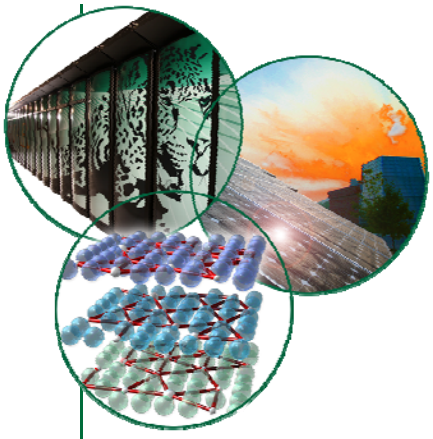
Theoretical and Experimental Thermal Performance Analysis of Complex Thermal Storage Membrane Containing Bio-Based Phase Change Material



Envelope XI

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PCM property evaluation

- Performance of PCM-enhanced building envelope depends on the quality and amount of PCM
- No standard small-scale testing procedure is currently available to analyze the dynamic thermal characteristics of PCM-enhanced materials
- DSC is widely used, but this method requires relatively uniform and very small specimens of the material

PCM property evaluation

- ORNL is developing a methodology for dynamic heat flow analysis for PCM-enhanced building materials
- Bio-based PCM encapsulated between two layers of heavy-duty plastic film was evaluated for building envelope applications

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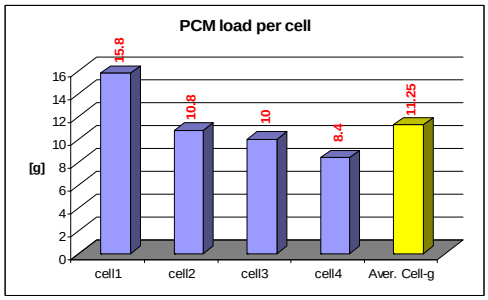
This prototype specimen had non-uniform cell loading



The tested cells were filed with a mixture of about 80 wt% organic PCM with the balance being fire retardant

About 20% of each PCM cell volume was filled with air

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A standard testing procedure using a HFMA was modified to allow dynamic testing

Initial uniform temperature: 15.5°C (59.9°F)

Then the temperature of the bottom plate of the HFMA was changed to 43°C (109.4°F)

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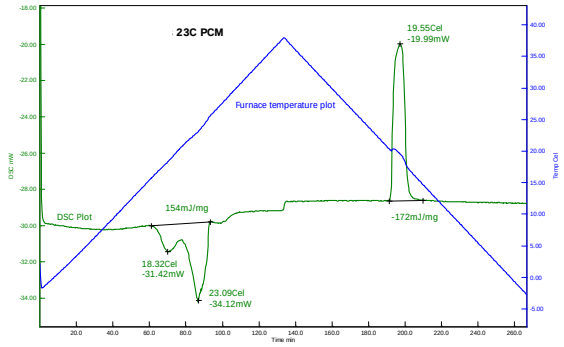
DCS test data used in simulations



Heating and cooling rates, °C/min	0.3	1.0
Melt energy, J/g	160	157
Freeze energy, J/g (Btu/lb)	172	173
Melt Temperature, °C*	18 / 23	19 / 26
Freeze Temperature, °C	20	19

*The DSC enthalpy curve showed two peaks during the melting process, both temperatures are listed here.

The enthalpy data generated during the DSC tests was modified to reflect the proportional weights of PCM and fire retardant

