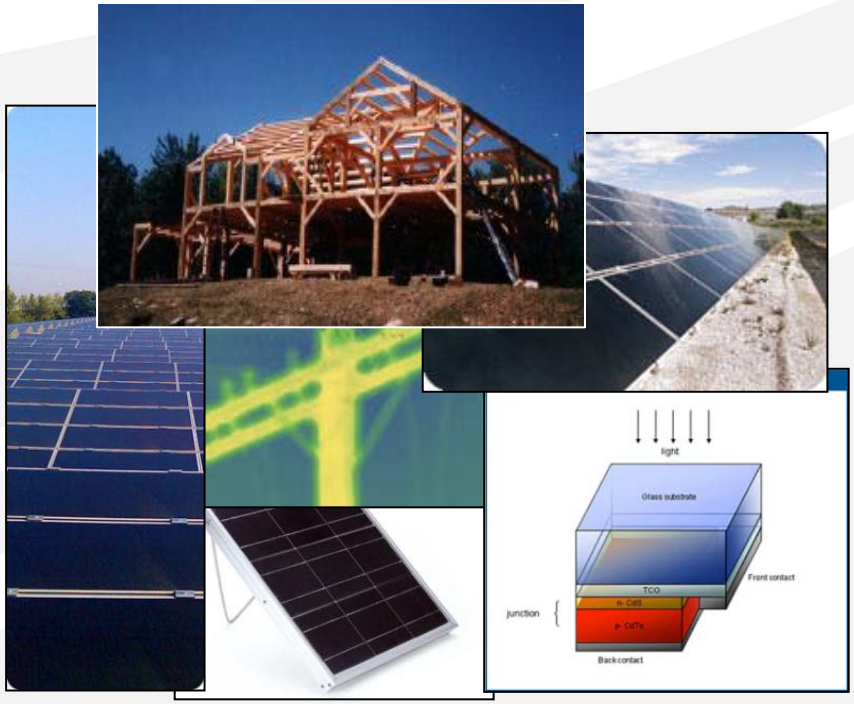
Building Enclosure
Program Lead

Residential Energy Efficiency Meeting, sponsored by the U.S. Department of Energy's (DOE) Building America Program

Denver, CO
July 21, 2010



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Massive Stone Cave - A First Home for Human Beings:

WHY…?

- **flat temperature profile year around**
- **uniform radiation temperature fields**
- **uniform humidity**
- **no drafts**
- **fresh air ???**

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Our Predecessors Knew How to Use Thermal Mass and Live in Hot Climates Without Air-Conditioning

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Native Americans Preferred Massive Adobe Homes

Igloo is a First Known PCM House Developed for Heating Dominated Climates

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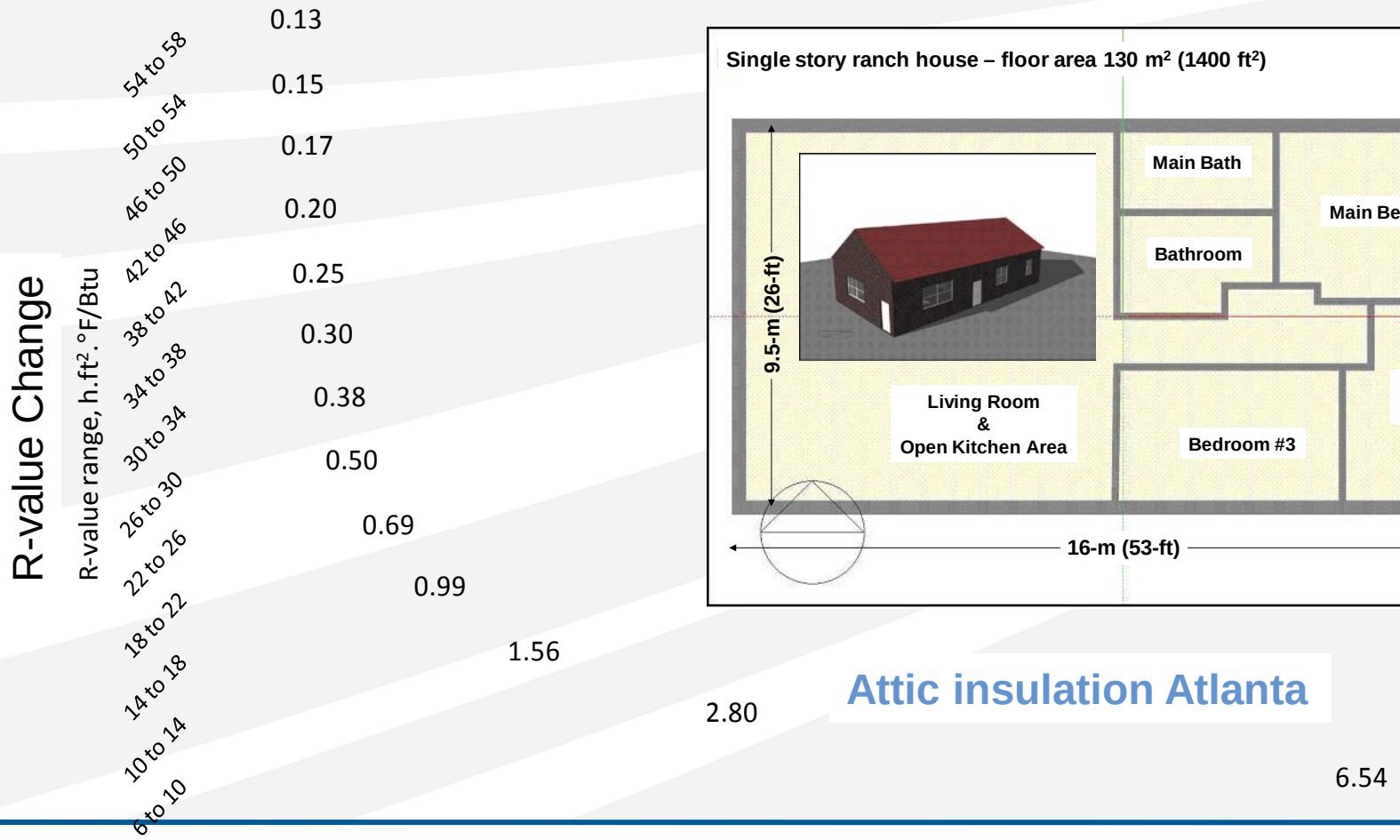
Today, there is a serious reason why, we may utilize PCM thermal mass in building envelopes?

