A Composite Insulation with Twice the R-value of Existing Technologies

Presented by:

André Desjarlais

Oak Ridge National Laboratory

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Windows and Building Envelope R&D ET roadmap

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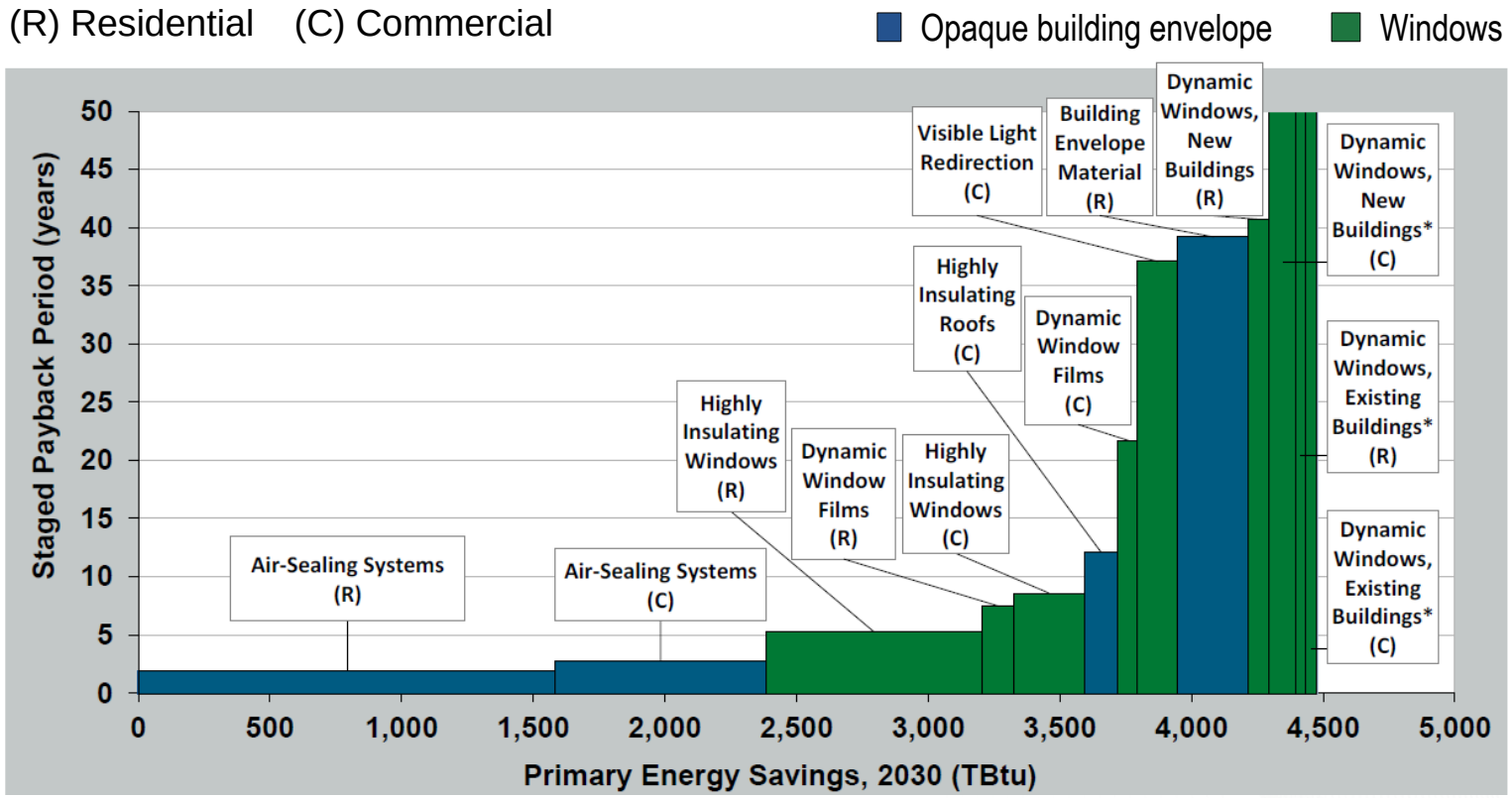


Residential Buildings

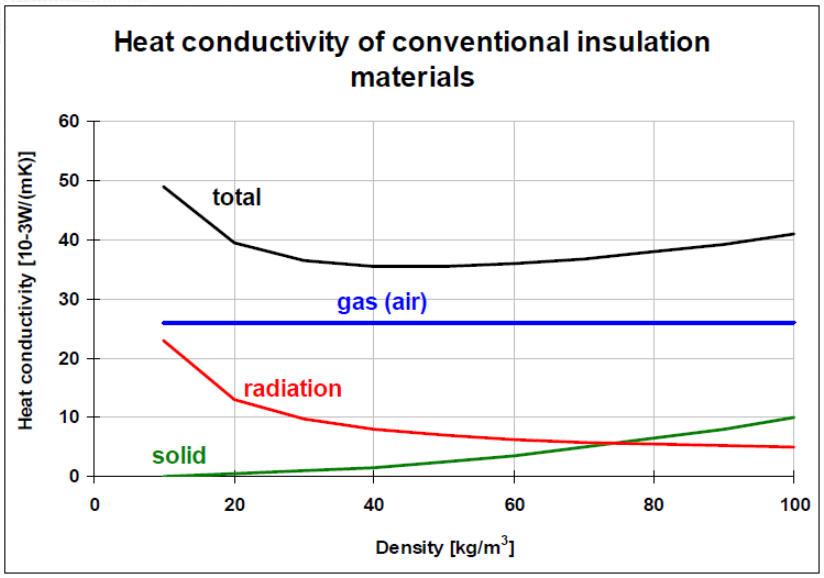
- ~1600 TBtu staged energy savings by 2030

