IEA Building Envelope Technologies and Policies Workshop, Paris, 17/11/2011

Insulation Technologies and Materials Technologies, Systems and Tools in the U.S.

Stephen Selkowitz

Building Technologies Department

Lawrence Berkeley National Laboratory

Content Provided by

Marc LaFrance, USDOE

Andre Desjarlais, Theresa Stovall, ORNL

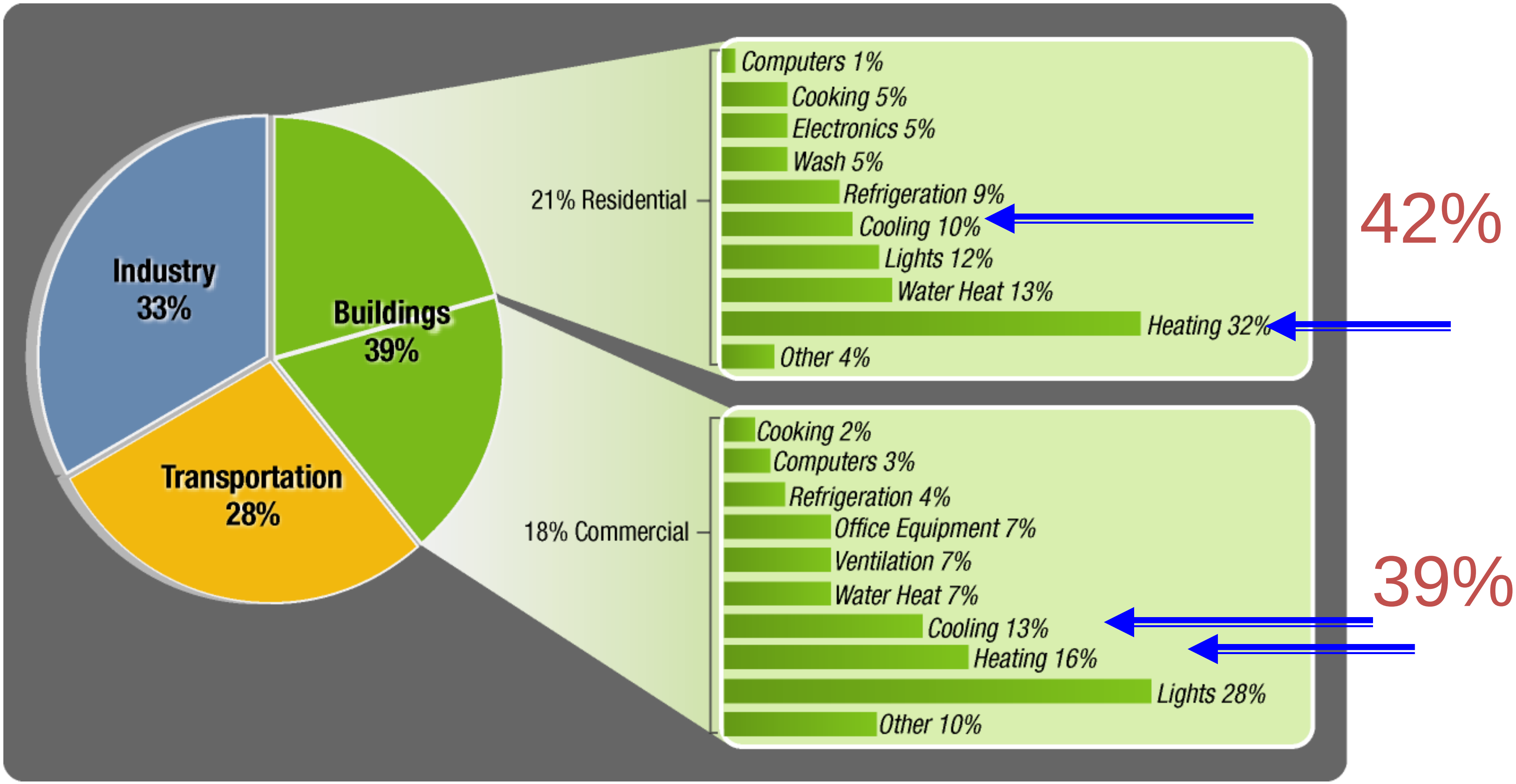
Envelope Impacts on Building Energy Consumption

Buildings consume 40% of total U.S. energy

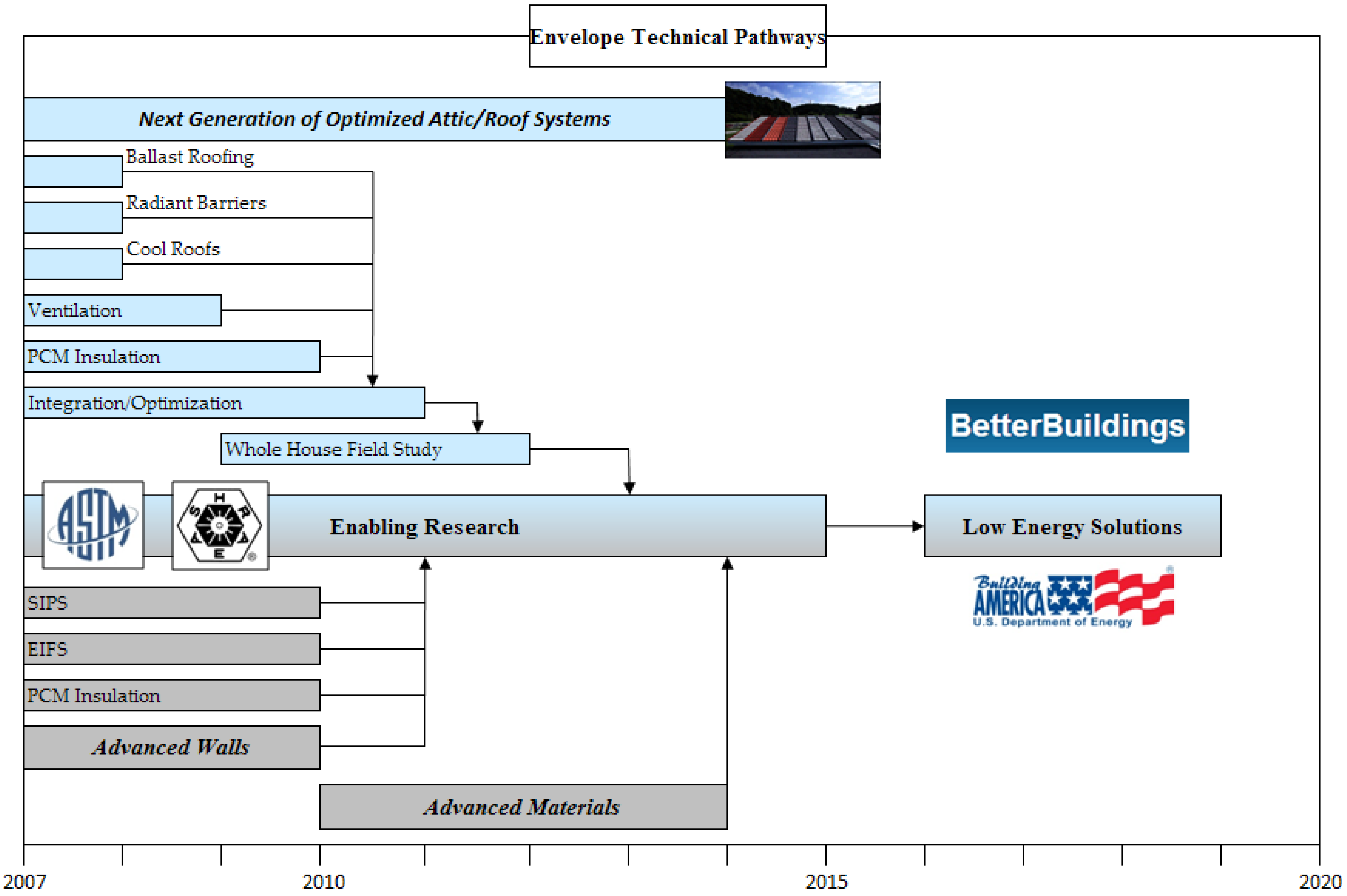
- *71% of electricity and 54% of natural gas*

