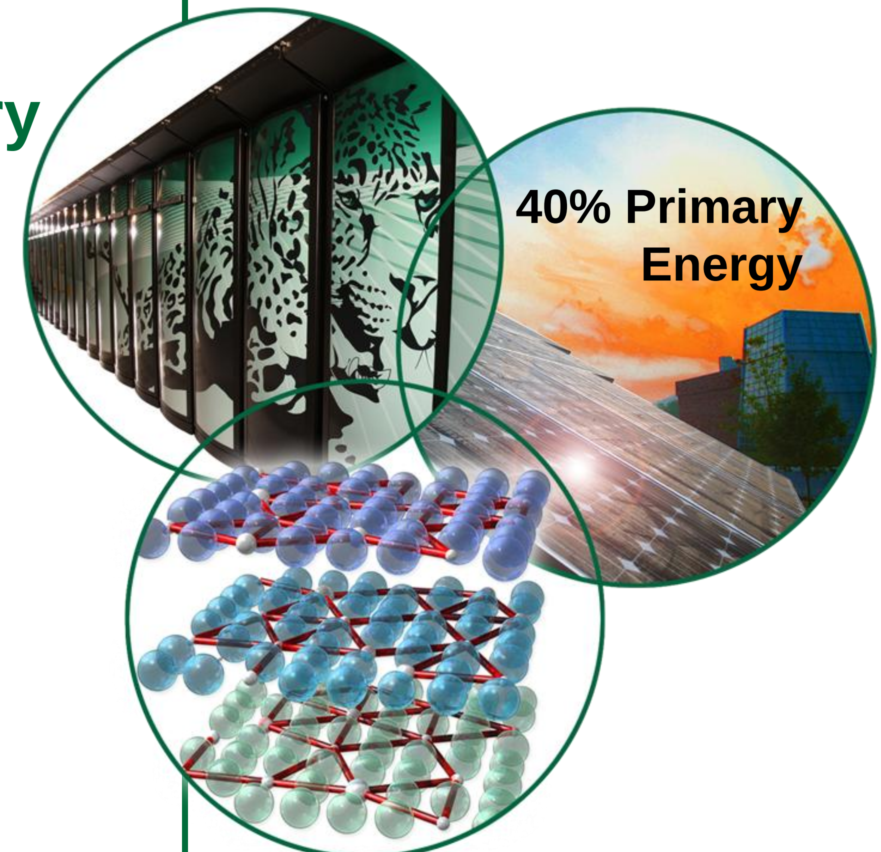
PROTOTYPE ROOF DECKS

NEXT GENERATION OF ATTIC SYSTEMS

Building Envelope Program
Oak Ridge National Laboratory



Dr. William Miller,

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Billy Ellis

U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

OBJECTIVE

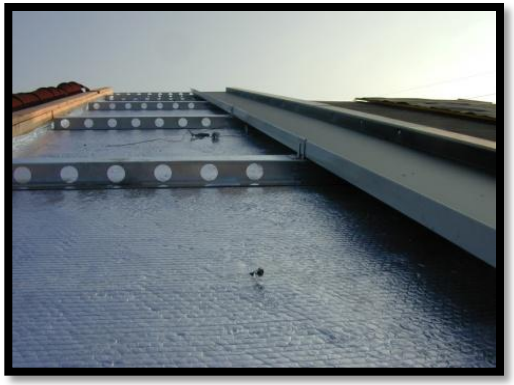
ESRA

- Develop Next Generation Roof/Attic
  - Ventilation **ASV**
  - Radiant barrier
  - Thermal mass
  - Cool color roofs
- Development of Design Guidelines
  - Hot Climates
  - Cold Climates

Roof and Attics Prototype Designs

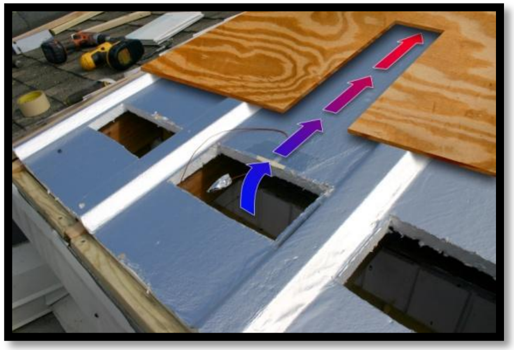
Insulated and Ventilated Tile Roof

High-profile tile that is highly reflective; the tile's high profile provides above-sheathing ventilation; a 1¼-in. (0.032-m) expanded polystyrene (EPS) insulation is placed on top of the deck, and a spray urethane foam adheres the tile and EPS assembly firmly to a fully adhered peel-and-stick, ice-and-water guard membrane.



Offset-mounted Metal Roof

Painted metal roof exploits cool color pigments; above-sheathing ventilation with a 1½-in. (0.038-m) inclined air space fitted with low-e surfaces and a sheathing doped with paraffin hydrocarbon PCMs.

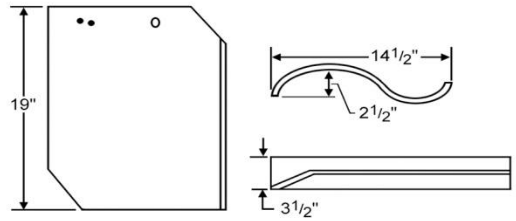


Insulated and Ventilated Shingle Roof

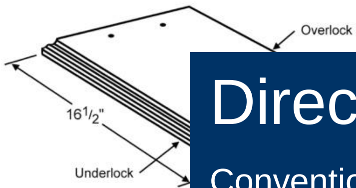
Conventional or cool color shingle; 1-in. (0.0254-m) air space made by profiled and foil-faced 1-in. (0.0254-m) EPS insulation placed above deck (retrofit practice) or fitted between roof rafters (new construction); two low-e surfaces.

Field Tests Clay and Concrete Tile

High profile Clay (SR54E90) Direct-to-EPS foam



Flat Concrete (SR13E83) Direct-to-Deck

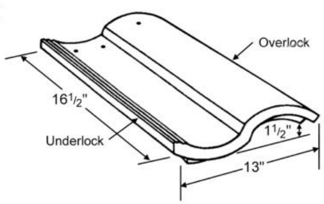


Direct-to-Foam

Conventional thermal mass works well when combined with foam insulation placed above sheathing