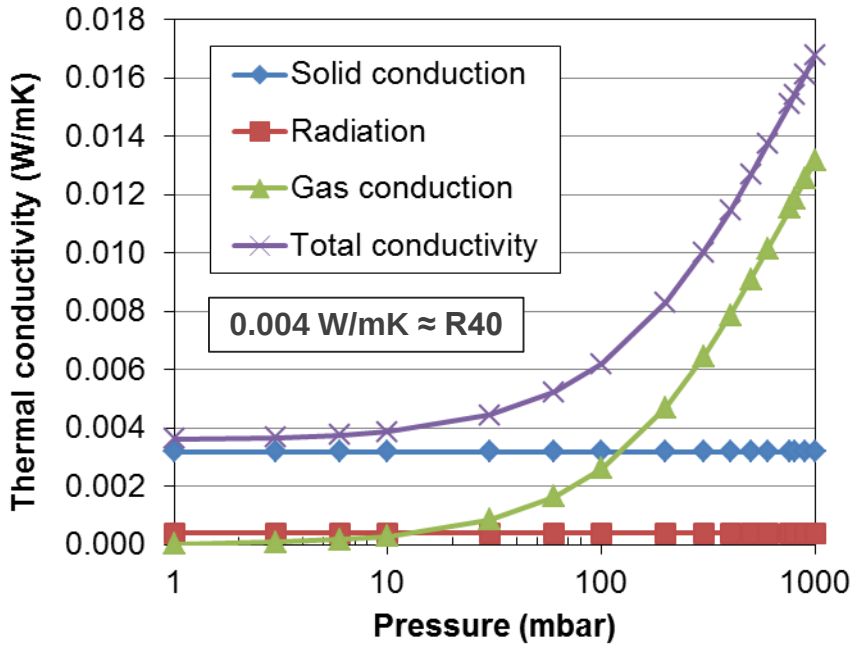
Commercial Buildings

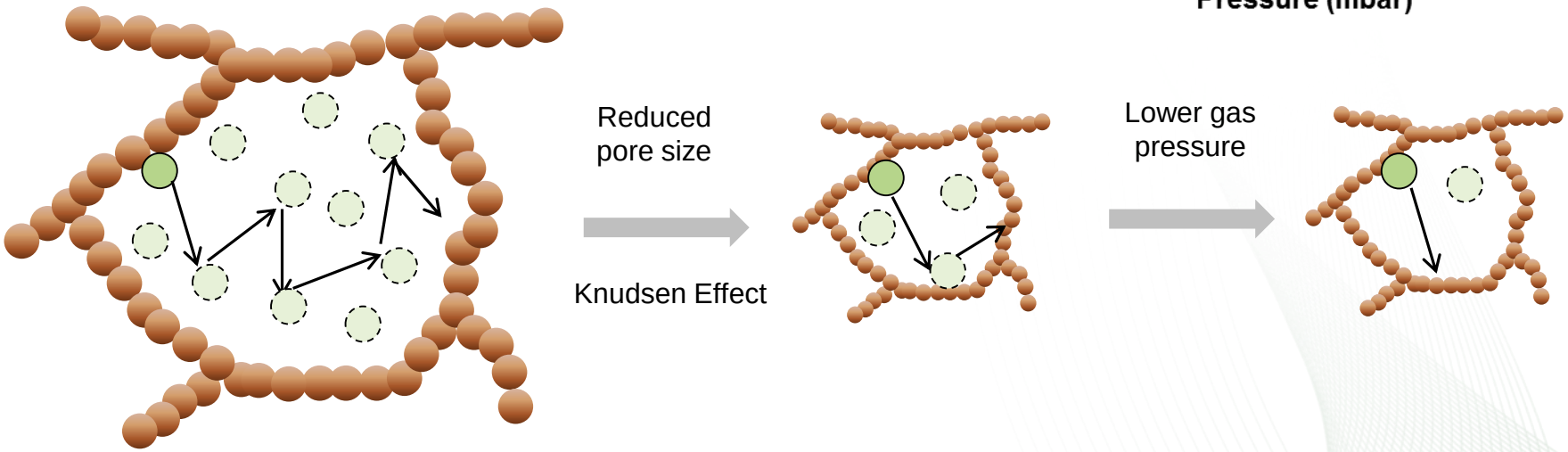
- ~800 TBtu staged energy savings by 2030