Envelope Does Not Directly Consume Energy

- ***Allocating Impact on End Use Energy is a*** *Challenge*



DOE Opaque Building Envelope Materials and Systems



7 Program R&D Areas

Materials, Components, Processes

- Insulation Materials
- Phase Change Materials
- Air Barriers
- Moisture Research

Building Systems

- Cool Roofs
- Roof and Attic Systems

Cross-cutting Fundamental R&D

- Enabling Technologies:
  - Performance simulation, measurement
  - Education, Training

Insulating Materials:
New Vacuum Insulation Panel Research

- **New Insulation Requirements require "thicker" insulation;**
  - **Poses design and installation challenges**
- **Research Challenges- Insulation with higher R/cm**
- **Vacuum Insulation is "again" of interest**
- **Long History; Development issues**
  - Durability and protection
  - Aging prediction techniques
  - Seal and barrier permeability
  - Innovative edge geometries
  - Cost reductions

Interest in Building Applications in Europe

- **Historic retrofit**
  - Under heated floors, Exterior sheathing
- **New buildings**
  - Integrated wall systems

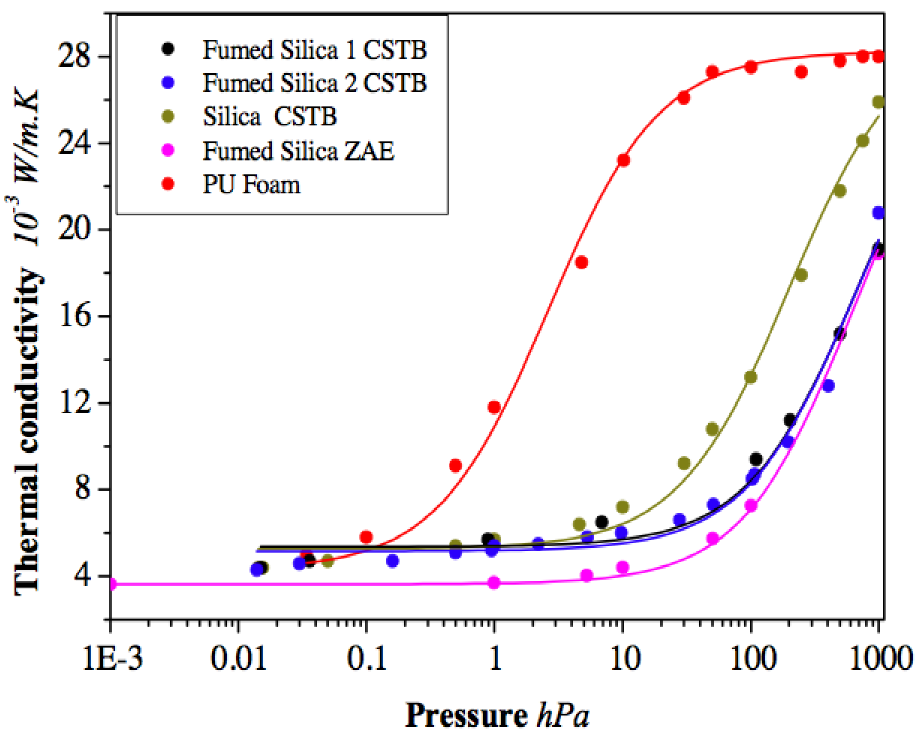
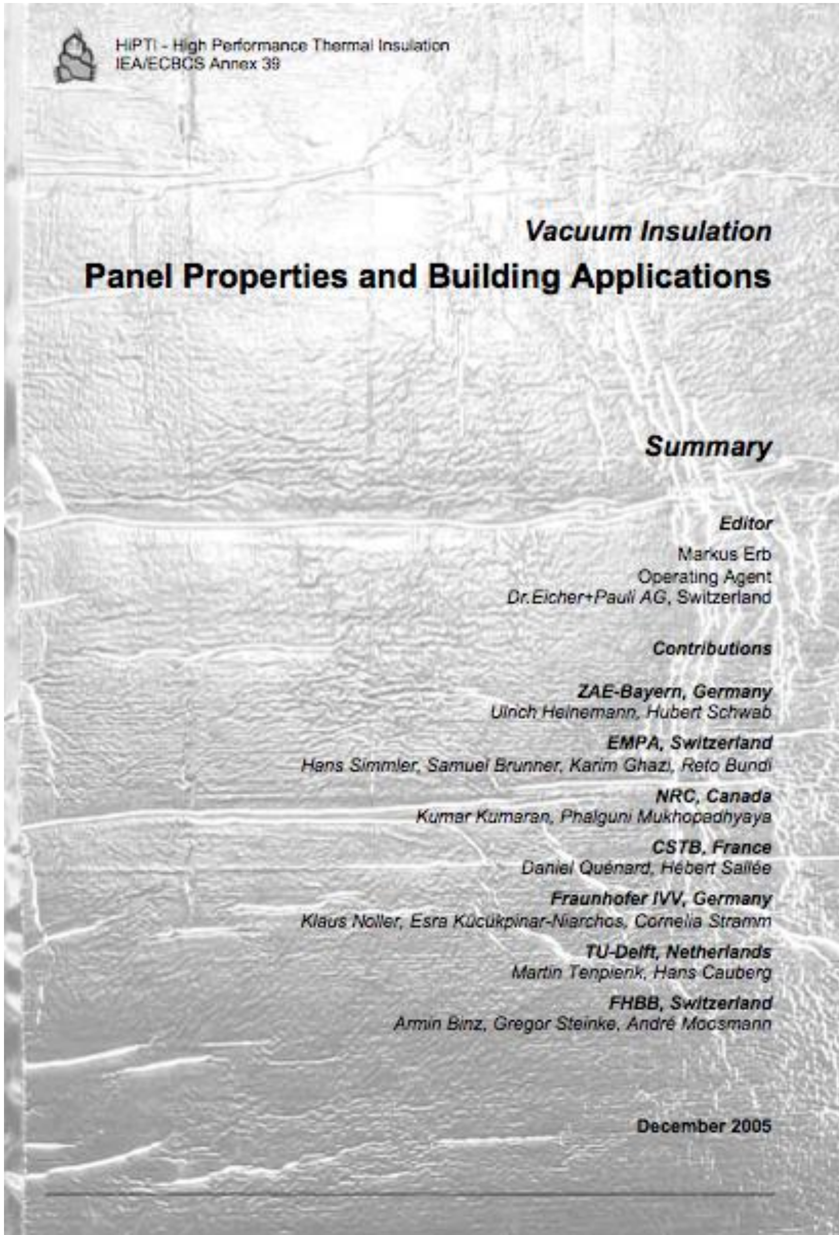


