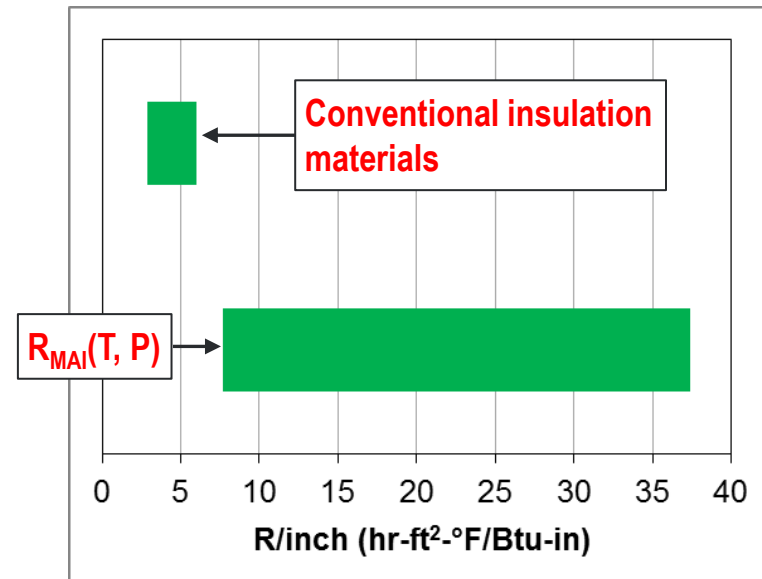


# Modified Atmosphere Insulation - Scoping Study for Next Generation Building Envelope Materials

2014 Building Technologies Office Peer Review



# Project Summary

## Timeline:

Start date: 10/1/2013

Planned end date: 12/31/2014

## Key Milestones

1. Develop critical path for producing MAI panels at or less than \$0.15/ft<sup>2</sup>/R-value (**40% less than regular VIPs**); 6/30/2013
2. Develop and test MAI-composites to increase whole-wall R-value by R-20; 12/31/2014

## Budget:

Total DOE \$ to date: \$225K

Total future DOE \$: \$400K

## Target Market/Audience:

Building envelopes in residential and commercial as well as new and retrofit construction.

## Key Partners:

Oak Ridge National Laboratory
NanoPore, Inc.

## Project Goal:

Vacuum insulation panels (VIPs) yield a step-change in performance over conventional insulation materials but at very high cost. This project is investigating the development of modified atmosphere insulation (MAI) technology with similar thermal performance but at 40% lower cost by substantially altering the manufacturing process.

# Purpose and Objectives

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**Problem Statement:** Address the EERE BTO's mission to develop low-cost, high-performance advanced insulation materials by evaluating a new modified atmosphere insulation (MAI) technology that yields the high performance of vacuum insulation panels but at low cost.

**Target Market and Audience:** The BTO calculator estimates the 2030 market size for opaque envelope-generated primary energy consumption to be 4299 TBTUs. The target market for this insulation technology includes both residential and commercial as well as new and retrofit construction.

# Purpose and Objectives

## Impact of Project:

1. Major output: Production process reducing high-performance MAI panel cost to \$0.15/R-value/ft<sup>2</sup>.
  - For comparison, cost of 1 inch thick foam insulation boards: \$0.06-0.10/R-value/ft<sup>2</sup> (2014 RSMeans<sup>1</sup>)
2. Adding R-16 (*2 inches of R-8/inch insulation*) to walls in residential and commercial building has an energy savings potential of 951 TBTUs.

## Impact Path:

1. Targeted goals at the end of current project period (Dec, 2014)
  - Thermal performance  $\geq$  R-30/inch, at targeted cost (\$0.15/R-value/ft<sup>2</sup>)
  - MAI composites that will add R-20 to the whole-wall R-value
2. Mid-term: Evaluate long-term performance of MAI composites in buildings.
3. Long-term:
  - Further cost-reduction through commercialization in the building sector.
  - Meeting code-mandated R-values using ~2 inches of MAI composites.
  - Realize energy-saving potential through widespread market adoption.