Develop R12/inch insulation

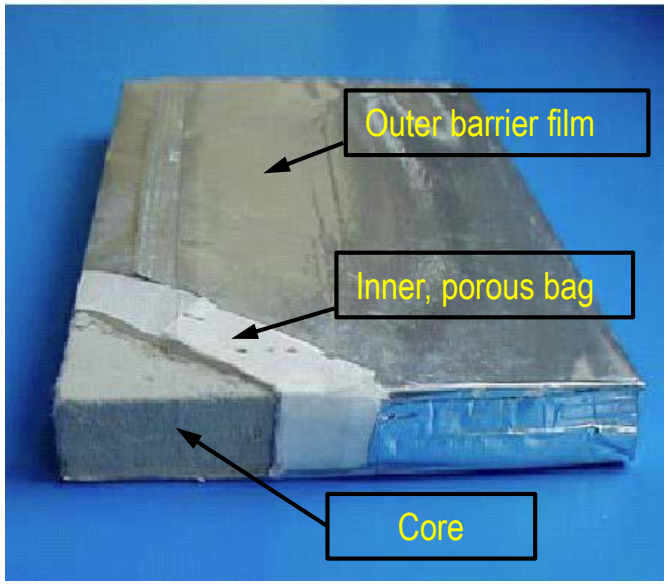
Heat transfer in insulation materials

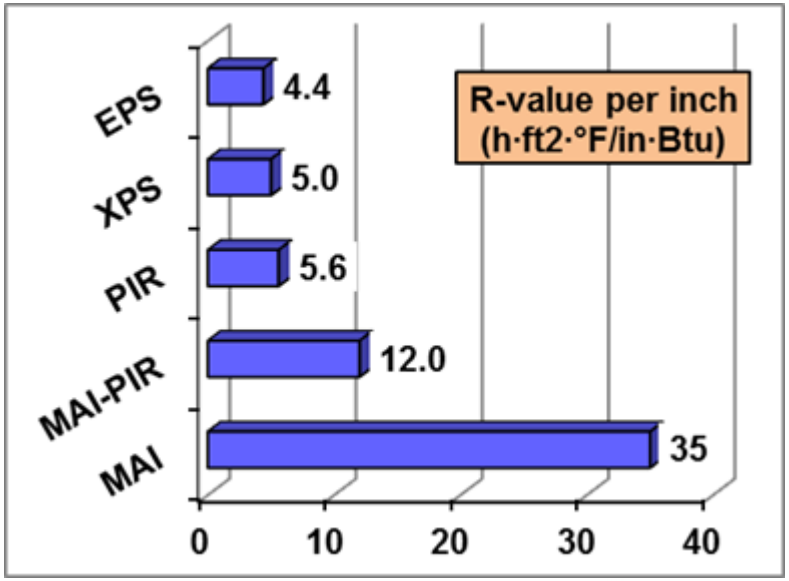






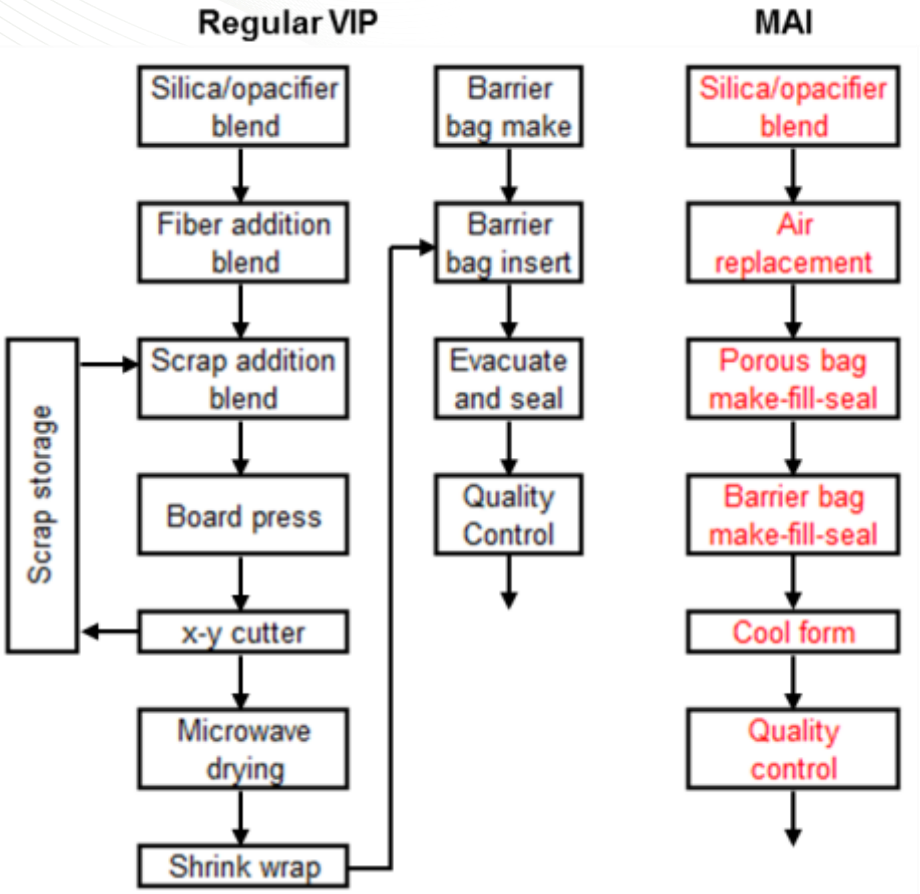
New technology being developed based on Vacuum Insulation Panels (VIPs)





- Modified Atmosphere Insulation (MAI) is a lower cost variant of VIPs.
- VIPs provide a significantly higher R-value that current insulations materials.
- VIPs usually comprise of a nano-/micro-porous core (e.g., fumed silica) encapsulated in an air and vapor impermeable barrier film and evacuated (~ 5 mbar).

Modified atmosphere insulation

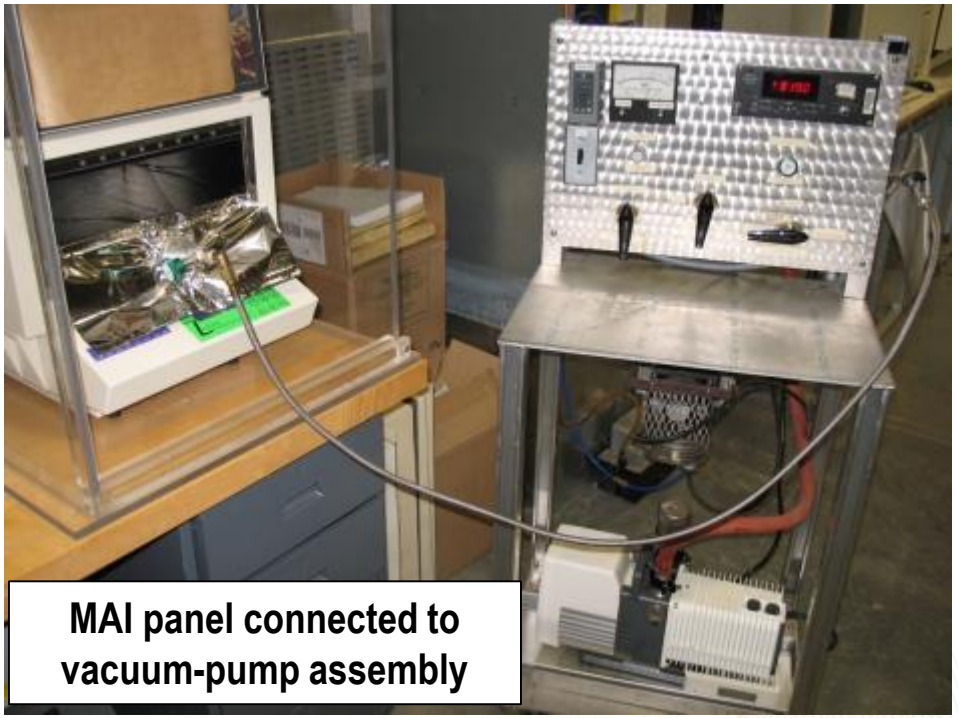


- Lower-cost version of VIPs
  - \$0.13/ft^2/R vs. \$0.25/ft^2/R
- Cost: 20% silica core, 5% barrier film, 75% processing/overhead.
  - MAI production process has ~50% fewer steps than VIP.
- VIPs need to be evacuated to very low pressure and sealed under vacuum
  - Time-consuming process needing specialized equipment.
- Vacuum in MAI panels is mainly created by condensation of steam (which replaces air)
  - Sealed at atmospheric pressure using standard equipment at much faster rate.