Figure 3: Thermal Conductivity versus pressure of a PU, three fumed silica and one precipitated silica sample.



HiPTI - High Performance Thermal Insulation
IEA/ECBCS Annex 39

Vacuum Insulation

Panel Properties and Building Applications

Summary

Editor
Markus Erb
Operating Agent
Dr.Eicher+Pauli AG, Switzerland

Contributions

ZAE-Bayern, Germany
Ulrich Heinemann, Hubert Schwab
EMPA, Switzerland
Hans Simmler, Samuel Brunner, Karim Ghazi, Reto Bundi
NRC, Canada
Kumar Kumaran, Phalguni Mukhopadhyaya
CSTB, France
Daniel Quénard, Hébert Sallée
Fraunhofer IVV, Germany
Klaus Noller, Esra Kücükpinar-Niarchos, Cornelia Stramm
TU-Delft, Netherlands
Martin Tenpierik, Hans Cauberg
FHBB, Switzerland
Armin Binz, Gregor Steinke, André Moosmann

December 2005

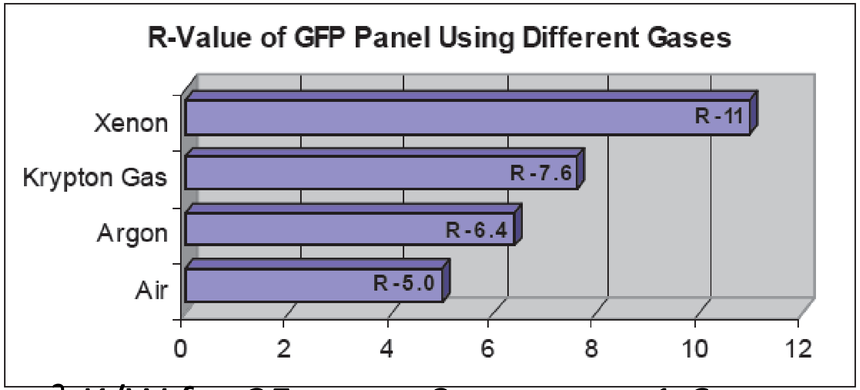
Gas Filled Panel (GFP) Insulation

- Spin off from High-R Windows R&D
- “Airliner” insulated shipping container

GFP Insulation™

GFP Insulation™ is an advanced insulation technology. The product is composed of two external aluminum foil / polymer laminates and five internal specially formulated, aluminum metalized films. When expanded, the internal, low-emittance aluminum layers form a honeycomb structure. These sealed exterior aluminum foil barrier films provide thermal resistance, flammability protection, and properties to contain air or a low-conductivity inert gas. GFP Insulation™ incorporates an advanced design and specially formulated components to effectively address the three methods of heat transfer: radiation, conduction, and convection.

Panel Type	Thickness at Room Temperature in. (mm.)	Mean Test Temperature °F (°C)	Total Resistance h·ft²·°F/Btu (m2·°C/W)
Krypton-GFP	1.0 (25.4)	45.1 (7.3)	12.6 (2.21)
Krypton-GFP	2.0 (50.8)	54.1 (12.3)	25.7 (4.52)
Xenon-GFP	1.0 (25.4)	52.7 (11.5)	18.4 (3.24)



m^2-K/W for 25mm: .9 1.6

Panel Type	Thickness at Room Temperature in. (mm.)	Mean Test Temperature °F (°C)	Total Resistance h·ft²·°F/Btu (m2·°C/W)
Krypton-GFP	1.0 (25.4)	45.1 (7.3)	12.6 (2.21)
Krypton-GFP	2.0 (50.8)	54.1 (12.3)	25.7 (4.52)
Xenon-GFP	1.0 (25.4)	52.7 (11.5)	18.4 (3.24)