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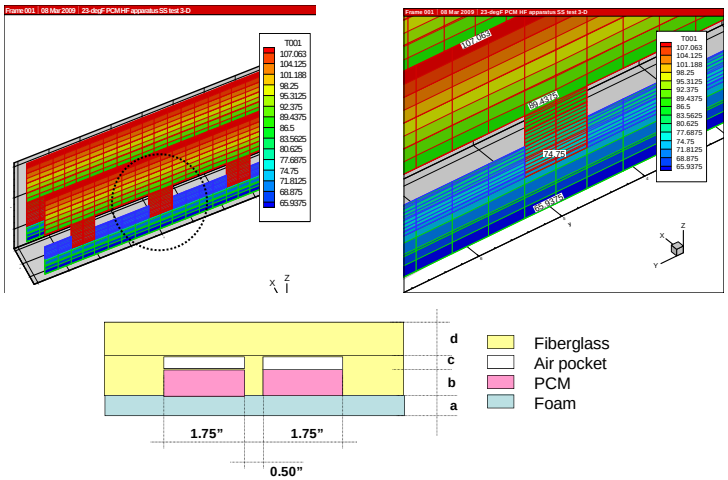
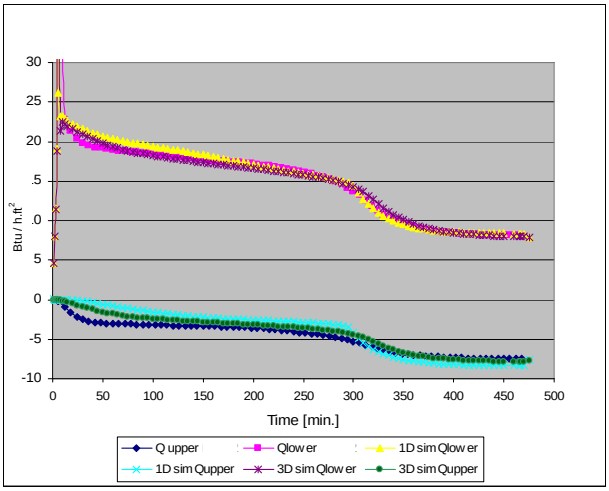
Finite Difference simulation was carried out to compare with the HFMA test result



HFMA test results agreed well with the 1-D and 3-D simulation results



Artificial exterior walls composition and thermal properties of layer developed for *E+* model

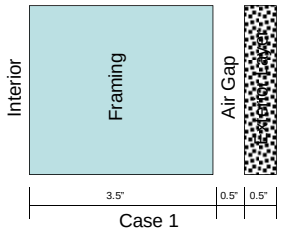
Conductivity: 0.7206 W/m.K
Density: 1922 kg/m^3
Specific Heat: 837.4 J/kg.K

Conductivity: 0.0556 W/m.K
Density: 19.2 kg/m^3
Specific Heat: 1214.2 J/kg.K

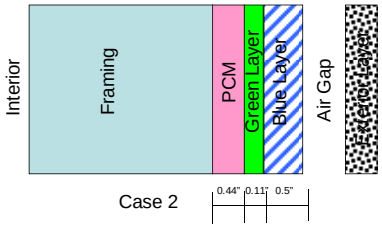
Conductivity: 0.0288 W/m.K
Density: 32 kg/m^3
Specific Heat: 1214 J/kg.K

Conductivity: 0.0457 W/m.K
Density: 22.1 kg/m^3
Specific Heat: 460.5 J/kg.K

Conductivity: 0.1845 W/m.K
Density: 541.4 kg/m^3

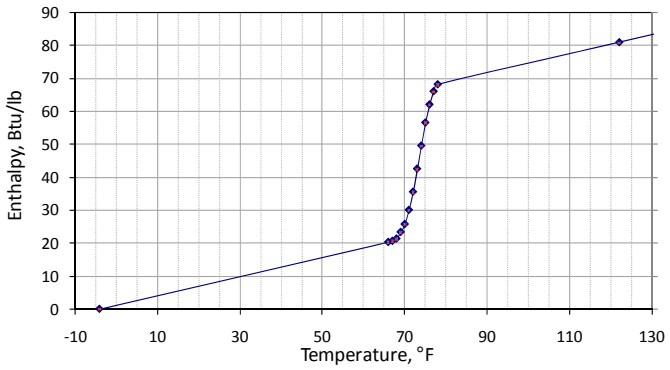


Case 1

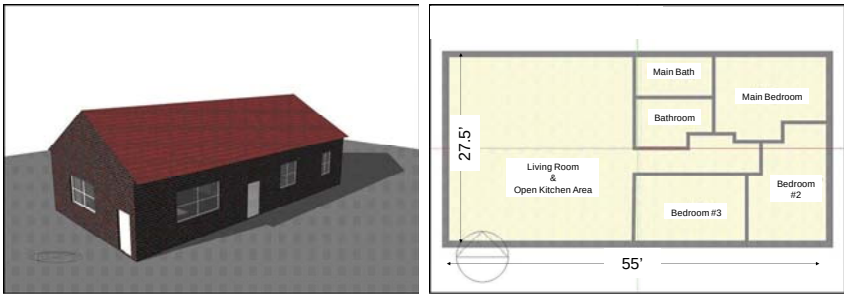


Case 2

PCM enthalpy-temperature relationship used in *E+* finite difference wall model



Single story ranch house with three bedrooms, one living room and an attic was used for the Study