FY14 scoping study

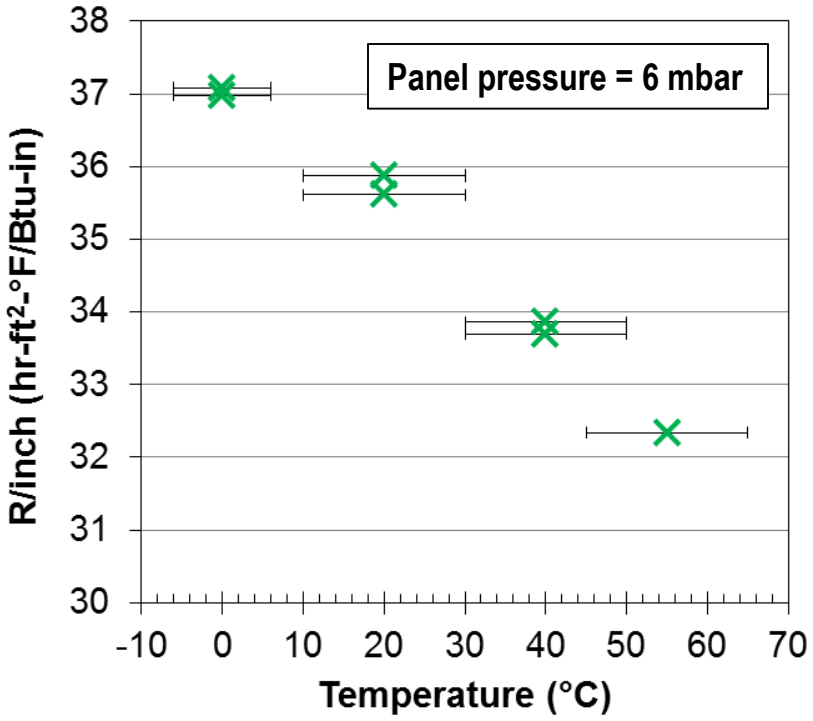
- Measurements of R-value at different temperatures and internal pressure conditions.
- Cost analysis projecting $\$0.12/ft^2/R$
  - $\$4.2/ft^2$ for a 1 inch MAI panel assuming R35/inch

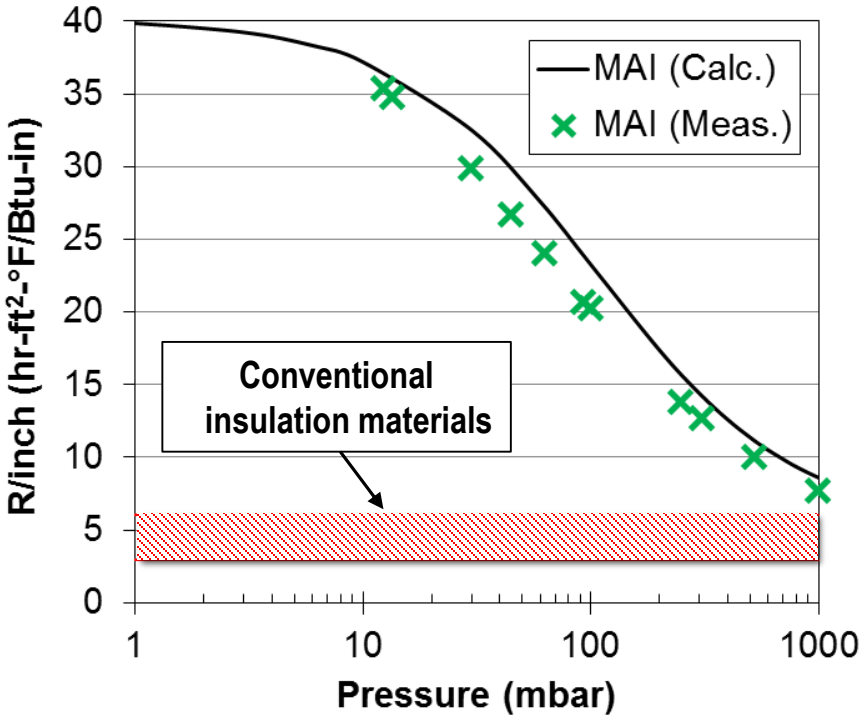
HFMA & MAI panel



MAI panel connected to vacuum-pump assembly

Thermal performance tests





- Even with complete loss of vacuum, MAI panels expected to have higher R/inch than conventional insulation materials.

R25 (R12 per inch) polyisocyanurate composite insulation material

Project Goal:

Develop a 2-inch thick polyiso board insulation with modified atmosphere insulation (MAI) cores that have an R-value of 25 (R12/inch) and a cost premium of no more than $0.30 per square foot with a simple payback of ten years.

- Preliminary analysis indicates, 2 inches of R12/inch insulation has a primary energy-saving potential of more than 1320 TBTUs (1.32 quads).

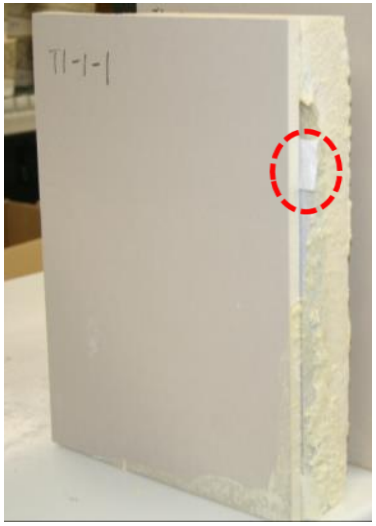
Target Market/Audience:

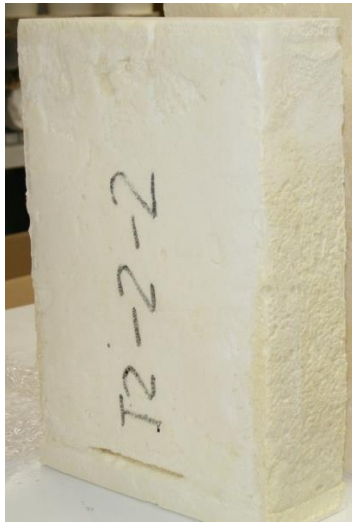
Primarily retrofits of residential walls and commercial roofs, but also applicable to new buildings.