Phase Change Energy Research

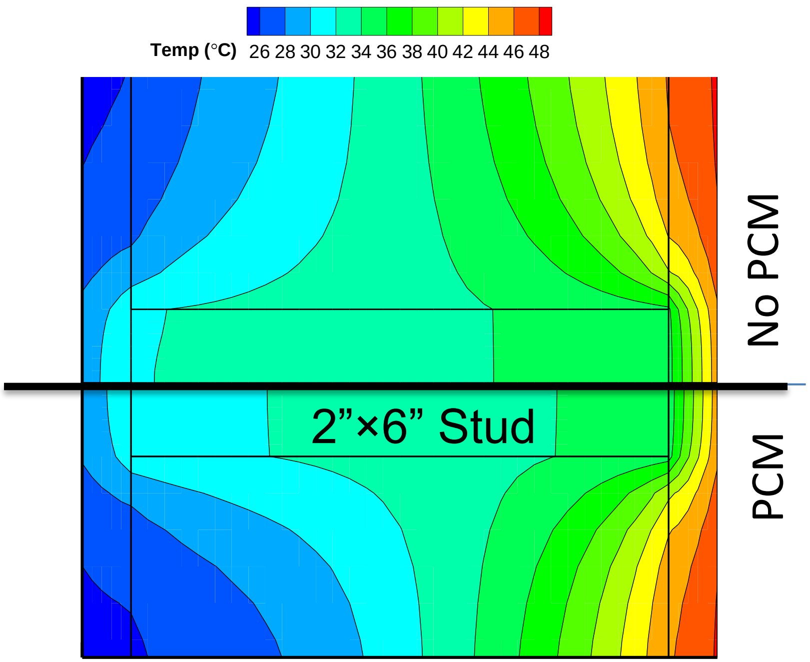
A New Look at an "old" technology

Goals

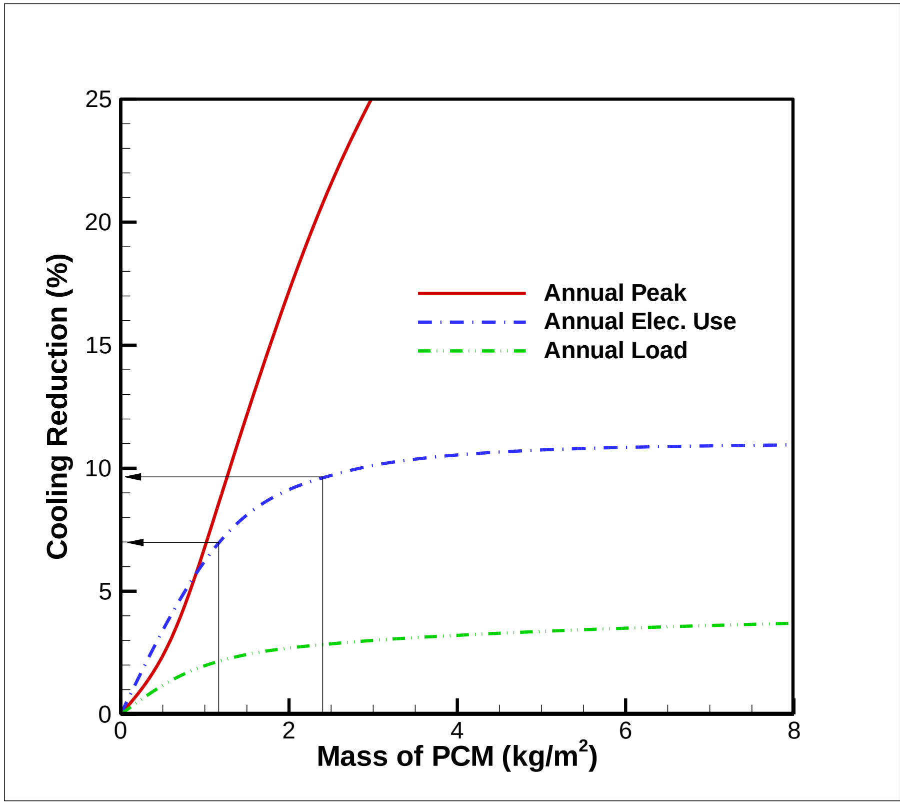
- Advance fundamental science of PCMs as applied to building envelopes
  - Develop new test methods
  - Apply advanced analysis techniques
- Support US industry in their efforts to reduce costs of PCM building products
- Nearing economic and dimensional limits on traditional envelope measures
- Proactively manage interactions with variable environment: Take advantage of diurnal variations in ambient conditions
- Explore Energy vs Temperature/Comfort and Peak impacts
- Explore impacts on peak cooling demand and other time-dependent issues
  - Cooling system sizing issues
  - Time of day- utility pricing

Parametric Evaluation: Phoenix, Az

- Total energy flux THROUGH the wall very nearly the same whether there is PCM in the wall or not.
- Wall energy savings (~8%) are almost entirely due to SHIFTING the interior COOLING LOAD to the cooler part of the day when the air conditioner operates more efficiently.
- Wall economic savings (~30%) are greater than energy savings when time-of-day pricing is available
- Optimization of PCM properties, internal distribution, and amount has to consider wall orientation, thermostat set point, savings goals
- Latest discovery: Savings are greater when consider interactions between insulation and framing



Hot summer afternoon



Future Plans for PCM Project

- Determine optimal amount and placement of PCM taking hysteresis and 2-D thermal bridging into account.
- Continue dynamic test method development
- Examine attic applications (greater temperature swings, better retrofit opportunities)
- Continue to work with partners on building projects to develop low-cost PCM
- Continue to support efforts to improve modeling and apply to Energy Plus

Air Barriers for Residential and Commercial Buildings

- **Air leakage: 20 - 30% of conditioning loads (Huang, 199**
- **Lack of comprehensive research**
  - Energy conservation
  - Durability of building materials
  - Means to meet 2009 and 2012 IECC
  - Retrofit of existing buildings
- **Field and laboratory tests**
  - Quantify air barrier benefits
  - Identify major sources of air leakage
  - Evaluate sealing mechanisms
  - Benchmark simulation tools


Fluid-applied non-foaming


Interior


Self-adhered


Mechanically fastened


Non-insulating boardstock

Spray-applied foam


Insulating boardstock


Sealers w/ backup structure

Recently Completed Work

- Complete Phase 1 at Syracuse NET Facility
- Begin Phase 2 at Syracuse NET facility