# Approach

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## Approach:

- This is a new scoping study to demonstrate energy-savings opportunity for MAI in building applications.
- Determination of thermal performance as a function of temperature, pressure, and opacifier and filler gas components, and simple payback based on a reduced-cost manufacturing process.

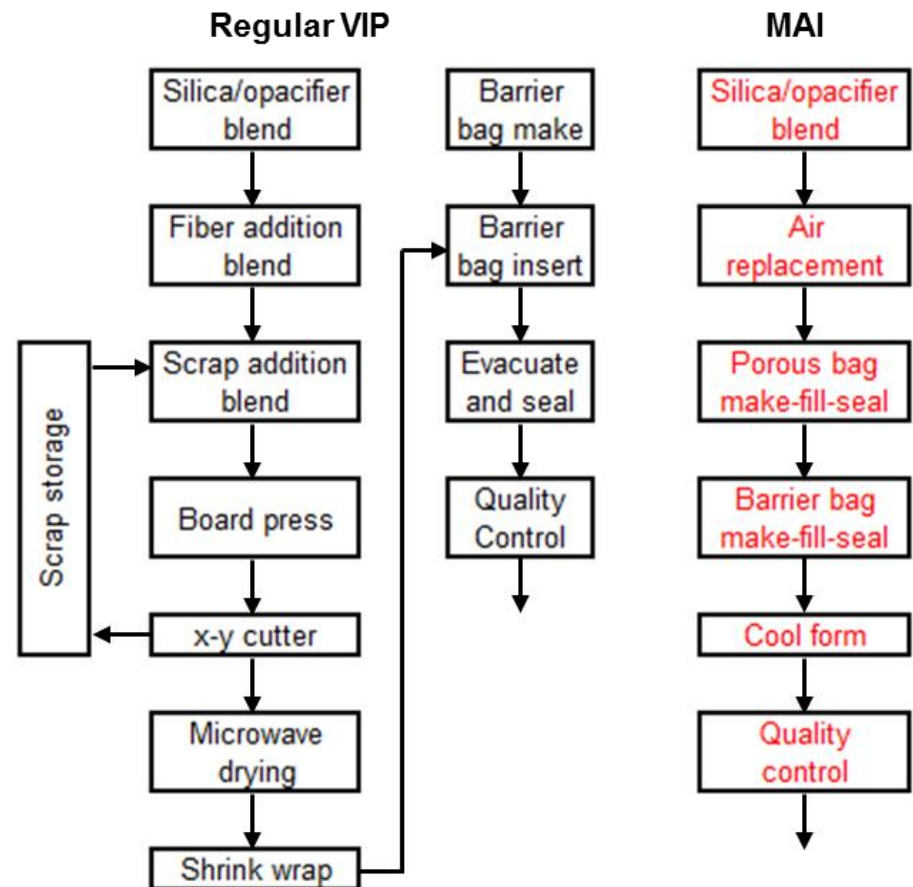
## Key Issues:

- High cost of vacuum insulation panels (VIP) is a major hindrance to their commercialization. The project goal is to produce MAI panels at 40% lower cost than VIPs.
- Long-term performance in building applications.