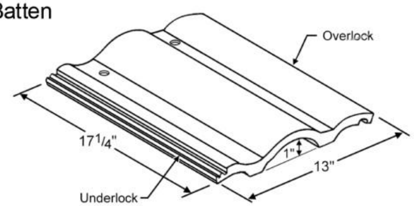
High profile Concrete (SR26E86

- Direct-to-EPS foam
- Spray foam to deck
- On Battens

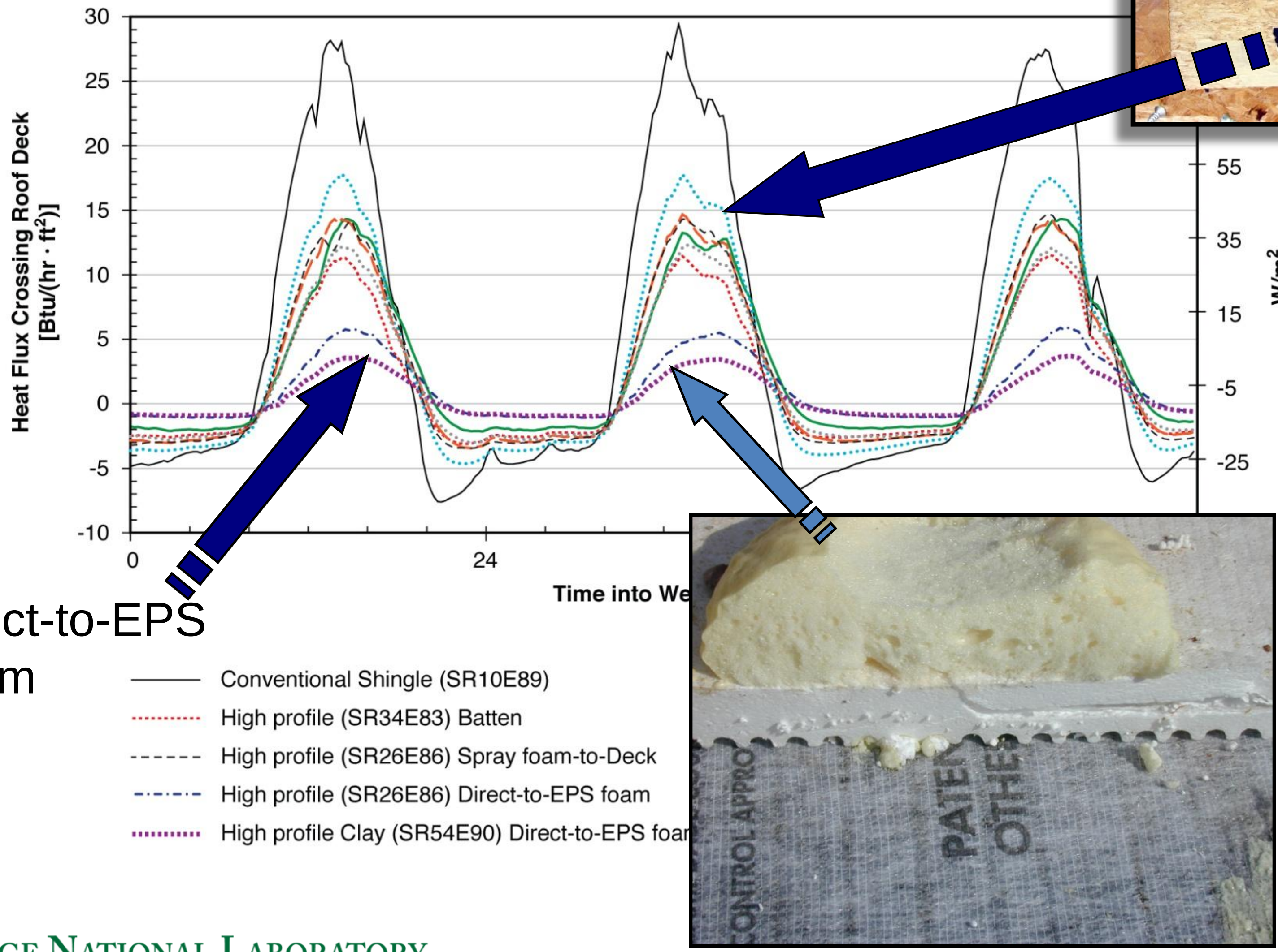


Medium profile Concrete

- (SR37E93) Direct-to-Deck
- (SR10E93) Double Batten
- (SR37E93) Batten



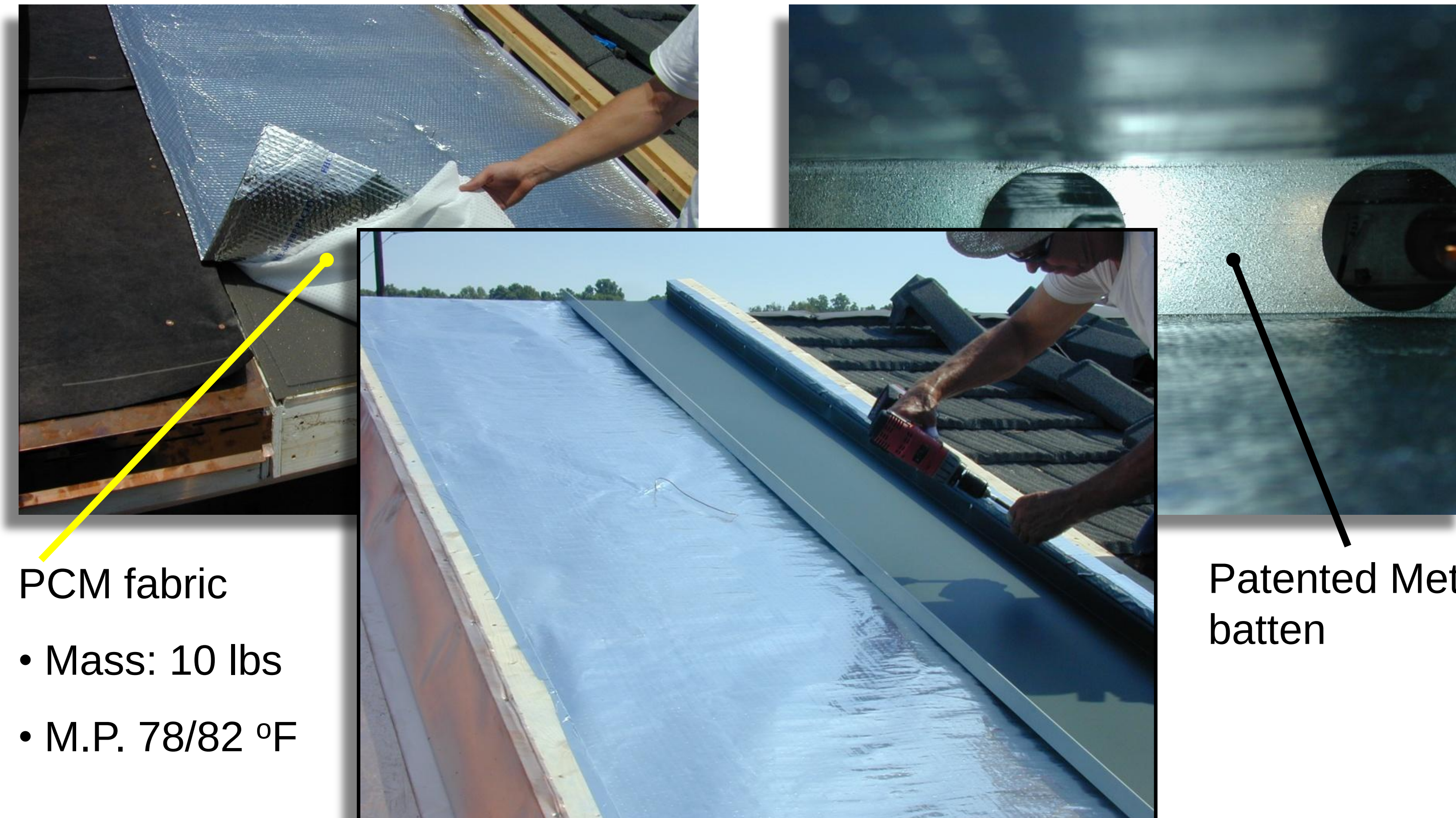
High Profile Clay and Concrete Tile with EPS foam above deck best perfor



Direct-to-EPS Foam

Offset Mounted Painted Metal Roof

Painted metal roof (SR28E81, 4-in air space, 2 Low-e, PCMs)