Diminishing energy savings' returns for conventional insulations



Attic insulation Atlanta

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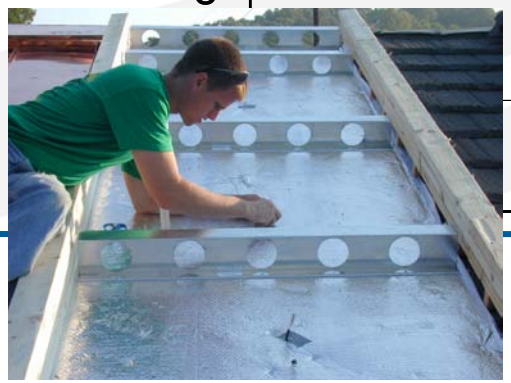
PCMs are only one of many engineering means helping to enhance thermal performance of buildings

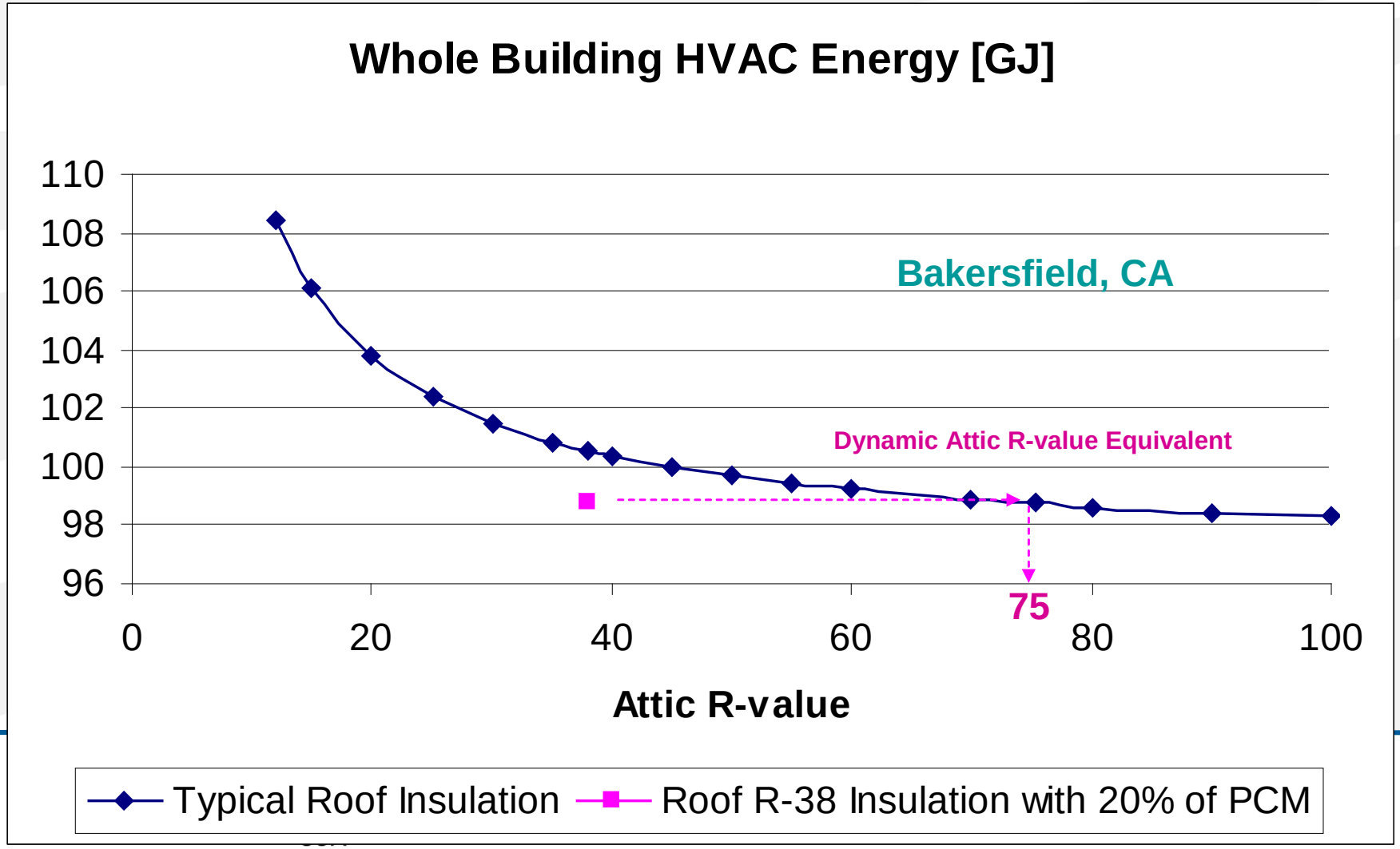


Other Enabling Technologies for New Generation of Dynamic Multifunctional Envelopes

- Thermal Insulations
- Reflective Insulations
- Radiant Barriers
- Cool Coatings (cool roofing, cool walls)
- Conventional Thermal Mass
- Phase Change Materials
- Ventilated Cavities
- BIPVs and Solar-Thermal Systems
- Mechanical or Radiant Systems and Hydronic Heat Exchangers

PCMs can be blended with conventional insulations

R-38 PCM-enhanced Attic Insulation in Bakersfield, CA works like R-75 conventional Insulation



Understanding of PCMs

Phase Change Process

"Melting/Crystallization heat"

Ice-Water: $\Delta H = 333$ kJ/kg

at 0°C

(32°F)

Temperature Difference

"Heat capacity"

Water: $c_p \approx 4.2$ kJ/kg · K

1°C → 80°C

(34°F → 176°F)

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Engineering Functions of PCMs

- Local Temperature Control
- Peak Load Time Control
- Dynamic Thermal Break
- Enhanced Heat Storage
- Thermal Comfort

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Key Physical Characteristics and Other Important Parameters of PCMs