# Approach

## Distinctive Characteristics:

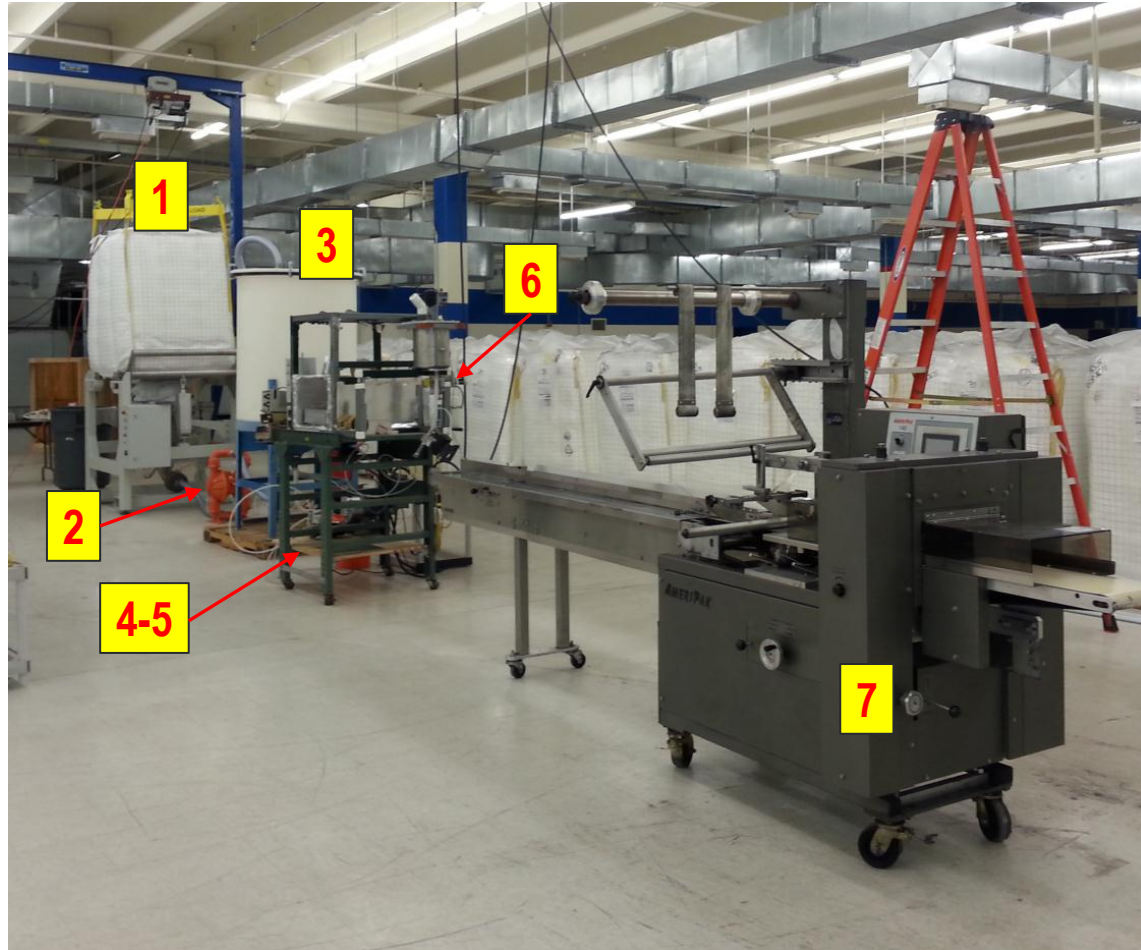
- Cost: 20% silica core, 5% barrier film, 75% processing/overhead.
  - MAI production process has ~50% fewer steps than VIP.
- VIPs need to be evacuated to very low pressure and sealed under vacuum
  - Time-consuming process needing specialized equipment.
- Vacuum in MAI panels is mainly created by condensation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



# Approach

## Pilot-scale production:

1. Silica unloading station
2. Silica transfer pump
3. Silica/opacifier pre-mix tank
4. Powder mix transfer pump
5. Liquid ring pump (evacuation of core to ~50 mbar)
6. MAI reactor with steam generator (air/steam substitution)
7. Horizontal flow wrapper (outer barrier bags)
8. Cool forming (not shown)



# Approach

## Distinctive Characteristics:

- Heat transfer in MAI panel: Solid (core) conduction, gas conduction and radiation within the core.
  - Performance improvement ( $> R40/\text{inch}$ ) with lower conductivity filler gas and opacifiers for reducing radiation (while considering the increase in solid conduction).
  - Investigate role of absorbed steam from MAI processing in reducing radiation heat transfer (water vapor has strong absorption bands in infrared spectrum).
- Investigate methods of incorporating MAI panel composites into building envelopes.
  - Incorporation of MAI panels with existing siding materials is expected to minimize the incremental installation costs.

# Progress and Accomplishments

**Accomplishments:** This is a new FY14 project. Major tasks and accomplishments-to-date are:

- Verification of thermal performance under variable temperature and panel pressure conditions
  - R-value of the MAI panel is a function of both temperature and pressure.
  - Variable temperature conditions were based on simulations of building in different climate zones to determine the temperature extremes.
- In process: Development of a pilot-scale production process to achieve one of the project end-goals of \$0.15/R-value/ft<sup>2</sup>.
- Major FY14 Q1 and Q2 milestones have been met.