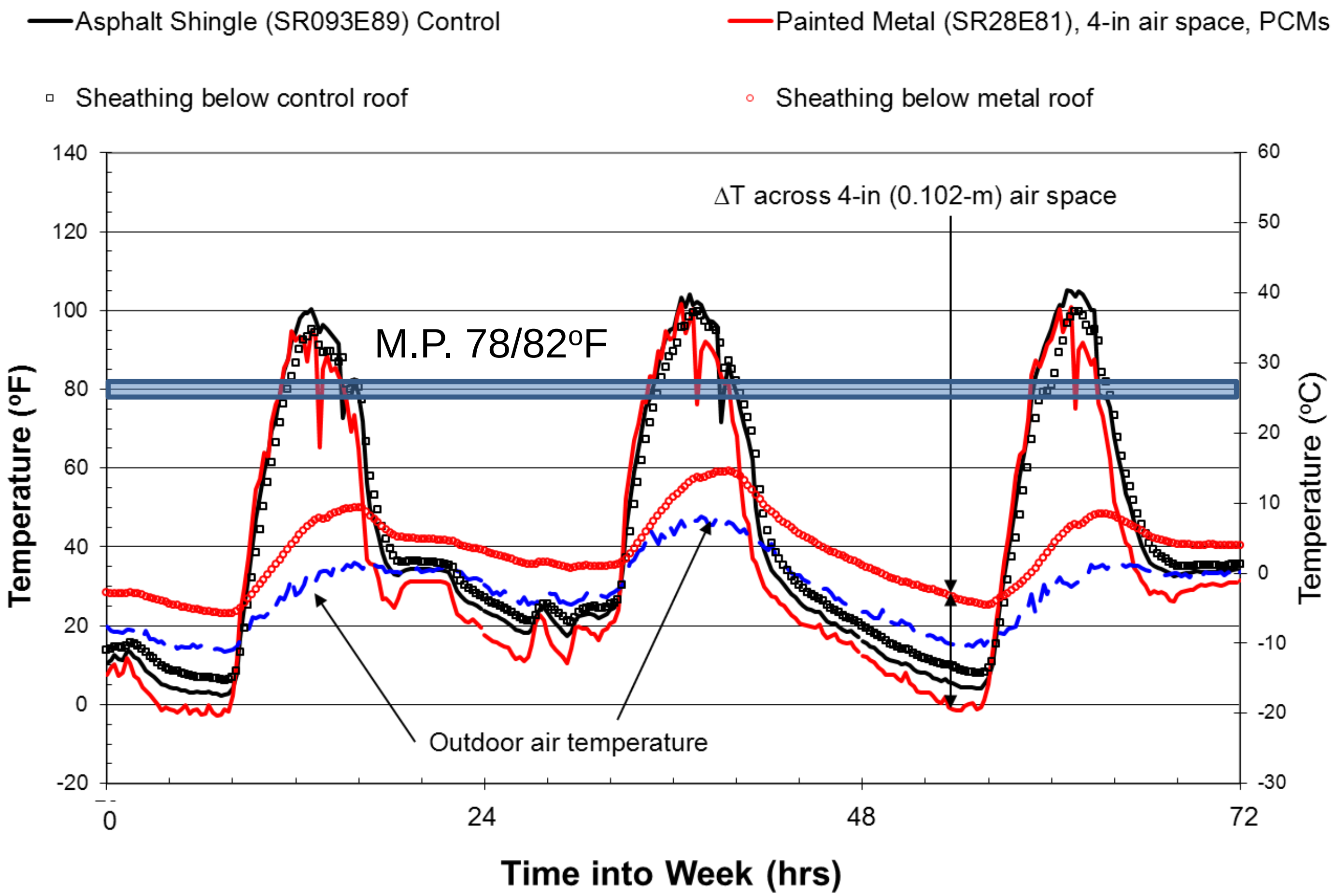


PCM fabric

- Mass: 10 lbs
- M.P. 78/82 °F

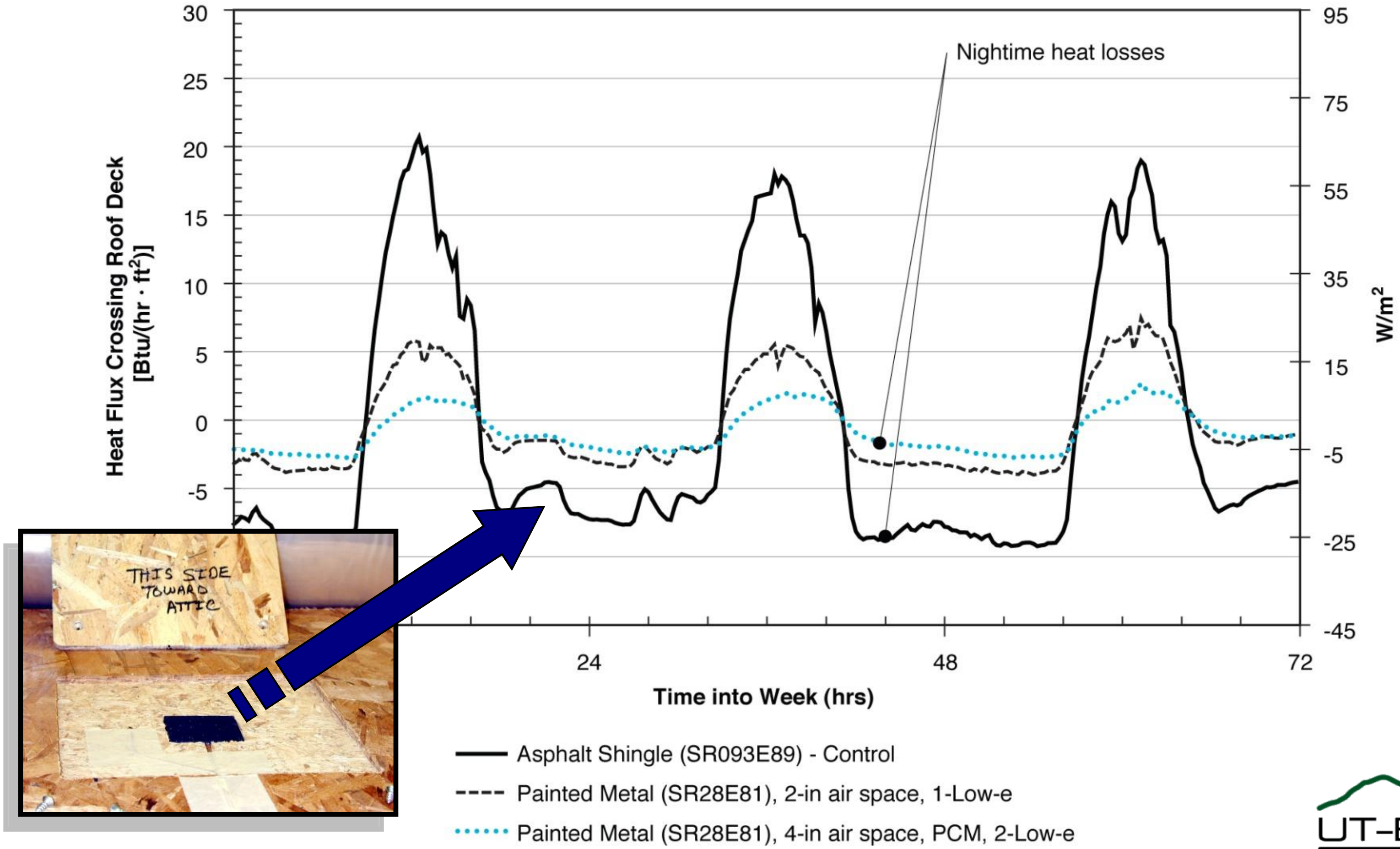
Patented Metal Z batten

Attic with Radiant Shields, ASV and PCM Helps Negate Heating Penalty



Reduced Heating Penalty for Cool Roof

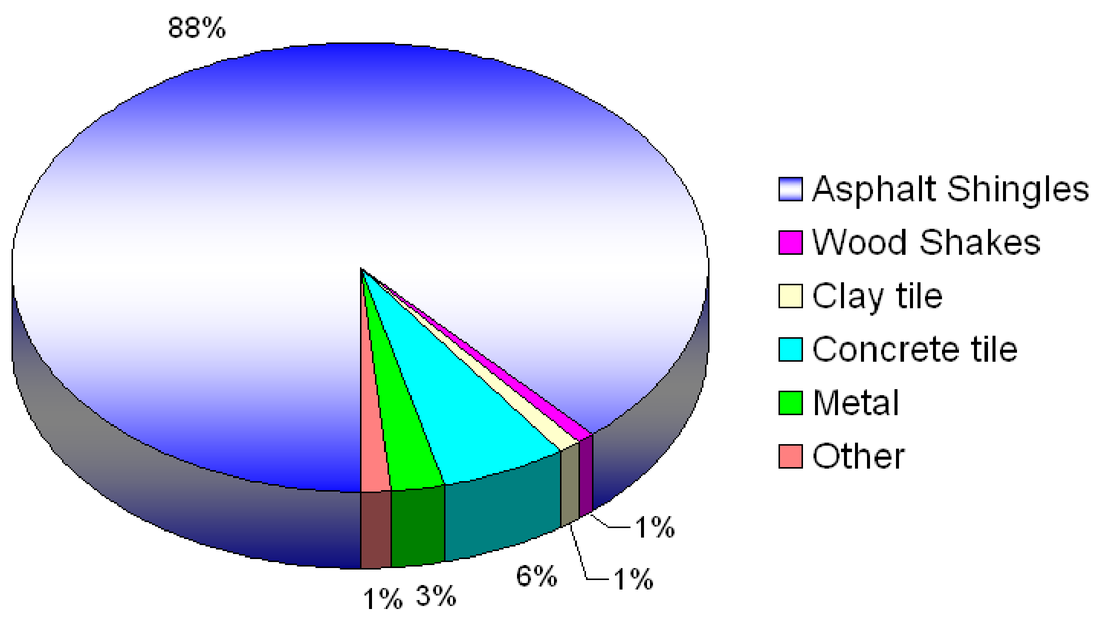
- Winter heat losses reduced 8% of direct nailed case
  Summer heat gains drop 40%



UT-BATTELLE