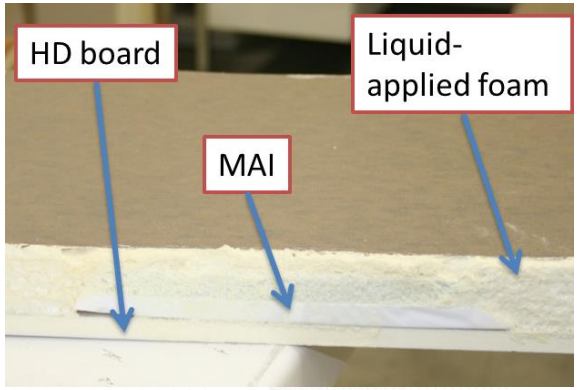
Year 1 progress and accomplishments

Laboratory-scale experiments: Foam encapsulation of MAI panels

- MAI panels with metallized and all-polymer barrier films were tested.
  - Polymer barriers significantly reduce thermal bridging around MAI panels.
- Foam encapsulation of MAI panels was satisfactory, except one test.
- MAI panels withstood the exothermic foam expansion.
  - No measureable dimensional changes to MAI panels.
  - Barrier surface temperature rise (<90°C) less than damage threshold (110°C).



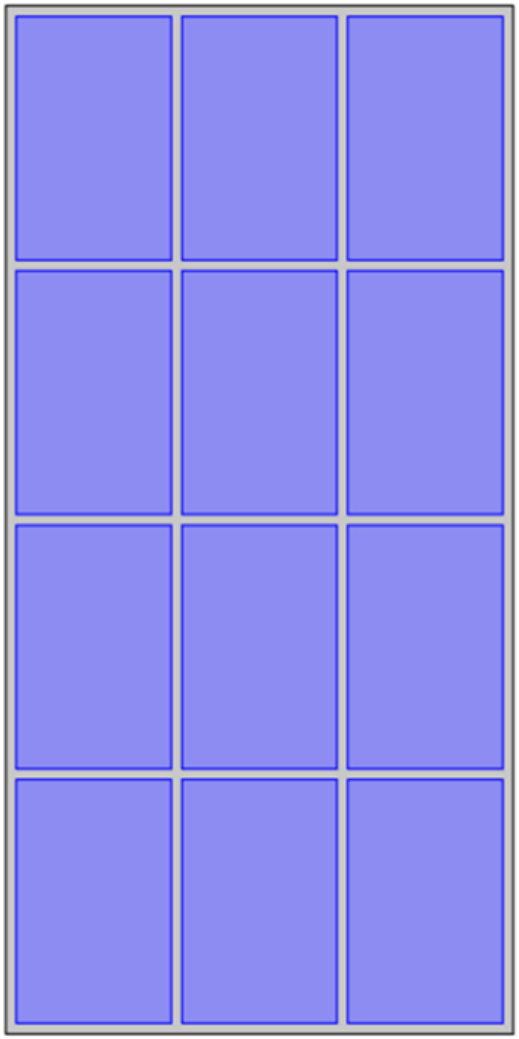


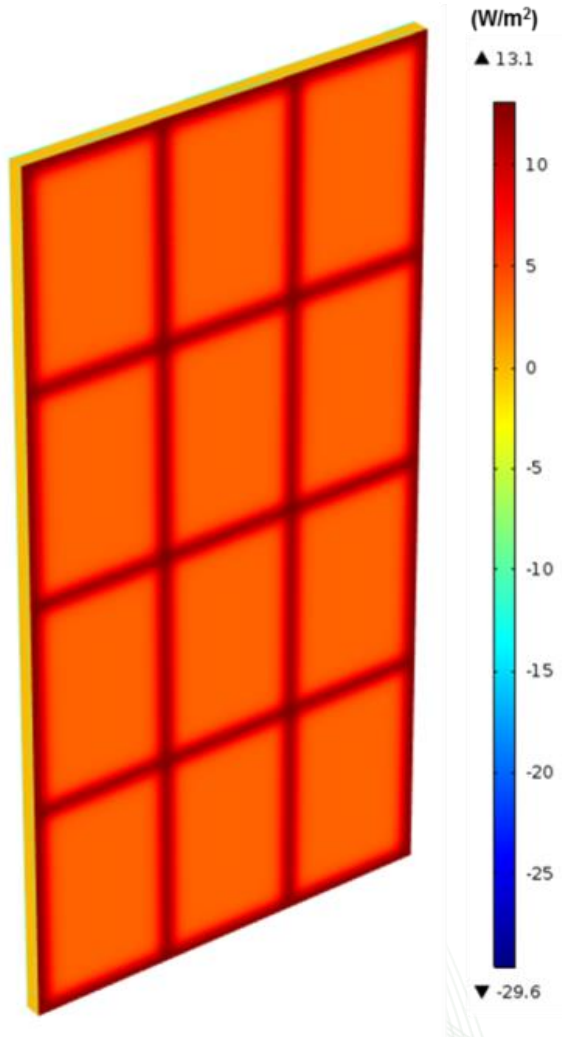


Year 1 progress and accomplishments

Design of MAI-Polyiso Composite Boards Based on Thermal Modeling

- First-generation 4’ x 8’ composite design
- 4x3 array of MAI panels (22.75” x 14.7”)
  - 1 inch gaps for mechanical fasteners
  - 87% MAI coverage
- Estimated R-value of the 2-inch board: 25.5 hr-ft^2-°F/Btu (*R12.7/inch*)

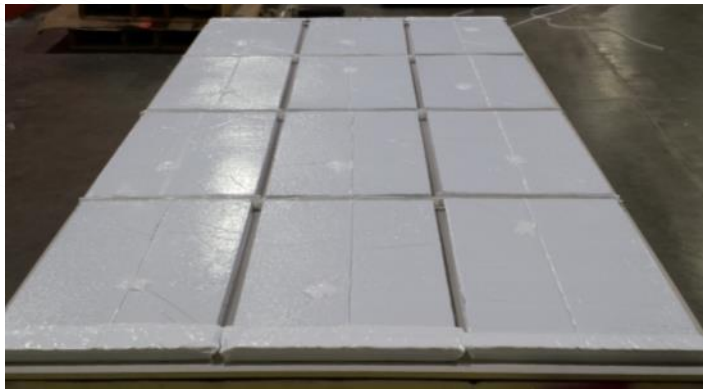




Simulated heat flows through a MAI-foam composite board.