} **Field tests**

- Continue characterization of air barriers
- Plan sub-assembly tests

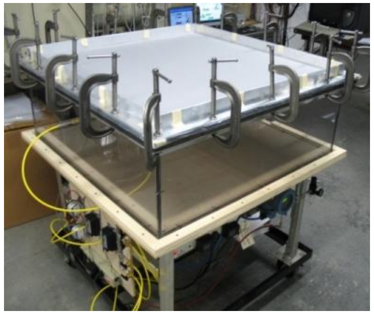
} **Lab tests**

Syracuse NET Facility

Phase 1 wall panels

Phase 2 wall panels

Laboratory Setups

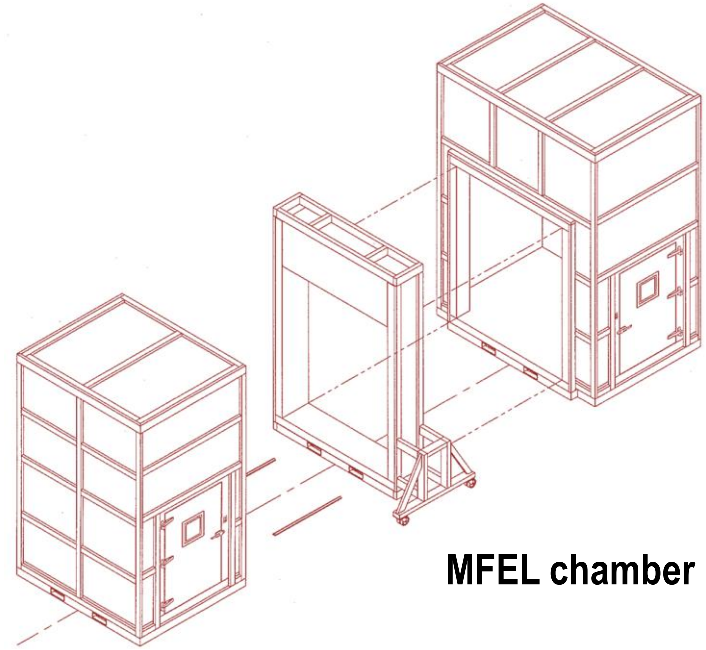


Material test

Sub-assembly test

Tasks for FY12 (Pending Funding)

1. Finalize Industry Collaborative Plan
2. Monitor Phase 2 at NET Facility
   - Collect and analyze data
3. Finish air barrier characterizations
   - Issue reports to manufacturers
4. Begin sub-assembly tests



MFEL chamber

5. Coordinate Multi-Functional Envelope Laboratory Chamber
   - FY10 funded facility upgrade
   - Supports air barrier and moisture research programs

Moisture Engineering and Metal Buildings

- **Challenge**
  - Moisture is increasingly a durability issue in “efficient” wall sections as more insulation, vapor barriers are added
  - Must produce materials and installation guides that result in durable, “dry”, wall and roof sections without mold and rot
- Tasks
  - Validate the WUFI software against the measured Charleston, SC field data for at least 2 wall systems
  - Measure hygrothermal properties of ten construction materials
  - Enhance the WUFI-ORNL software by including the temperature dependencies of the thermal conductivity; hold workshops
  - Report summarizing the thermal performance of metal building roofs
- Partnership: ORNL with Fraunhofer IBP, U. Minnesota, NREL

Measure Hygrothermal Properties

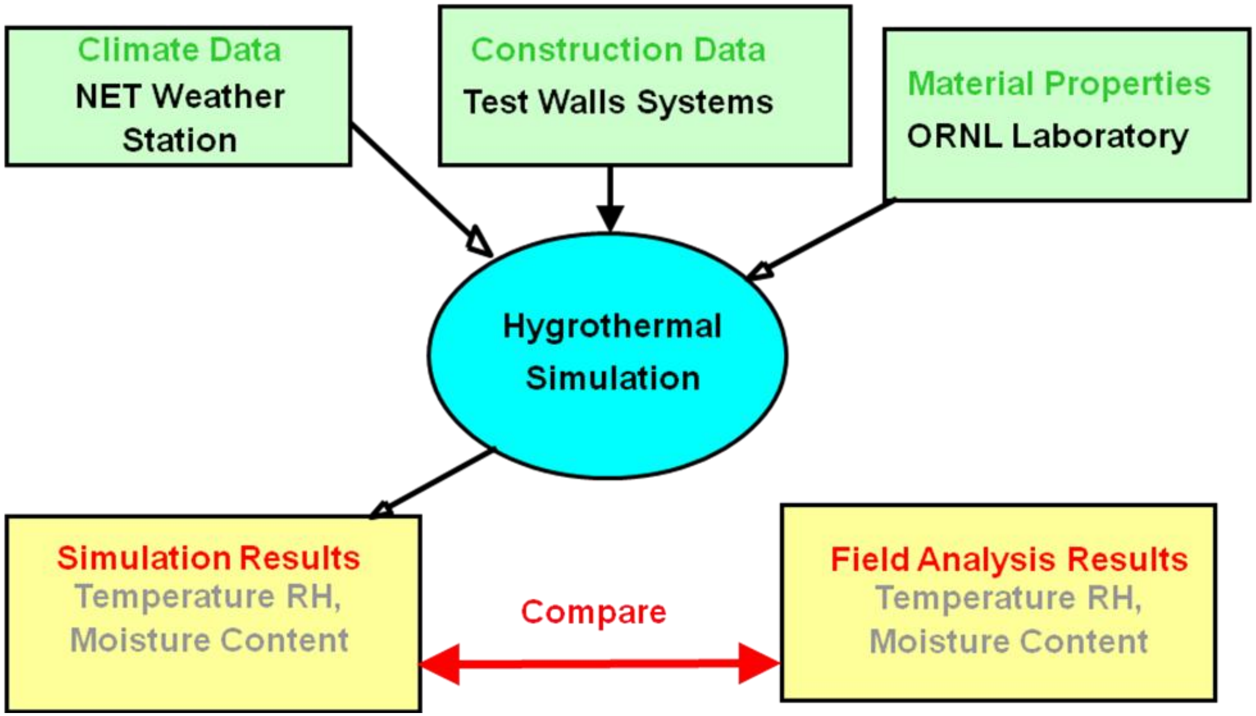
Material	Number of Products	Percent Complete			
		ASTM E 96	ASTM C 1498	ASTM C 1699	Liquid Uptake
Liquid applied non-foaming membrane	8	70	95	80	100
Non-insulating boardstock	1	80	100	40	100
Insulating boardstock	1	25	40	40	100
Mechanically fastened membrane	5	80	100	40	100
Self-adhered membrane	3	80	100	75	100
Spray-applied foam	3	25	70	40	100
Air sealers with back-up structure	1	25	40	40	100
Total	22	64	89	59	100

ASTM E 96 – 05: Water vapor transmission of materials

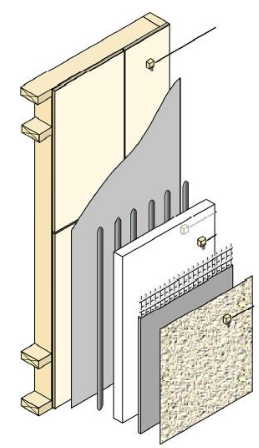
ASTM C 1498 – 04a: Hygroscopic sorption isotherms of building materials