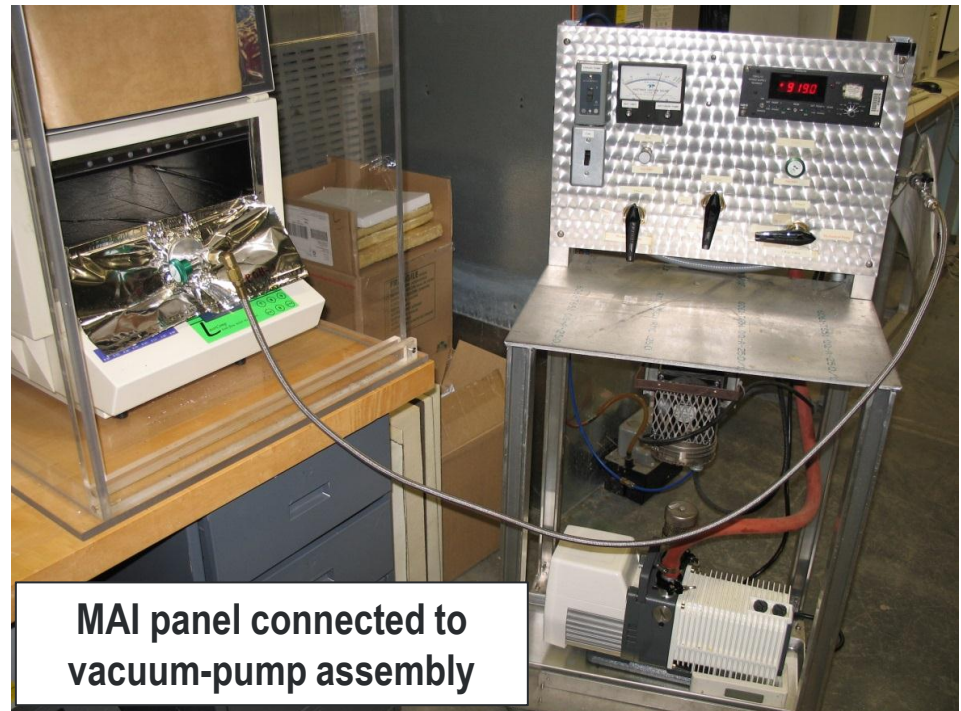
# Progress and Accomplishments

## Variable temperature & panel-pressure tests:

- Measurement of thermal conductivity per ASTM C518 (*Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus*).
- Heat flow meter apparatus (HFMA) contains two independently temperature-controlled plates with embedded heat flux transducers to measure the heat flow across the specimen.