Management Contractor for DOE's
Oak Ridge National Laboratory

Squares of Roof Products
F.W. Dodge Report

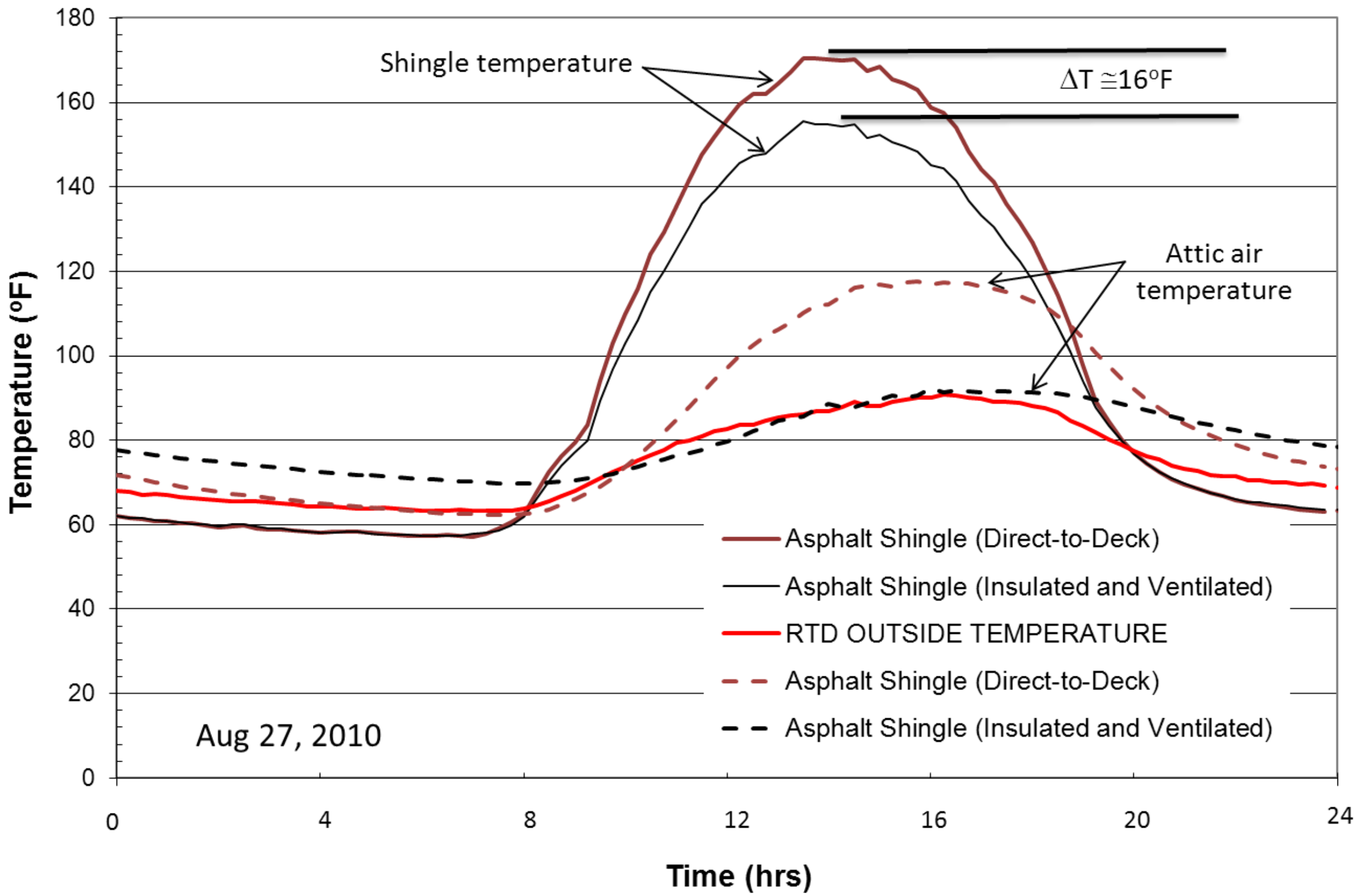
United States	Asphalt Shingles	Wood Shakes	Clay tile	Concrete tile	Metal	Other
New Construction	29,955,734	280,821	323,763	1,965,500	889,134	461,263
Reroof	115,054,533	6,445,277	892,926	1,657,307	466,234	4,400,195
Total	145,010,267	6,726,098	1,216,689	3,622,807	1,355,368	4,861,457