- Total Enthalpy (heat storage capacity)
- Necessary Amount => Cost
- Phase Change Temperatures
  - melting
  - freezing
- Sub-Cooling Effect
- Purity
- Location within the Building or Building Envelope

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PCM Thermal Mass in Buildings

can be almost everywhere

- **Parts of the building structure**
  - **roofs and attics**
  - **exterior walls**
  - **interior walls**
  - **floors, and ceilings**
  - **fireplaces, stairs, etc...**
- **Space Conditioning Systems**
- **Furniture**
- **Finish materials**
- **Passive solar heat storage containers**

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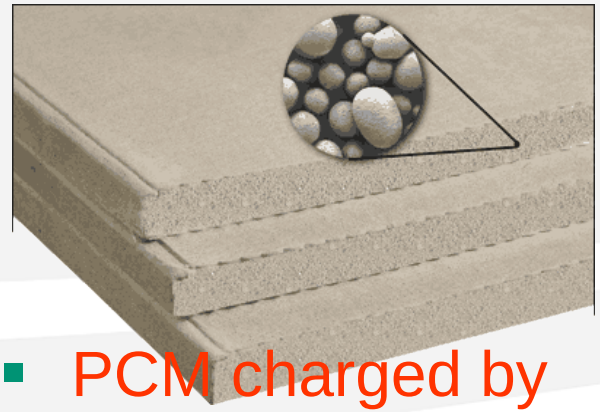
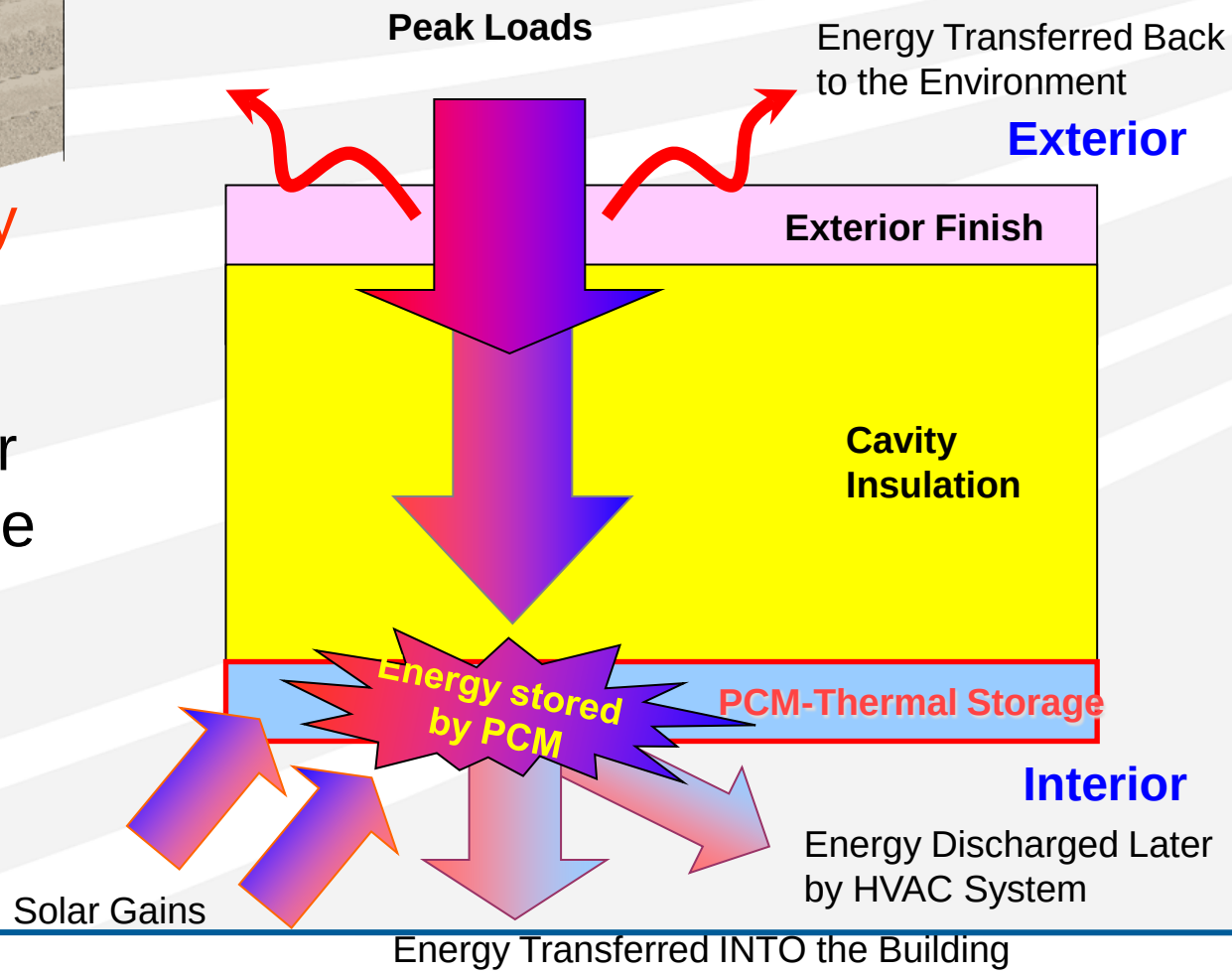
Traditional Approach – **Concentrated PCM** - Thermal Storage



- PCM charged by the interior temperature swings and solar gains through the glazing
- Building HVAC system used to discharge PCM