HFMA & MAI panel

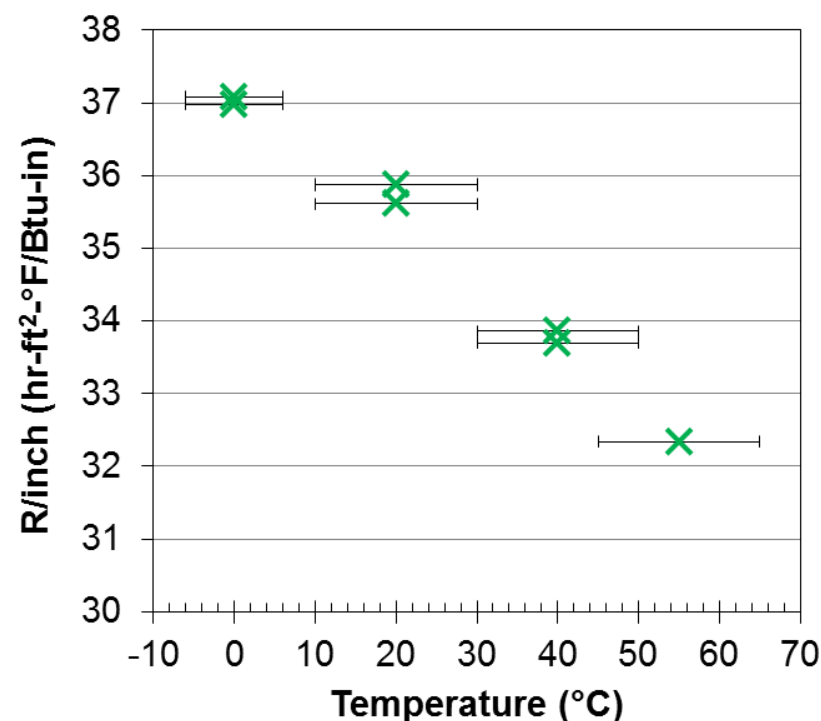
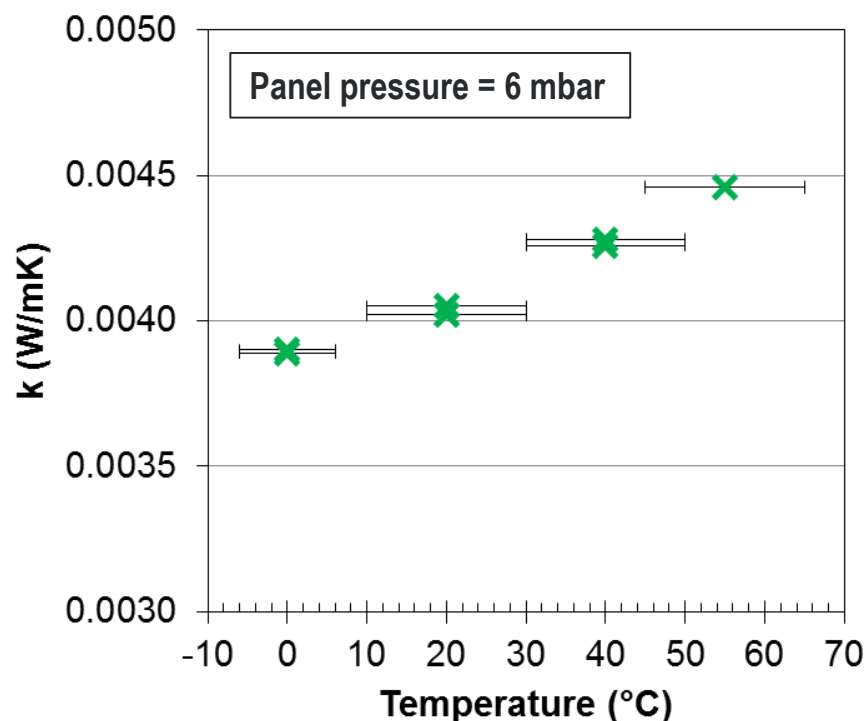