Above deck insulation and ventilation assembly under asphalt shingle

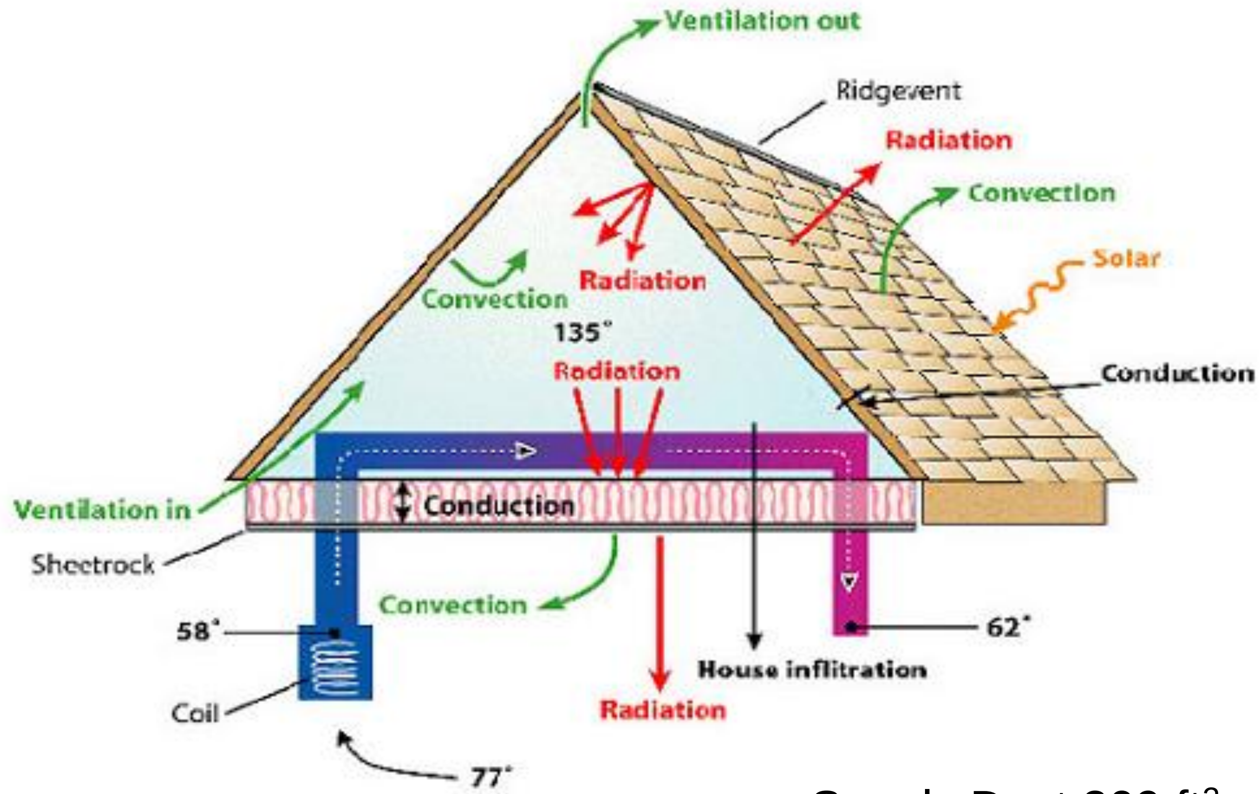
Above deck insulated and ventilated assembly under asphalt shingle

Key Observations
- Reduce the operating temperature of the shingle
- Reduce the thermal load to the building



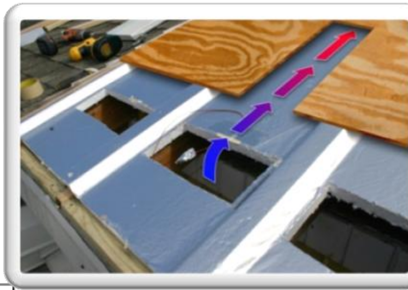
AtticSIM/Energy Plus Simulations with Duct System

- **ASTM C 1340-99 Standard For Estimating Heat Gain of Loss Through Ceilings Under Attics**



Supply Duct 309 ft^2
Return Duct 176 ft^2

AtticSim Benchmark against Field Data



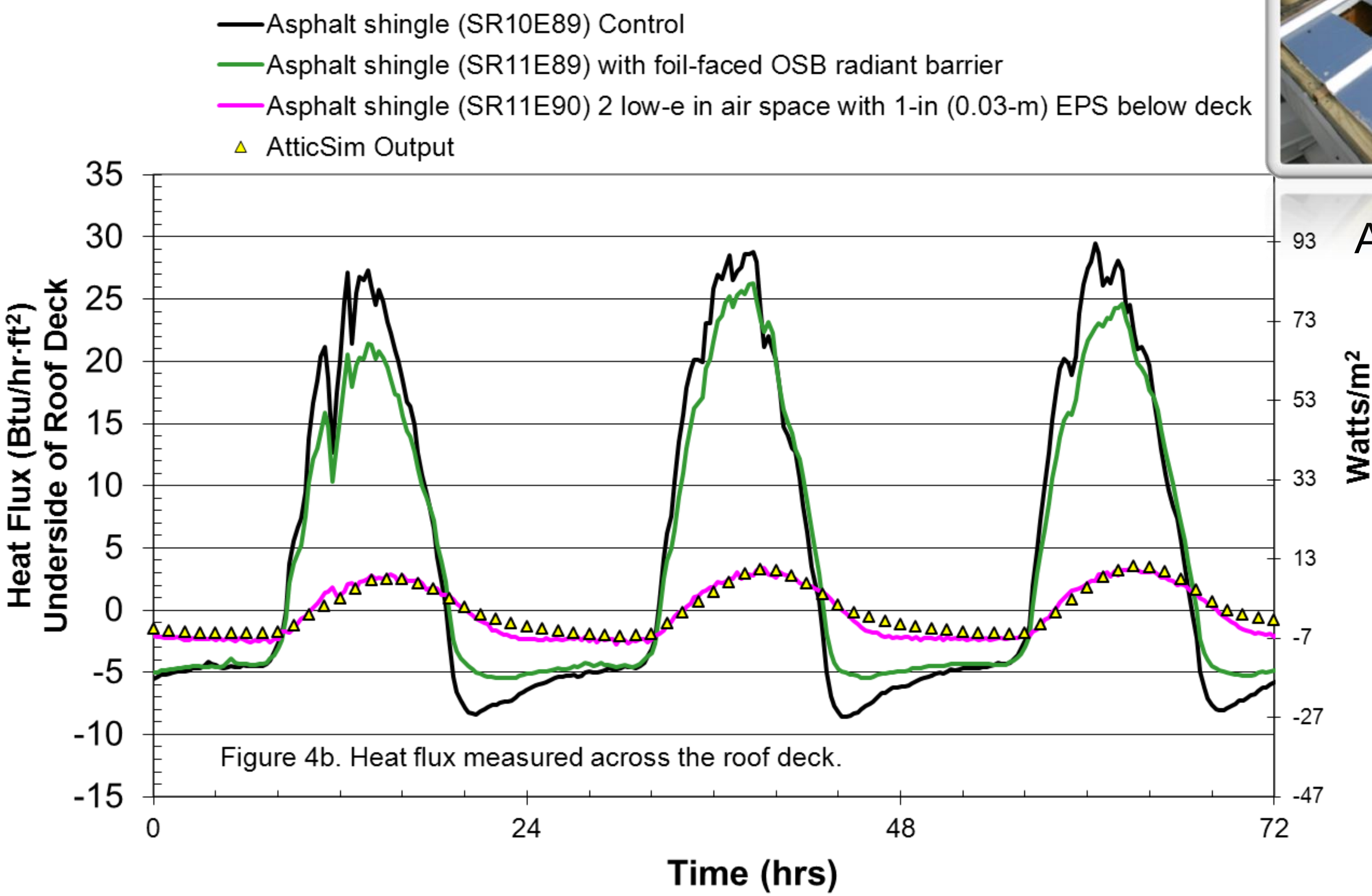


Figure 4b. Heat flux measured across the roof deck.