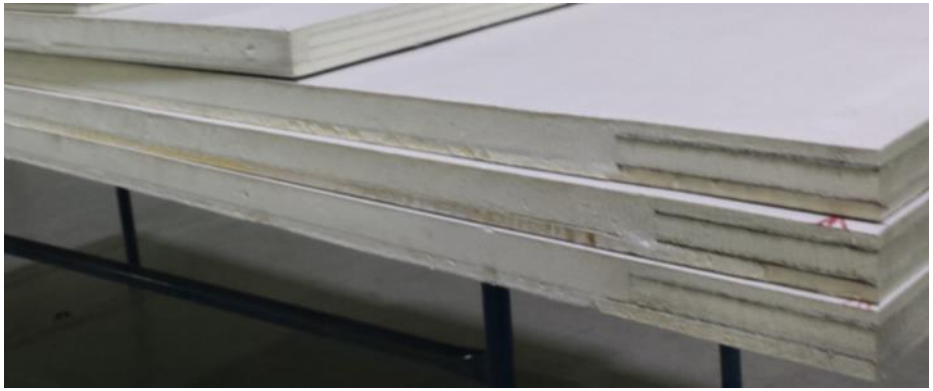
Year 1 progress and accomplishments

- July 2015: Three first-generation composites produced in a manufacturing plant. *No major changes needed to the assembly line; critical consideration with respect to cost premium of new composite insulation*.