ASTM C 1699 – 08: Moisture retention curves of porous building materials using pressure plates

Protocol for Hygrothermal Modeling Validation



S. Carolina
NET Facility

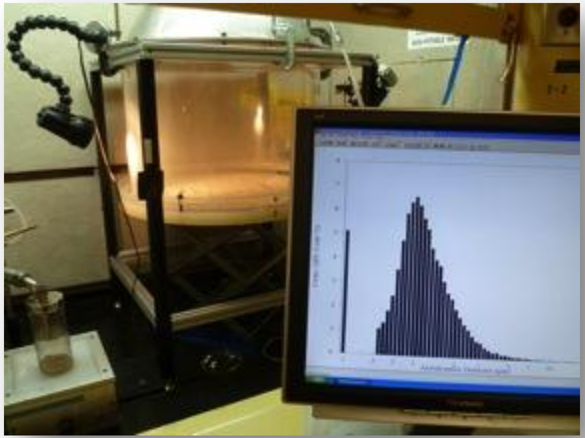


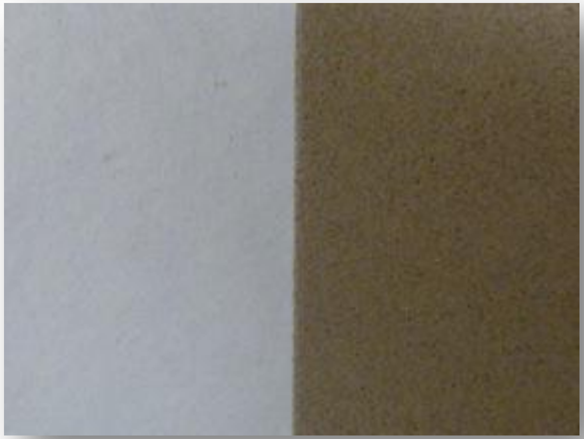
EIFS on 2x4@16“,
no Vapor Barrier

Cool Roofs: Key Tasks and Milestones

- **Issues**
  - What happens to thermal performance as roof surface "ages"
  - What are mechanisms for change in surface properties
  - Develop accelerated methods to assess these impacts
- **Field study on microbial species**
  - Species identified
  - Sampling protocol tested on roof facilities at 3 locations
- **Protocol development on white reflective and cool color roofs**
  - Chamber controls solar radiation, temperature, humidity, wetting cycle acquired to perform exposure testing
  - Specimens loaded with dust and inoculated with microbes will be inserted in chamber and evaluated

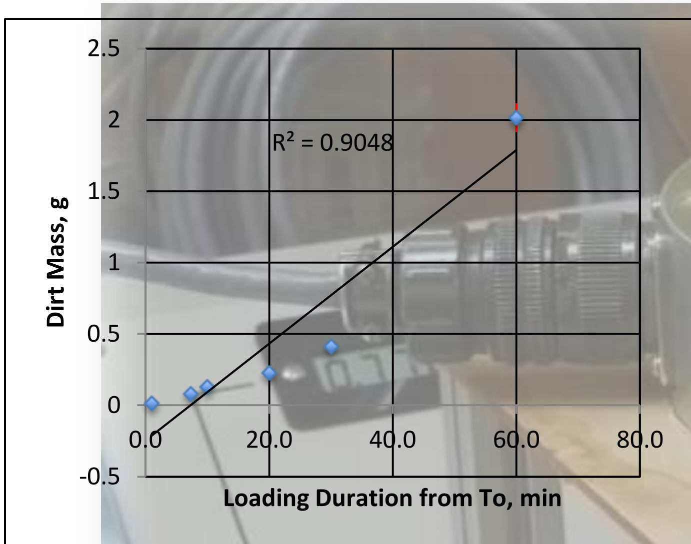
Load Chamber for Simulating and Accelerating Roof Contamination Rate

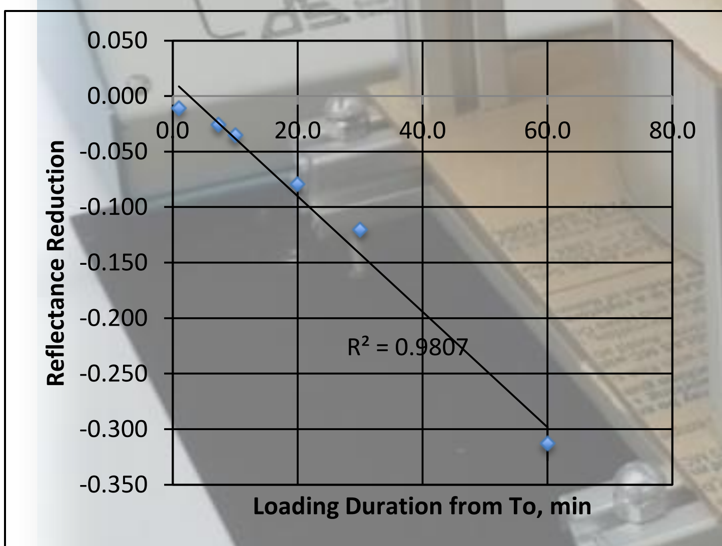




- Chamber built for accommodating a sample size up to 15” in dia. or multiple samples of smaller area size
- Real-time monitoring capability for contaminant loading
- Easy access to sample for reflectance measurement and loading verification
- Design for loading dry and or wet contaminants

Loading and Reflectance Reduction Rates



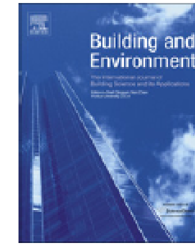


- Hi-fidelity simulation of atmospheric dust loading using real-world test dusts, e.g., Arizona test dust(ISO 12103-1 standard)
- Total surface reflectance measurement tested on Arizona test dust Mass loading function linear (R^2>0.9) following deposition theory
- Reflectance reduction also linear following dust load (R^2 > 0.98)

Contents lists available at ScienceDirect

Building and Environment

journal homepage: www.elsevier.com/locate/buildenv



Chemical and microbial effects of atmospheric particles on the performance of steep-slope roofing materials

Meng-Dawn Cheng [a,*], Susan M. Pfiffner [a,b], William A. Miller [a], Paul Berdahl [c]

[a] *Oak Ridge National Laboratory, PO Box 2008, MS 6038, Oak Ridge, TN 37831, United States*
[b] *University of Tennessee, Center for Environmental Biotechnology, Knoxville, TN 37996, United States*
[c] *Lawrence Berkeley National Laboratory, Berkeley, CA 94720, United States*