April, 2010

AtticSim Benchmark against Field Data

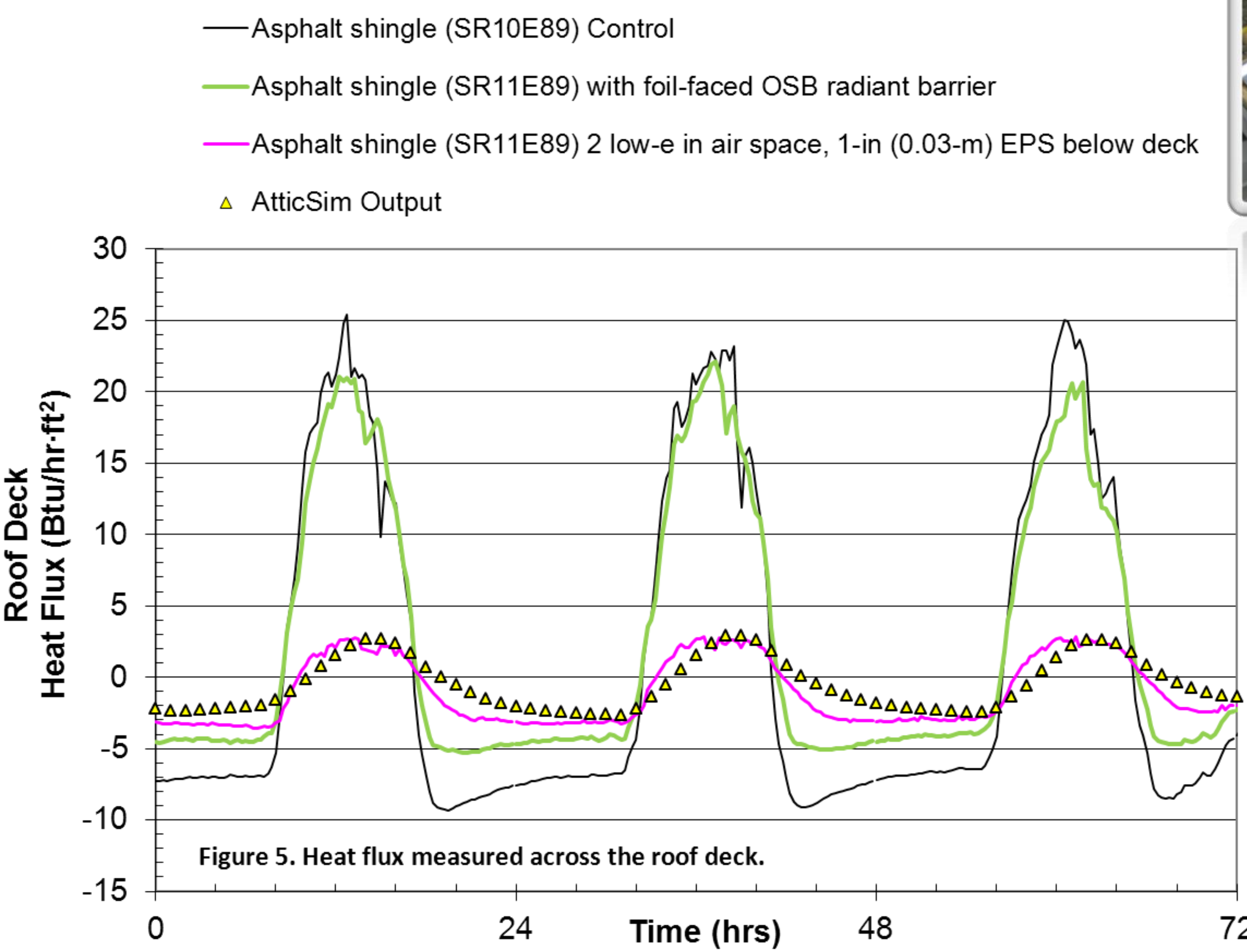
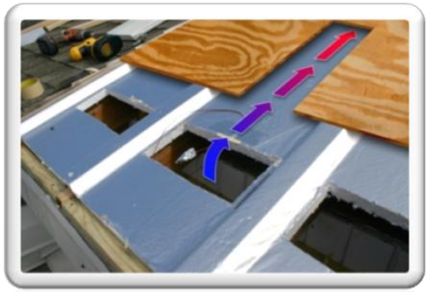
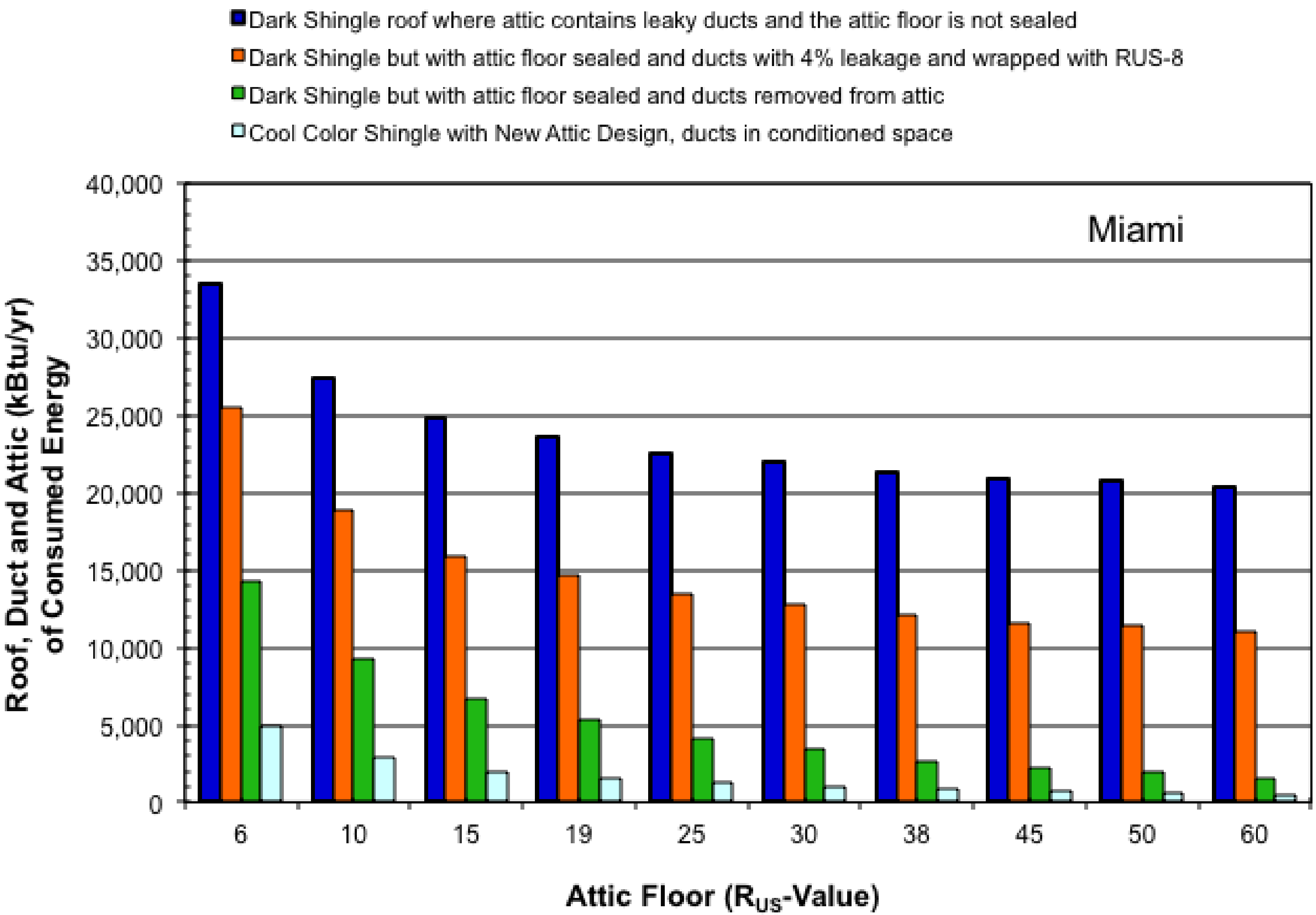


Figure 5. Heat flux measured across the roof deck.