Schematic of Distribution of Heating and Cooling Loads in Old PCM Applications



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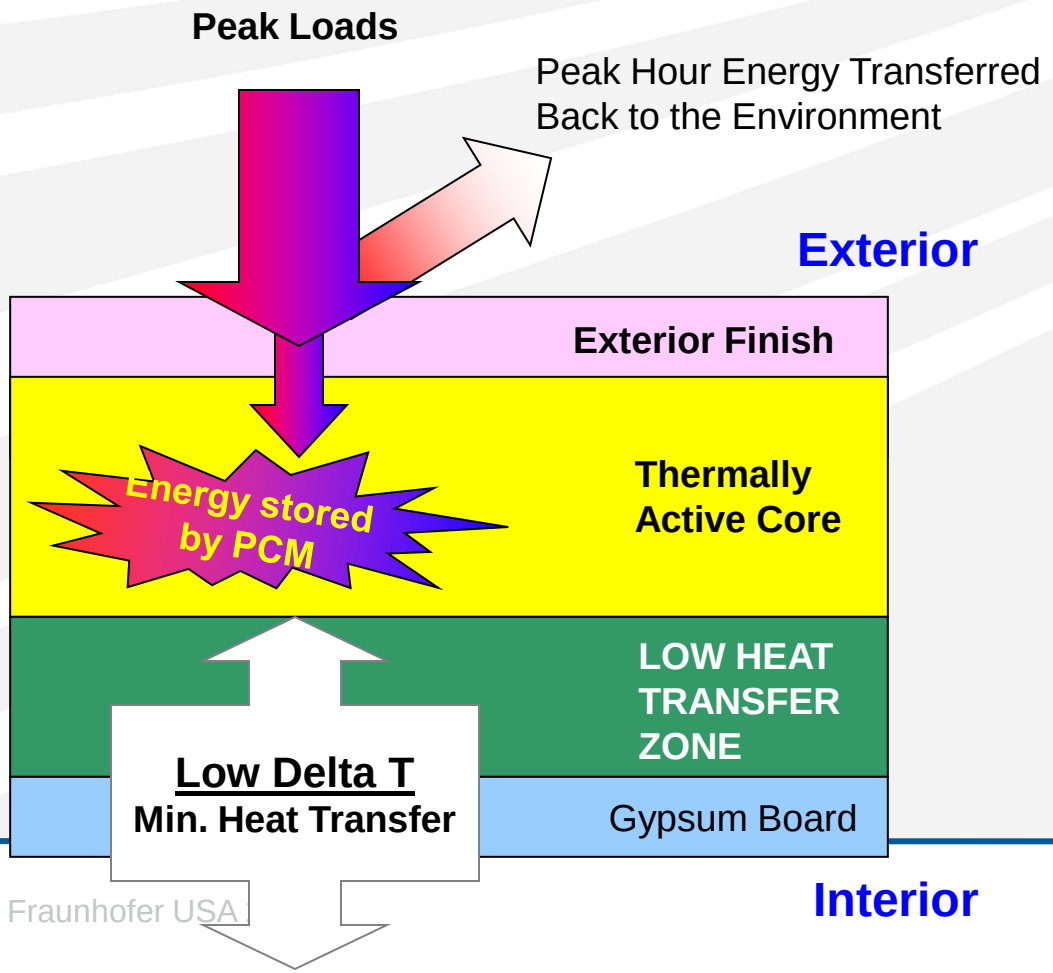
More Advanced PCM Applications

- Use fluctuations in exterior temperature and solar irradiation for charging and discharging of PCM
- PCM material has to be able to fully charge and discharge energy during 24-hour dynamic cycle

Schematic of Distribution of Heating and Cooling Loads in PCM-Enhanced Building Envelopes with Thermally Active Core



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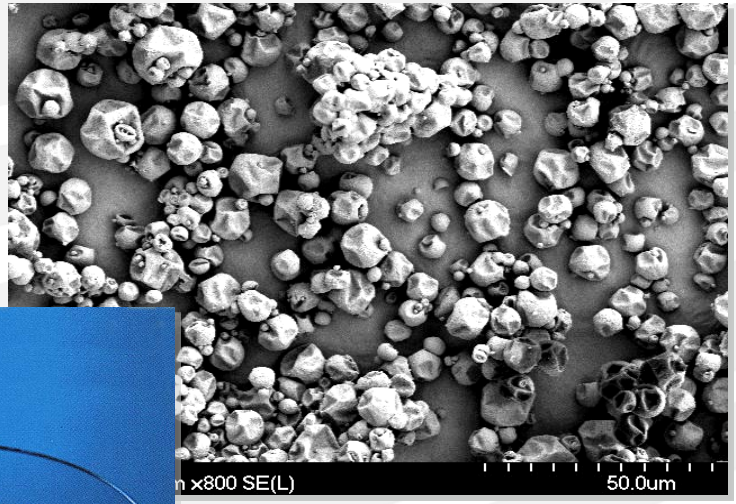
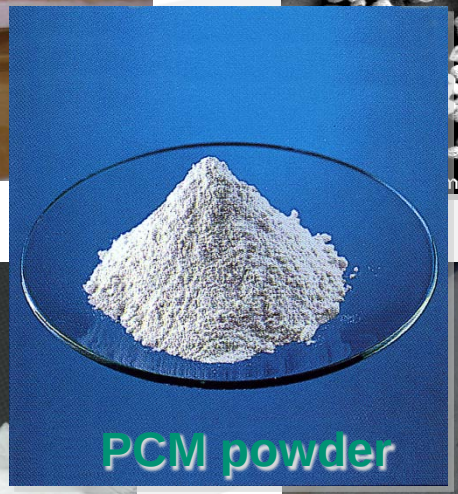
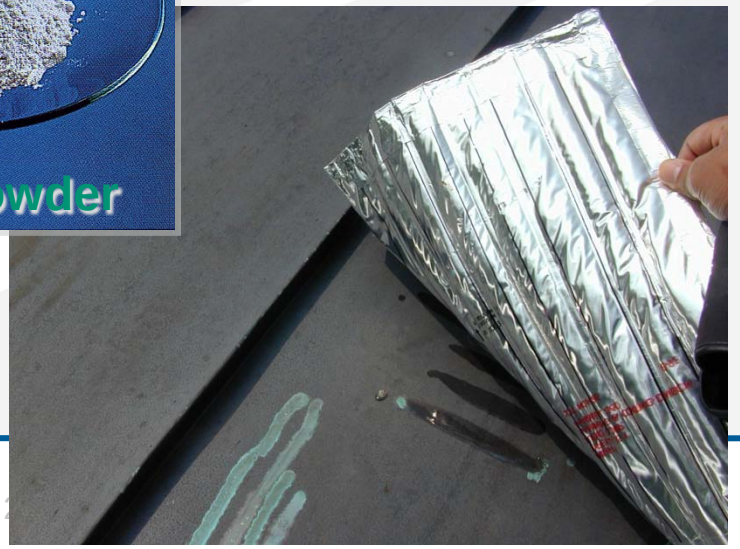
Large Selection of Inorganic and Organic PCMs is available today