CA Topographic Map

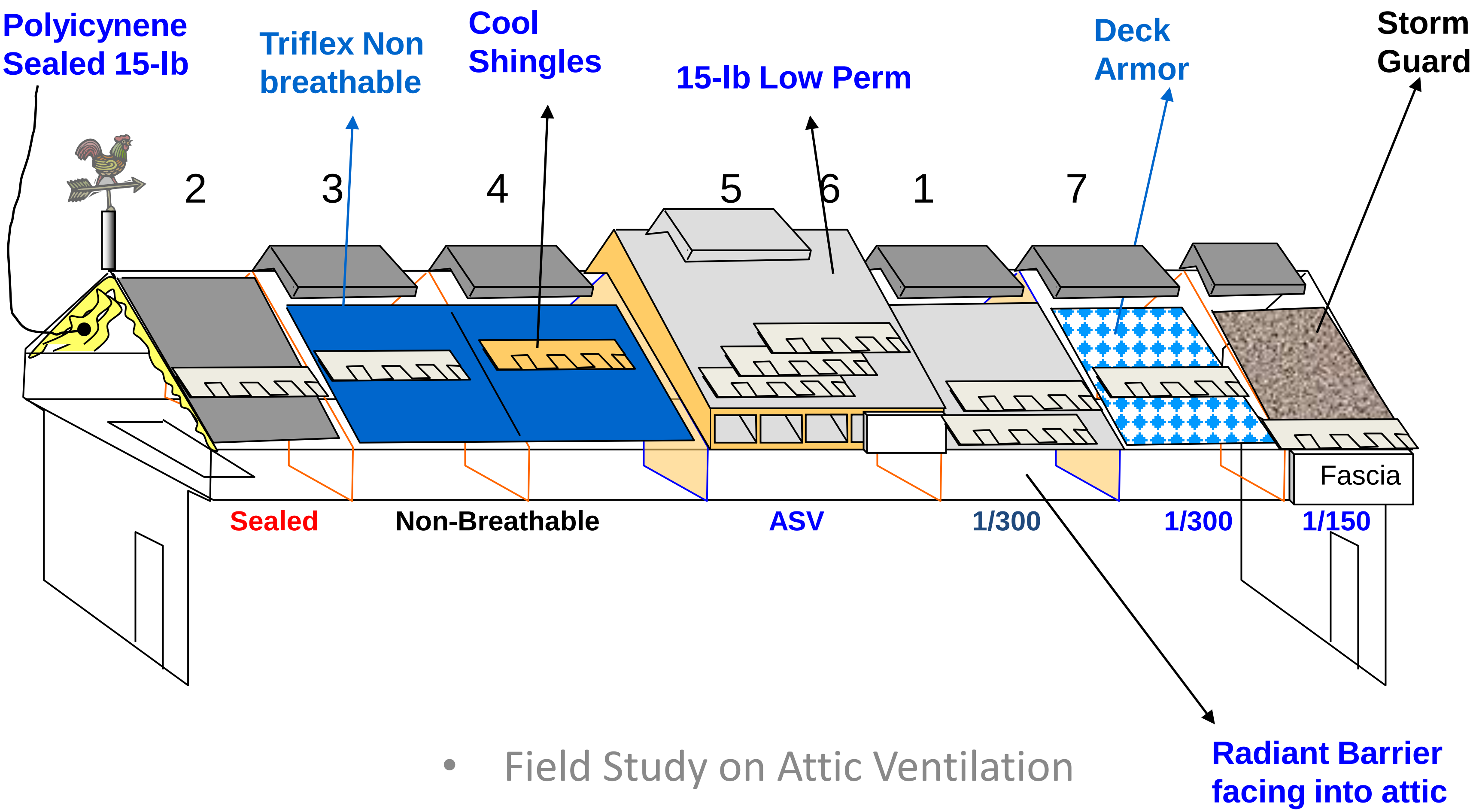
Field Exposure Sites

Sites	Company	City	County	Climate Zone
1	Custom-Bilt	**Sacramento**	Sacramento	12
2	Steelscape	**Richmond**	Contra Costa	3
3	BASF	**Colton**	San Bernadino	10
4	Maruhachi Ceramics of America	**Corona**	Riverside	10
5	ELK Corporation	**Shafter**	Kern	13
6	Department of Water Resources	**McArthur**	Shasta	16
7	Department of Water Resources	**Meloland**	Imperial	15

Next Generation of Roof and Attic Systems

- How do materials and components perform as a system?
- Validate tools with field data to extend results to all climates
- **Field study on attic ventilation** (NET Facility Charleston SC)
    - Data acquisition active
    - Tracer gas analyses of attics complete
    - Sensitivity study of attic ventilation (in progress)
- **Roof and attic design guidelines**
    - Hot climate design guides
    - Cold climate designs
    - Lab testing of radiant barriers
    - Field test on thermochromic surface