February, 2011

Avoid Placement of Ducts in Attic
Not the Best Choice



Roof and Attic Annual Cost of Energy

- The EIA (2008) average electric bill for Florida ≈ $1,570
- The EIA (2008) average electric bill for Texas ≈ $1,770
- The EIA (2008) average electric bill for Georgia ≈ $1,370

Location	New house[1] compliant with IECC 2006	New design 1—EPS insulation	New Design 2—Cool color metal	New Design 3 —High-profile tile
	$ per year per square (100 sq ft)			
Miami	$8.54	$0.66	$0.71	$0.64
Austin	$15.04	$2.31	$2.51	$2.41
Atlanta	$22.05	$4.67	$4.97	$4.84

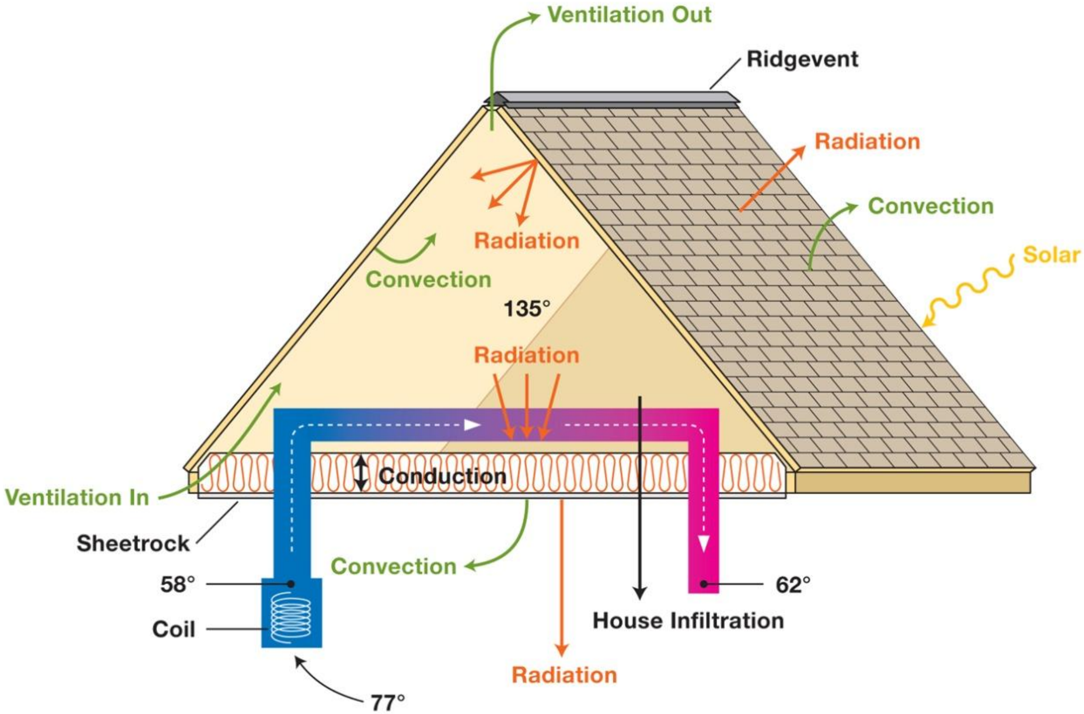
[1] IECC-compliant home has ducts in attic. Ducts wrapped with R_{US}-8 insulation; duct leakage 4%.

Design 1: Foil-faced 1-in. (0.0254-m) EPS insulation fitted between roof rafters; ventilation from soffit and attic to the inclined air space; radiant barrier in attic, 2 low-e surfaces in air space.

Design 2: Cool color metal roof offset-mounted from roof deck 1½-in. (0.038-m); low-e surface in inclined air space covers PCM membrane; radiant barrier in attic.

Design 3: Peel-and-stick, ice-and-water guard membrane, 1¼ -in. (0.032-m) EPS insulation above deck with high-profile tile; spray foam adhered EPS foam and tile to roof deck (no fasteners)

Heat transfer and energy costs for roof and attic retrofits in Miami, Austin, Atlanta and Baltimore



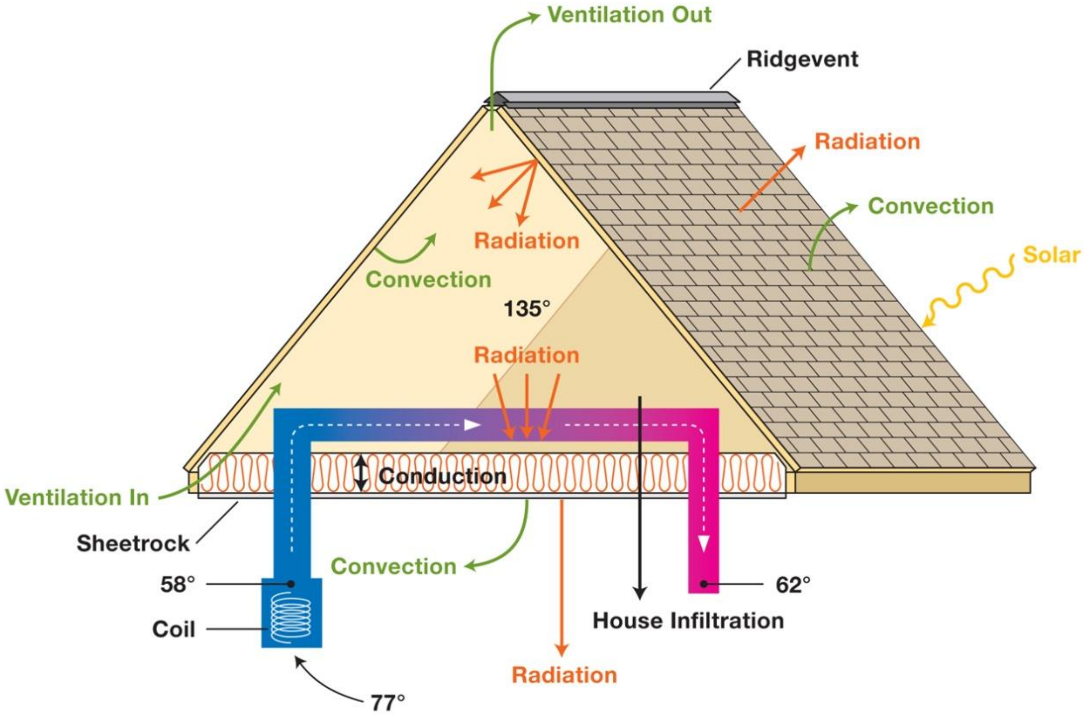
- Attic Floor
  - R_{US}-20 insulation
  - ACH of 1.3 attic floor
  - No radiant barrier
- Duct System
  - R_{US}-5.5 insulation
  - 10% air leakage
- Attic Ventilation 1:300
- Roof
  - 10% solar reflectance

Retrofit Options Based on Pre-1990 Home HVAC Duct in Attic

	Miami	Austin	Atlanta	Baltimore	Material and Labor Costs	Potential Payback (yrs)
ASHRAE Climate Zone	1	2	3	4		
HDD_{65} (^oF)	222	1481	2614	4731		
CDD_{65} (^oF)	9368	7435	4814	3598		
ASHRAE 90.2 [Note 1] Attic Insulation (R_{US})	30	30	30	38		
EIA[Note 2] Annual Electric Bill	$1,570	$1,770	$1,368	$1,724		
EIA[Note 2] Annual Heating Bill	NA	$590	$780	$1,070		
	$[Note 3] per square [100 square feet (9.3 m^2)]					
Pre-1990 Home[Note 4] Shingle Roof (SR 0.10) Attic Floor R_{US}-20 Duct with R_{US}-5.5	$15.23	$27.12	$39.18	$49.35		
Sealed Attic Floor Attic Floor R_{US}-20 Inspected Duct R_{US}-8 Duct; Leakage 4%	$9.57	$16.39	$23.40	$27.98	$50	9 to 3

[1] ASHRAE 90.2-2007 [8].
[2] Energy Information Agency (2008)
[3] Costs based on EIA 2008 data for electricity and natural gas.
[4] Pre-1990 Home: ASHRAE 90-1980 code. Duct in attic; leakage rate 10% of supply flow.