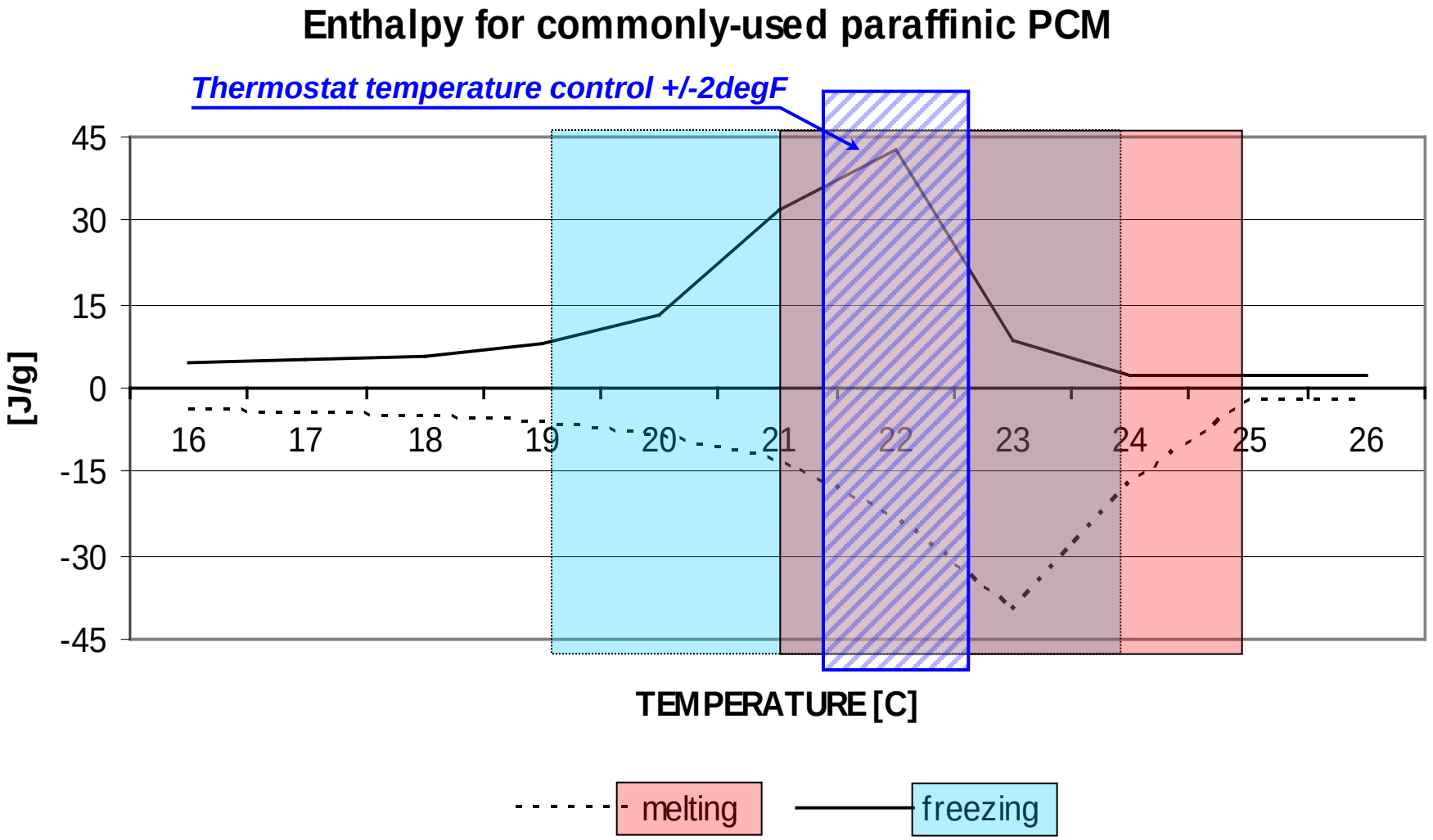




Basic Differences in PCM Technologies

- Inorganic Phase Change Materials
- Organic Phase Change Materials
- Different Encapsulation and Packaging Methods;
  - Micro-encapsulation
  - Macro-encapsulation
  - Macro-packaging
- Different PCM Applications:
  - Dispersed PCMs
  - Concentrated PCMs
  - PCM slurries

Thermal Characteristics of PCMs which have to be seriously considered



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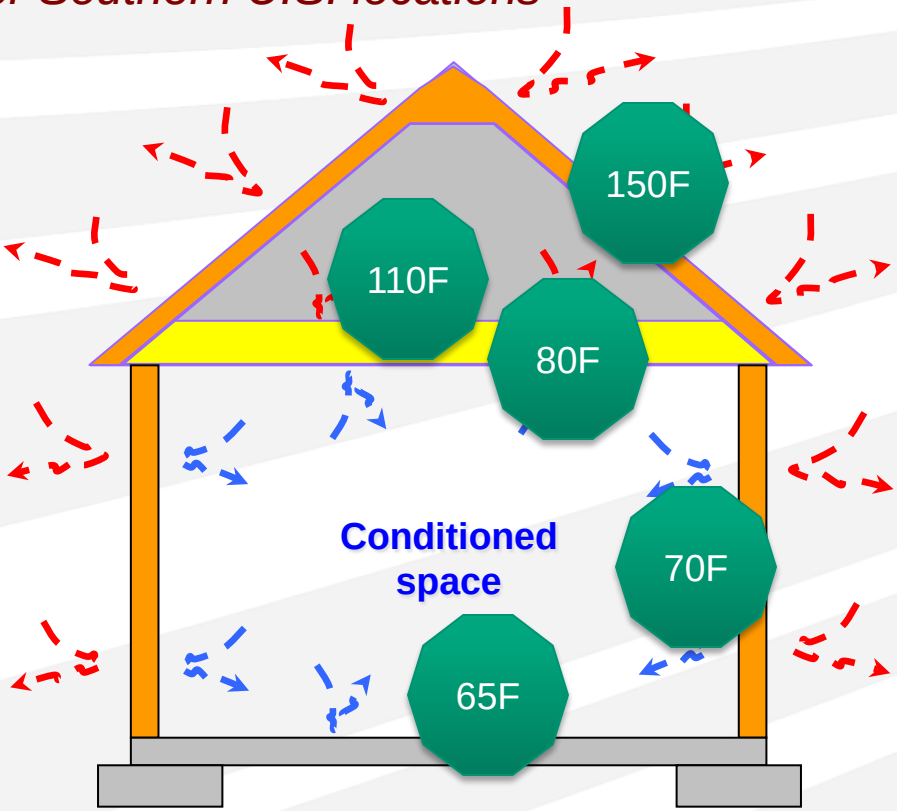
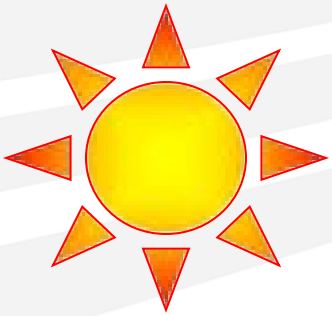
Current Estimates for Expected Thermal Characteristics of PCMs to be used in residential buildings