MAI panel connected to vacuum-pump assembly

# Progress and Accomplishments

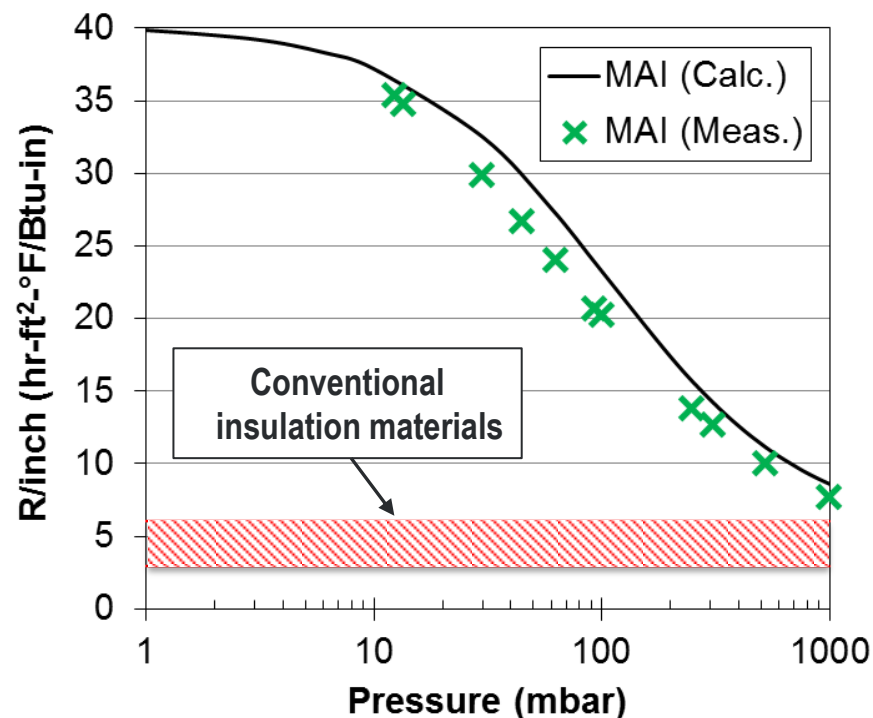
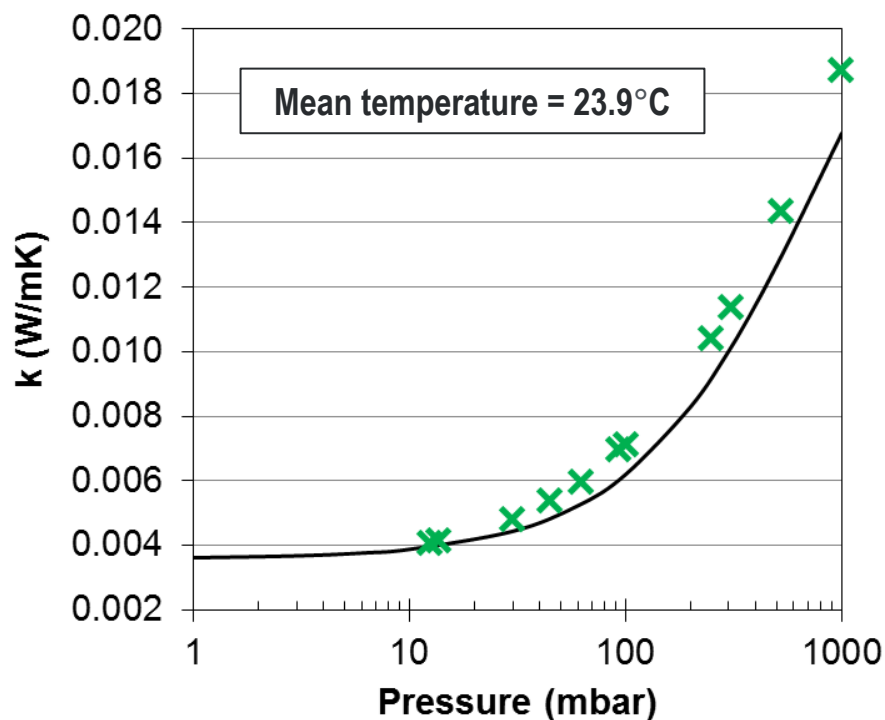
## Variable Temperature Tests:

- Conductivity ( $k$ ) and thermal resistance ( $R/\text{inch}$ ) vs. mean panel temperature.
  - The horizontal error bars represent the two plate temperatures.
- $R/\text{inch}$  within 20% of the measurement at a baseline mean temperature of 20°C.



# Progress and Accomplishments

## Variable Pressure Tests:



- Calculations performed using NanoPore proprietary mathematical model.
- Even with complete loss of vacuum, MAI panel expected to have higher  $R$ /inch than conventional insulation materials.

# Progress and Accomplishments

## Pilot-scale production:

- Need to produce MAI panels at 2 panels (1' x 1') per minute to demonstrate low cost/R-value.
  - Silica unloading: > 10 lbs/min, corresponding to ~10 panels/min
  - Opacifier pre-mix step under evaluation, but it is not the rate-controlling step (from prior VIP-related experience)
  - Silica core weighing and dosing: 4 panels/min
  - Air/steam replacement (liquid ring pump and reactor): > 4 panels/min
  - Horizontal flow wrapper: 5-20 panels/min
- All process steps meet or exceed the necessary throughput rates.