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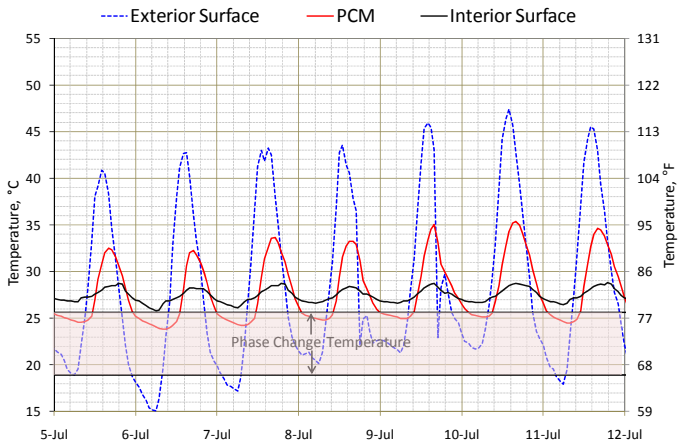
PCM selection must match desired service



During hot summer days, PCM did not solidify on south wall

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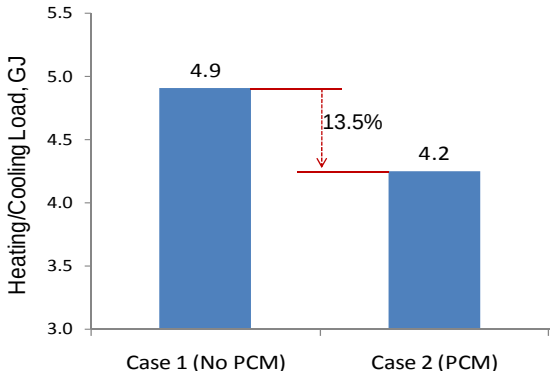
PCM reduced heating/cooling load from wall heat transfer by 13.5%



For this simulation walls contributed ~ 10% of the total building load

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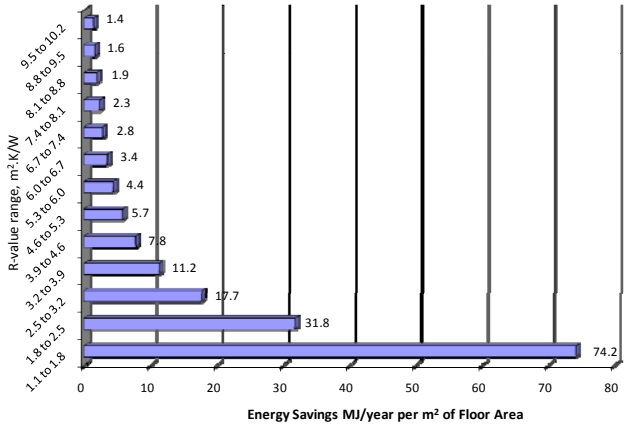
Diminishing load savings associated with addition of R_{SI}-0.7 (R_{US}-4) insulation



For a single-story residential building located at Atlanta

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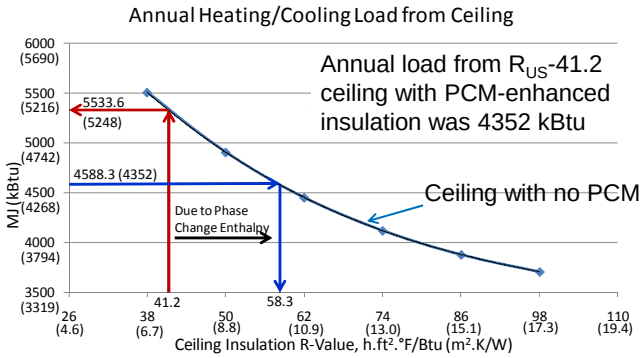
Equivalent thermal performance of PCM-Enhanced ceiling



The result is valid only for the climate, PCM properties, building geometry and configuration considered in the simulation

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Summary

- PCM-enhanced materials can reduce energy needed for space conditioning, shift the peak loads and improve occupant comfort
- ORNL is developing a methodology for dynamic heat flow analysis for PCM-enhanced building materials
- Energy savings potential of PCM-enhanced materials can be evaluated using *E+*
- PCM selection must match desired service

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