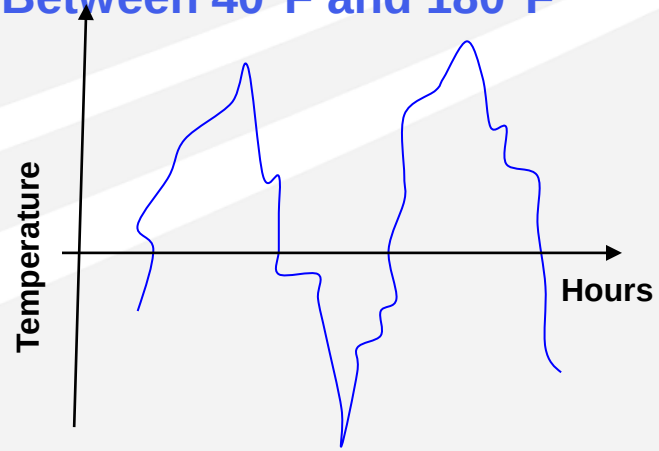
Approximate PCM melting temperatures for Southern U.S. locations





Solar

Approximate Range of Useful Temperature Fluctuations in Different Parts of the Building is Between 40°F and 180°F



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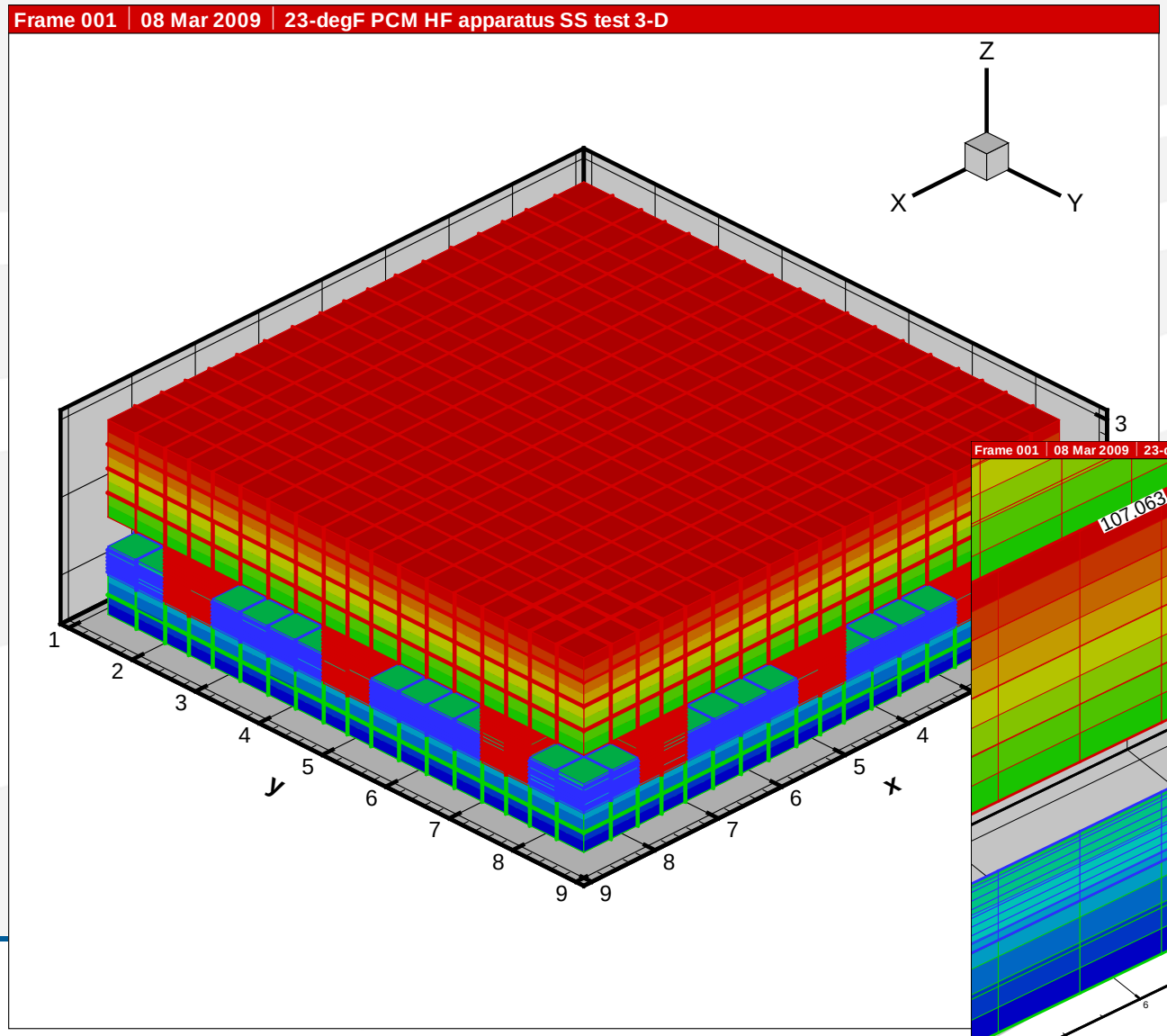
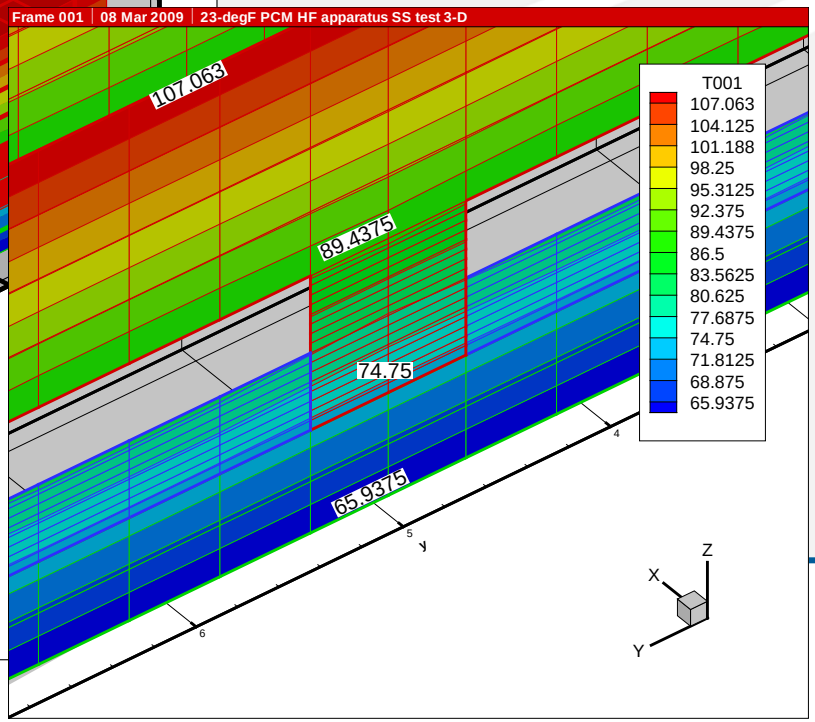
Some **PCM Products are pretty COMPLEX** and may require detailed simulations and advanced testing methods