# Progress and Accomplishments

**Market Impact:** Since this is a new project related to a scoping study of a next-generation insulation technology, the potential market impacts are listed.

- Based on simulations of standard residential models<sup>1</sup>, adding R-20 insulation to walls of new and pre-2010 buildings has a primary energy savings potential of 769 TBtus
  - The savings potential was estimated using BTO's Market Definition Calculator.
  - The savings are based on wall applications in residential construction only.
  - The pre-2010 building model was based on IECC 2006.
    - Older buildings are usually not insulated up to IECC 2006 requirements; therefore, achievable energy savings should be higher than the estimated 769 TBtus.

<sup>1</sup> [http://www.energycodes.gov/development/residential/iecc\\_models](http://www.energycodes.gov/development/residential/iecc_models)

# Project Integration and Collaboration

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**Project Integration:** The project is a collaboration between Oak Ridge National Laboratory (ORNL) and NanoPore, Inc.

- Regular exchange of information, progress updates and results between ORNL and NanoPore

**Partners, Subcontractors, and Collaborators:** NanoPore has been working on nanoporous materials and advanced insulation since 1993. Its two spin-offs, NanoPore Insulation, LLC and NanoPore Insulation, Ltd are the largest VIP producers in the US and UK, respectively).

# Next Steps and Future Plans

- Long term field-testing in one of ORNL natural exposure test (NET) facilities and/or in a new or retrofit construction.
- Develop accelerated testing protocol to predict thermal behavior of MAI panels over the application lifetime.
- Evaluate dynamic performance of MAI: Due to its high heat of vaporization, water can be an effective surrogate for thermal mass. This dynamic effect can be demonstrated by testing silica MAI panels with various water contents and different desiccant amounts and locations.
- Test MAI panels with additional opacifiers and different core materials for further enhancement of thermal performance.
- Evaluation of in-field hygrothermal performance using measurements and simulations.

# REFERENCE SLIDES

# Project Budget

**Project Budget:** Received \$225K.

**Variances:**

**Cost to Date:** \$77K

**Additional Funding:**

## Budget History

FY2013 (past)		FY2014 (current)		FY2015-16 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
		\$225K		\$400K	

# Project Plan and Schedule

- Slipped milestone: Baseline MAI panels were developed and tested on schedule; Additional MAI panels were originally planned to be tested in FY14 Q3 and will be delivered and tested by 6/30/2014.
- Go/no-go decision points: (i) Cost of MAI panels  $\leq 0.15/\text{ft}^2/\text{R-value}$  (6/30/2014); (ii) MAI-siding composite to add R-20 to a wall assembly (12/31/2014)

Project Schedule								
Project Start: Oct 1, 2013								Completed Work
Projected End: Dec 31, 2014								Active Task (in progress work)
								◆ Milestone/Deliverable (Originally Planned)
								◆ Milestone/Deliverable (Actual)
	FY2014				FY2015			
Task	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)
Past Work								
Identify range of extreme exposure temperatures for MAI panels in walls		◆						
Develop prototype MAI panels (1 baseline and 5 more with different opacifiers, filler gases and barrier)		◆		◆				
Verify thermal performance of the baseline MAI panel to be $> R30/\text{inch}$ at $20^\circ\text{C}$			◆					
Perform tests of baseline MAI panel under variable temperatures and panel pressures			◆					
Current/Future Work								
10% improvement in $R/\text{inch}$ over baseline with different opacifiers and filler gases				◆				
Validate NanoPore's proprietary mathematical model to be within 10% of measurements				◆				
Demonstrate production process to achieve a cost of MAI panels of $\$0.15/\text{ft}^2/\text{R-value}$ or less				◆				
Demonstrate achievement of potential savings of 400 Tbtu in US in 2030 based on BTO P-Tool					◆			
Develop four 2'x2' MAI panel composites with different MAI panels sizes and configurations				◆				
Test the 2'x2' MAI panel composites to map the heat flow across the panel surfaces					◆			
Develop MAI-siding composites and design an optimized wall assembly with maximum possible R-value					◆			
Build and test the optimized wall assembly in ORNL's rotatable guarded hot box (RGHB)						◆		