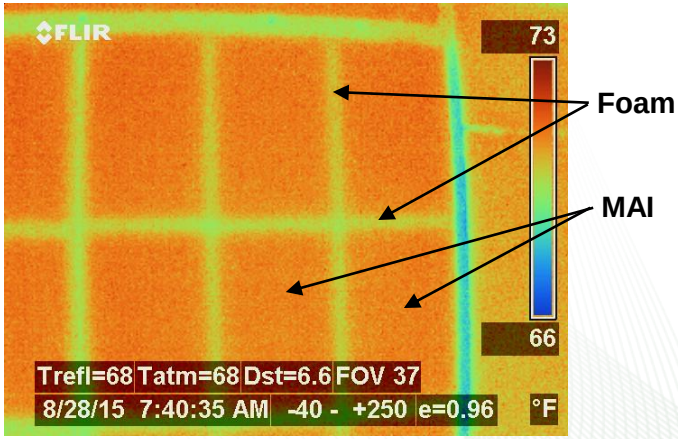


MAI panels attached to high-density (HD) foam substrate

MAI-HD board fed through foaming line



Finished composite insulation boards

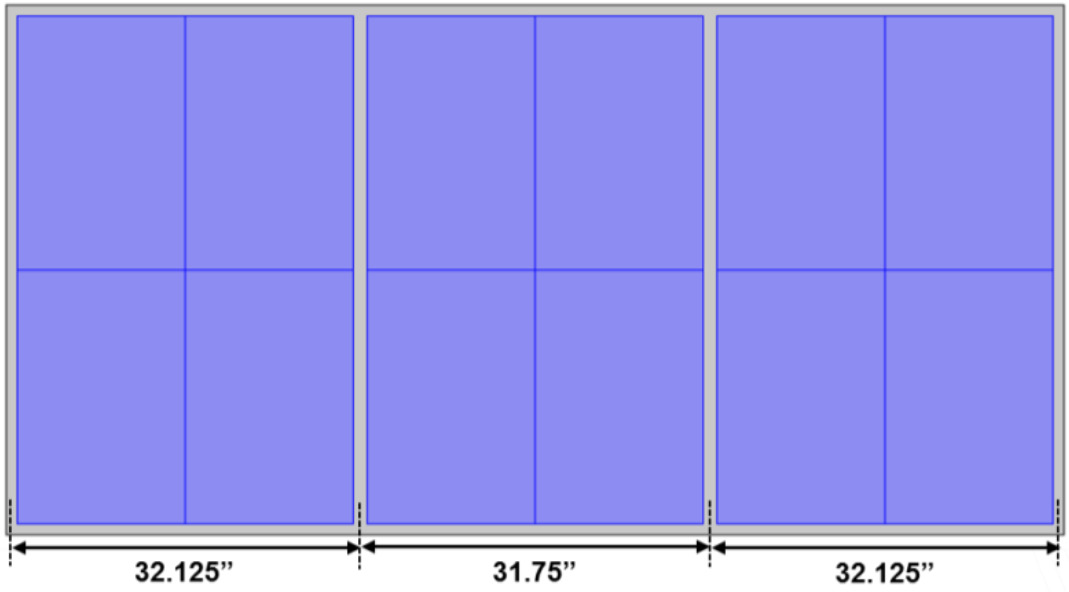


Year 1 progress and accomplishments

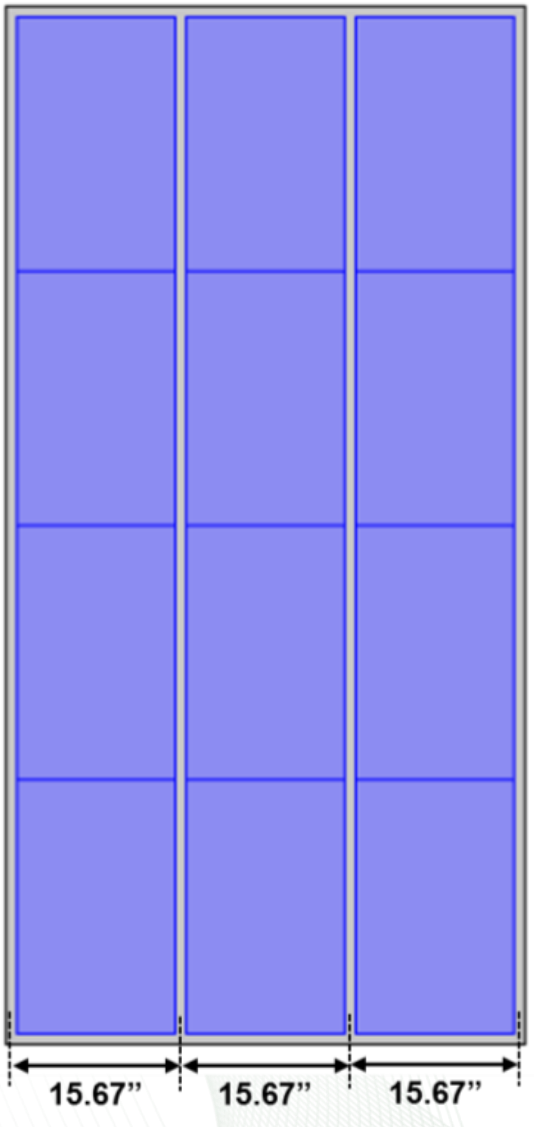
- September 2015: Guarded hot box tests (ASTM C1363) yielded R21.6 for the 2-inch composites (*R10.8/inch*).
  - Year 1 Go/No-Go target: R10/inch
- Autopsy of one board performed after the hot box test.
  - No discernible changes in MAI shape and dimensions.
  - One area had poor foam fill, with implications on measured R-value.

Year 2 progress and accomplishments

- Second generation composites: Higher MAI coverage to achieve R12/inch.
  - 89.8 - 91.3% vs. 86.9% in FY15
- Modeling indicates increases in overall R-values of 1.3 – 2.1 hr-ft^2-°F/Btu
  - *ΔR/inch of 0.7-1.1*



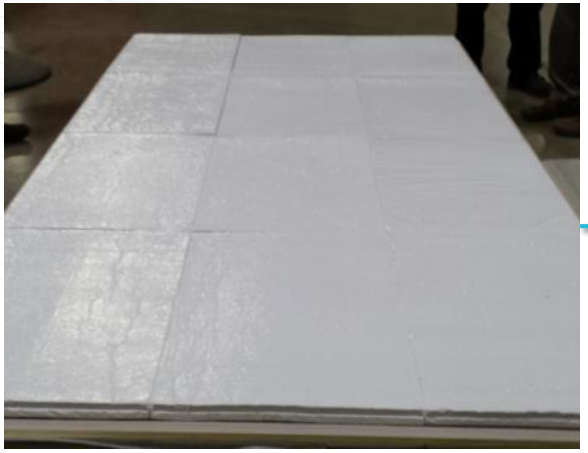
Skipping alternate studs on walls

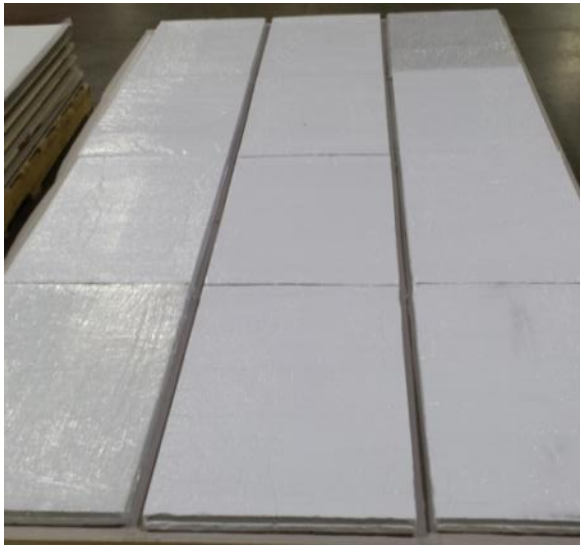


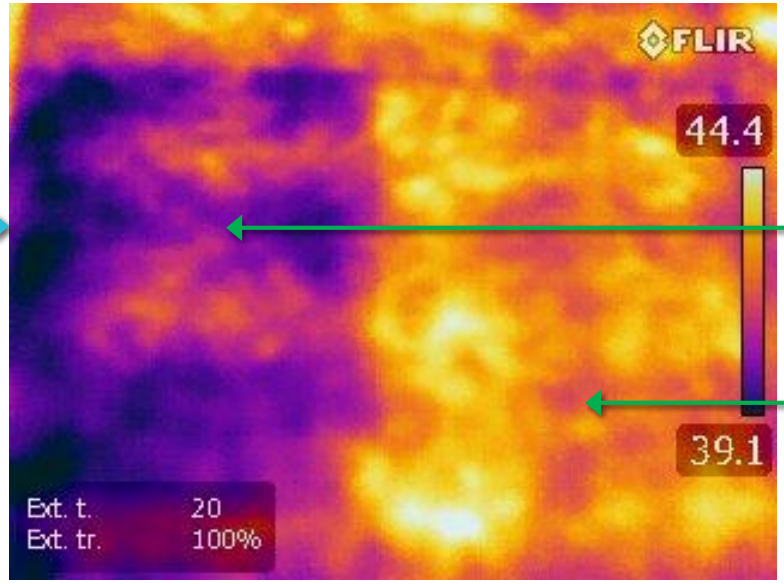
Eliminating foam gaps along the width

Year 2 progress and accomplishments

Second-generation composite production (March 3, 2016)