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PCM Technologies which have been Developed and already Field Tested in Collaboration with DOE's Building Envelopes Program

New PCM-Enhanced Fiber Insulations - New Approach for Dispersed Thermal Mass

Blown Fiberglass

Blown Cellulose

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PCM-Enhanced Cellulose Insulation has been Field Tested in Two Locations

Northern wall

Southern wall

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PCM-Enhanced Blown Fiberglas

Attic field testing in Oak Ridge, TN

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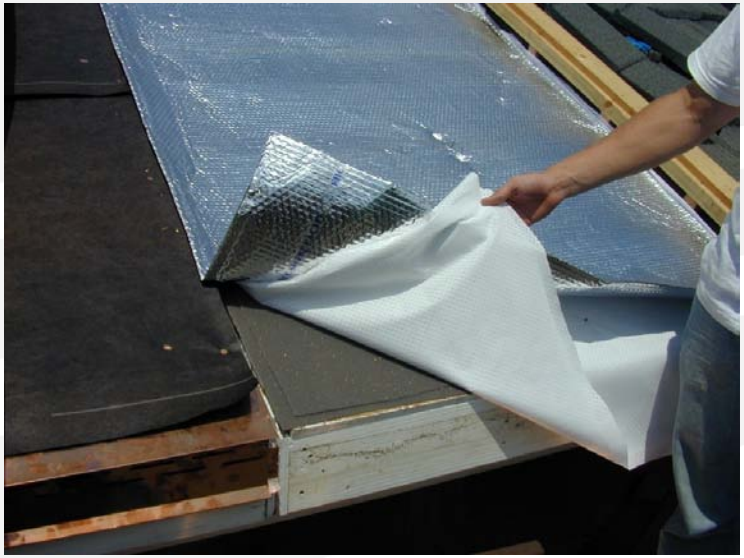
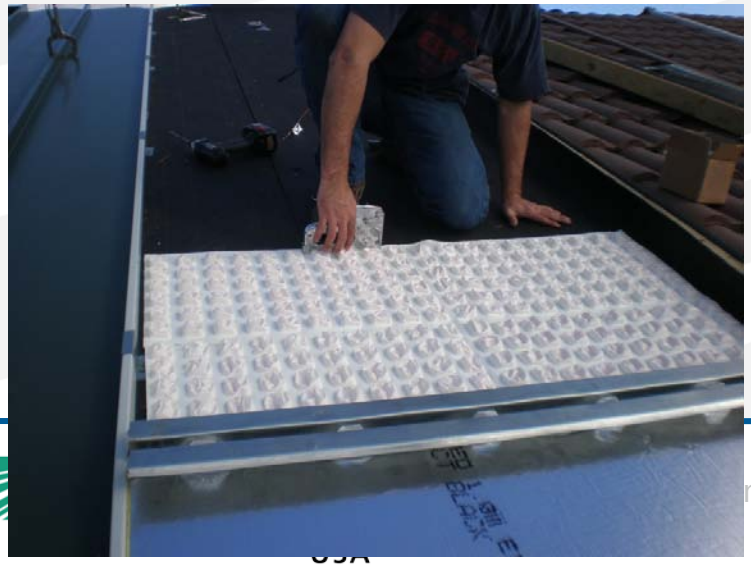
PCM Test House in Oak Ridge, TN with R-30 PCM Walls and R-50 PCM Attic Insulation

Four generations of roofs with PCM heat sinks have been field tested in Oak Ridge, TN