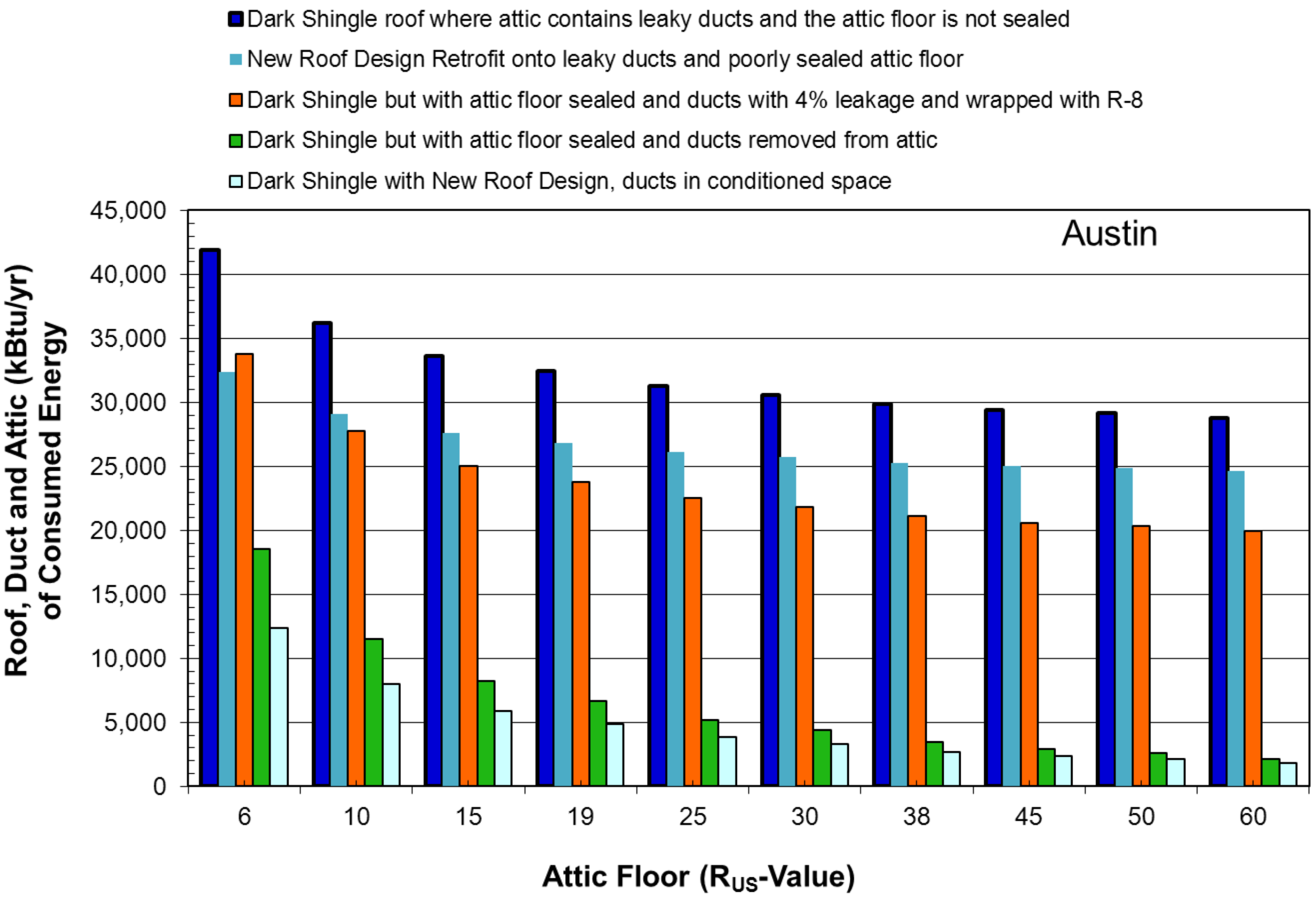
NET Measurement Facility Charleston, SC



- Field Study on Attic Ventilation
- Dearth of Research on Ventilation
- Diverse Opinions on its Effectiveness
- Results are empirical and dated

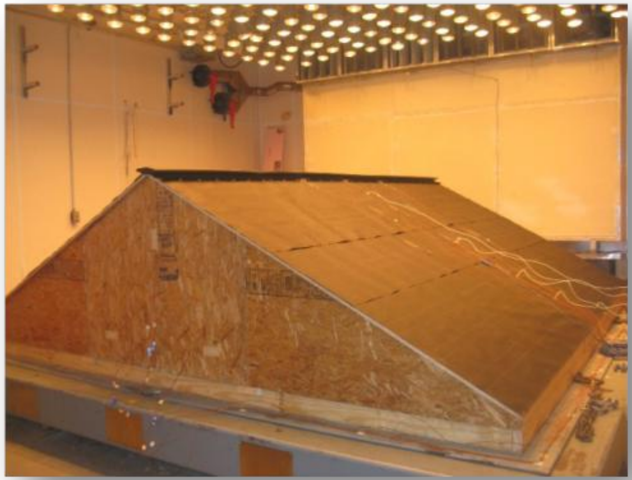
AtticSim/EnergyPlus Estimated Energy Savings

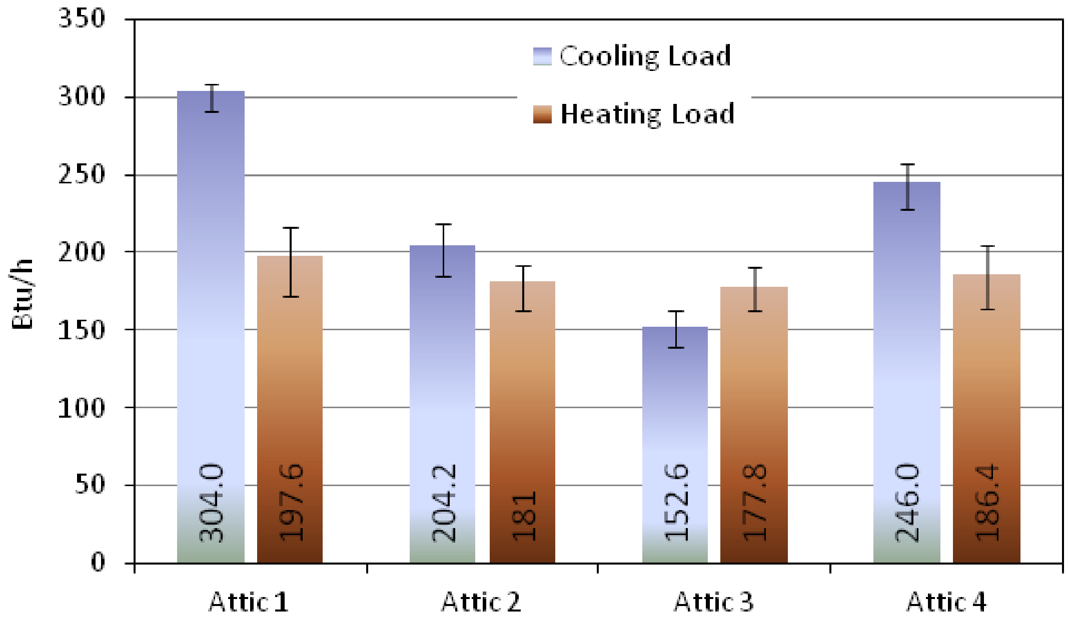
Effect of leaky and poorly insulated ducts predominate loss



Performance Evaluation of Attic Radiant Barrier Systems Using LSCS

Attic 1	Oriented Strand Board (OSB) without radiant barrier (RB), ε = 0.89
Attic 2	OSB with perforated foil faced Radiant Barrier, ε = 0.03
Attic 3	Radiant Barrier stapled to rafters, ε = 0.02
Attic 4	Spray applied low-e paint on roof deck and rafters, ε = 0.23





✓ The test attic had fiberglass batt insulation on the floor

✓ Summer daytime condition: climate chamber air temperature 38°C, roof exterior surface temperature 60°C

✓ Winter Night condition: climate chamber air temperature 0°C