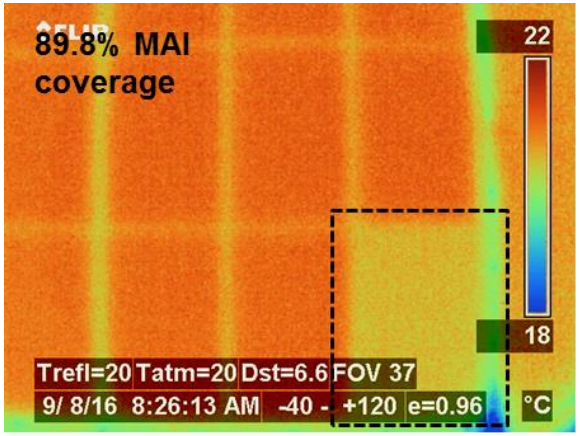
Damaged MAI panel

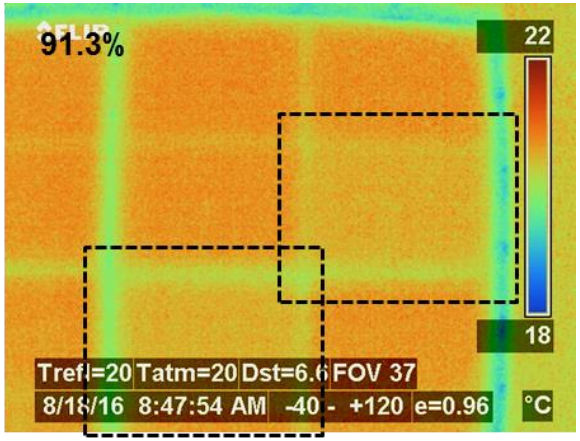
Intact MAI panel

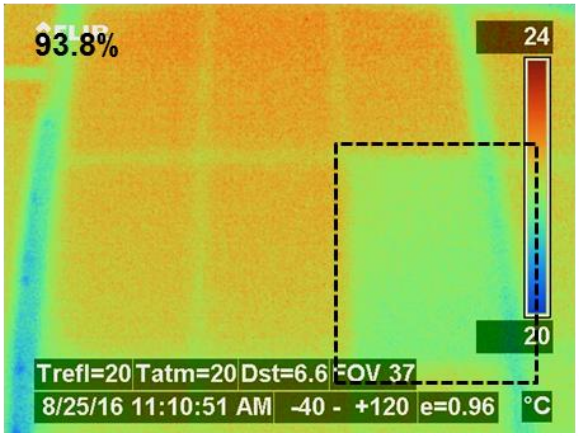
- Potential online quality control using IR imaging
- Thermal diffusivity ($k/\rho c_p$): Damaged MAI >> Intact MAI
  - Cools the 'warm' spray-applied foam faster

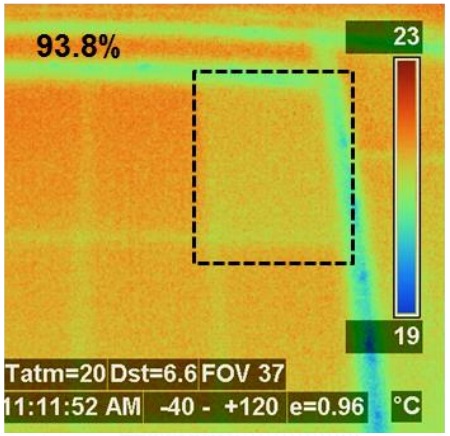
Hot box tests of second-generation composites

- Three different boards with MAI coverages of 90, 91, and 94%
  - FY15 boards had 87% MAI coverage
- Pairs of 4’x8’ boards tested per ASTM C1363
- Each pair exhibited at least one damaged MAI panel



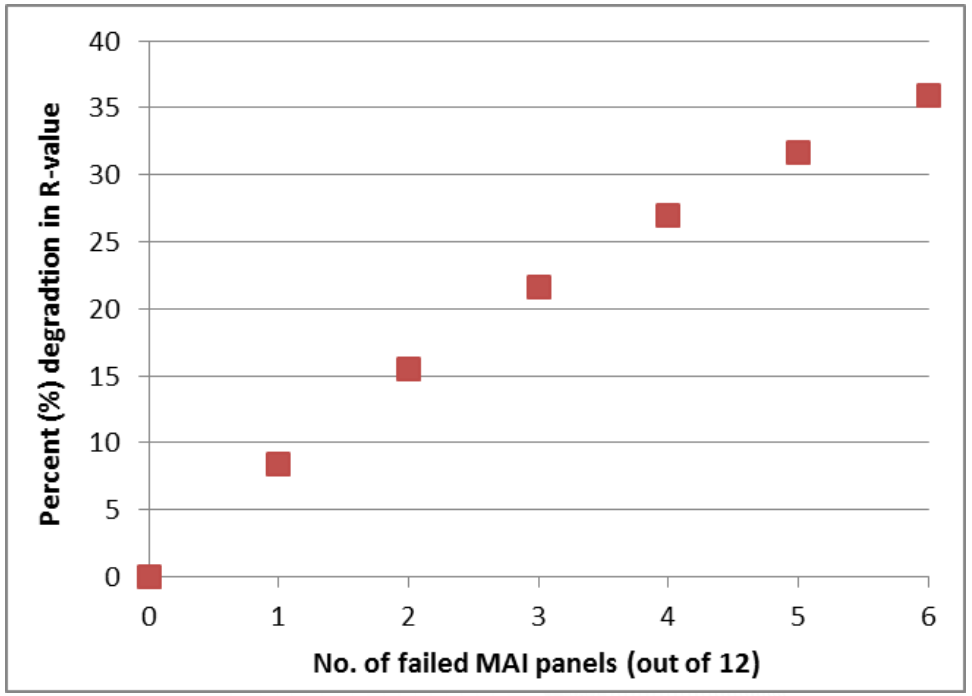






Hot box tests of second-generation composites

- Measured R-values
  - 89.8%: R23.12 (R11.6/inch)
  - 91.3%: R22.88 (R11.4/inch)
  - 93.8%: R23.72 (R11.9/inch)
- Numerical modeling used to predict loss of R-value with damaged MAI panels
- Assuming 5% degradation, with all intact MAI panels, the R-values of 12-12.5/inch can be expected.



Next steps

- Detailed techno-economic analysis and cost optimization
- Field-testing of thermal performance of composite boards in ORNL's natural exposure test (NET) facilities
- Estimate market opportunity
- Evaluate cost of automating MAI and foaming process

Discussion

André Desjarlais
desjarlaisa@ornl.gov

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