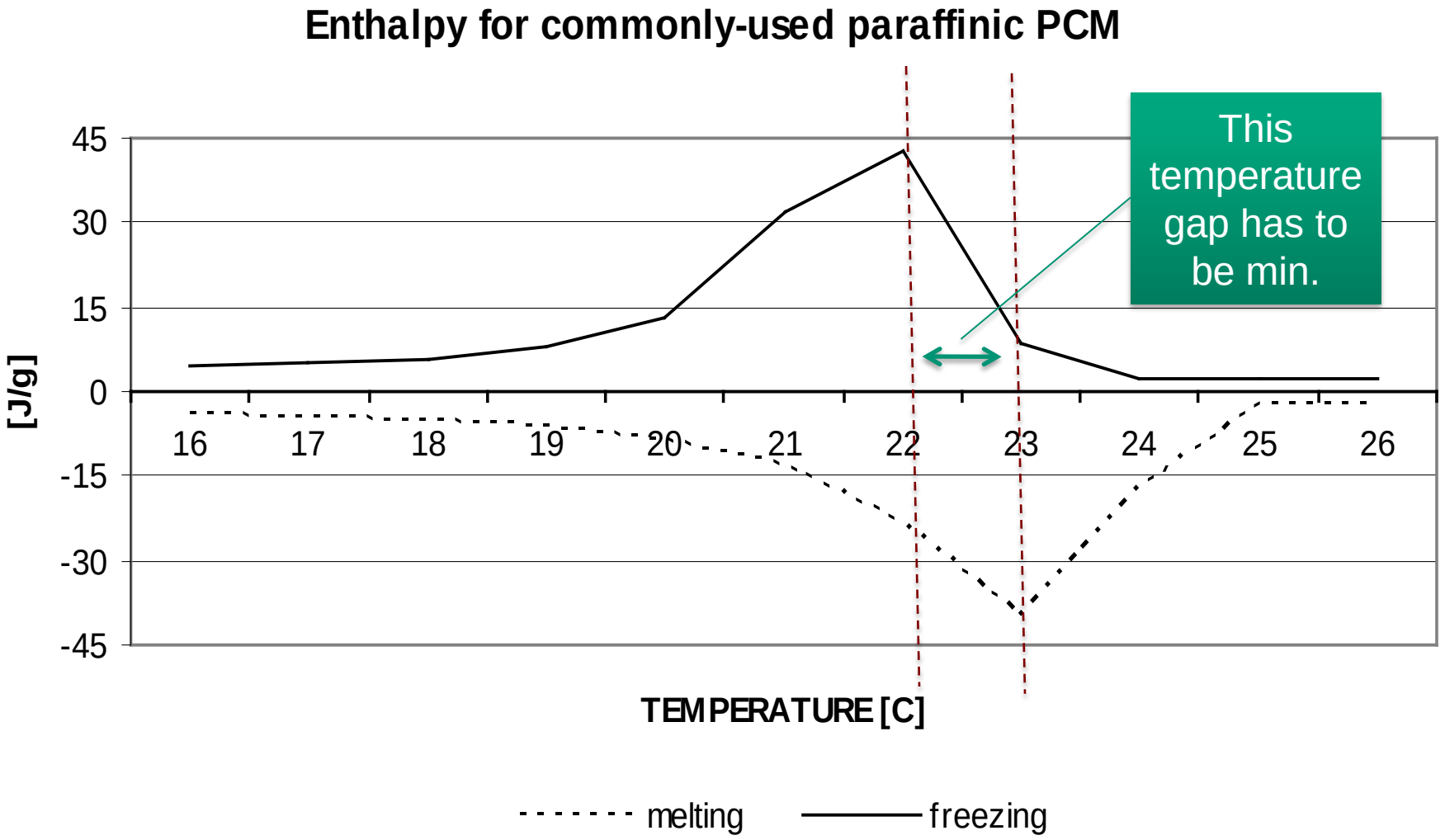


What to Avoid with PCM Technologies?

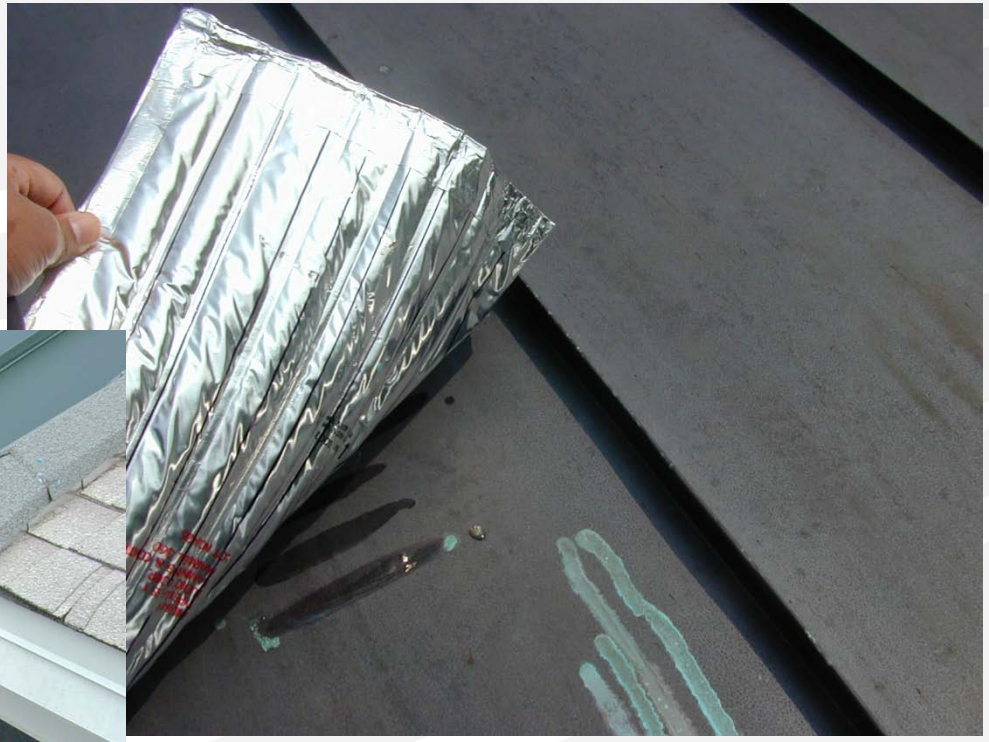
Price over $3.50 per lb for material of minimum heat storage density of 150 J/g

Final enthalpy of the PCM heat sink product lower from 120 J/g

PCMs with significant sub-cooling effects



Potentially Leaky PCM Packages with Corrosive PCMs



Let’s Work Together!

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