Heat transfer and energy costs for roof and attic <u>retrofits</u> in Miami, Austin Atlanta and Baltimore



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Retrofit Options Based on Pre-1990 Home

No Duct in Attic

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	$[Note 3] per square [100 square feet (9.3 m²)]					
Pre-1990 Home[Note 5] Shingle Roof (SR 0.10) Attic Floor R_{US}-20; No Duct in Attic	$3.47	$6.23	$9.26	$9.98		
Pre-1990 Home Retrofit Option(1): Code Insulation Shingle Roof (SR 0.10); No Ducts in Attic	$2.23	$4.17	$6.41	$5.60	$65 $103	50 to 20
Pre-1990 Home Retrofit Option(2): Radiant Barrier in Attic Attic Floor R_{US}-20; No Ducts in Attic	$2.41	$5.03	$8.27	$8.94	$40	≈ 40
Pre-1990 Home Retrofit Option(3): Above Sheathing Vent Shingle Roof (SR 0.10) Attic Floor R_{US}-20; No Ducts in Attic	$4.95	$5.49	$8.56	$9.37	$55	> 75
Pre-1990 Home Retrofit Option(4): Cool Shingle (SR 0.25) Attic Floor R_{US}-20; No Ducts in Attic	$3.05	$5.95	$9.32	$10.04	$50	> 100

Conclusions

1. Placement of ductwork in condition space crucial for best performance
   - make it a priority in retrofit programs
   - systems approach yields best payback potential

2. Insulation and Radiant Barriers show good performance in hot climates
   - new cool roof shingles not economic if at code insulation
   - Insulation payback (Miami 50 yrs); (Baltimore 20 yrs)
   - Radiant barrier payback (Miami 40 yrs); Baltimore 41 yrs)

3. Building America's best practice calls for R_{US}-50 attic floor insulation and for the ducts to be located in the conditioned space (BA 2003).

   - The integrated roof designs described here are able to reduce that energy loss while using code levels of insulation.

Thank you for your time!

QUESTIONS??

ZEBRAlliance™

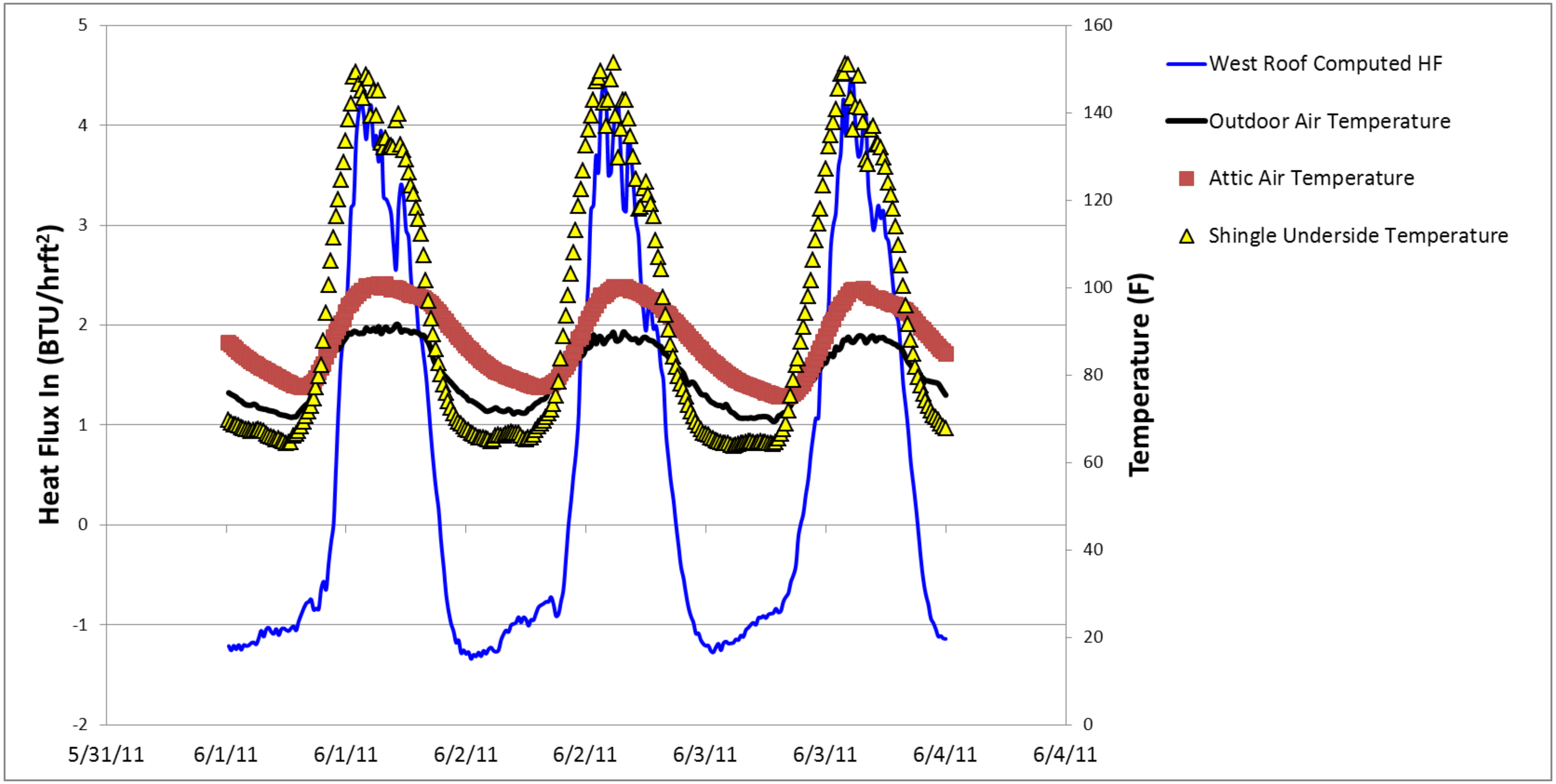
An Alliance Maximizing Cost-Effective Energy Efficiency in Buildings

- ZEBR*Alliance established to promote* Cost-Effective Energy Efficiency in Buildings
  - Functions as a public-private research project and as an energy-efficiency education campaign

ZEBRA House 4 Roof Insulation Installation December 15, 2009

ZEBRAlliance EIFS HOME

Deck Heat Flux and Attic Temperatures



DOE EERE SOLAR FOA

Extreme Balance of System Hardware Cost Reductions (BOS-X)

Objective : Development of a complete BIPV product
Key Goals : Reduce the operating temperature of the PV cell
Reduce the thermal load to the building

Deliverables:

- Develop a business case for integrating PV into a roofing product
- Develop a partnership with a roofing company
- Demonstrate a business case for achieving a $2 per watt total installed PV system cost goal at large scale
- Develop a high reliability product with lifetimes of 25 years or more
- Demonstrate a form factor that can be quickly and easily installed.
  - Prefabricated PV systems
  - New, reliable, wiring connectors for BIPV modules
  - Lightweight materials
  - The integration of power electronics
- Demonstrate a BIPV system that is optimized for energy efficiency performance of the building

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ASHRAE 90.2 Note 1 Attic Insulation (R_{US})	30	30	30	38
Retrofit Options	**Potential Payback (yrs)**			
Repair Ducts R_{US}-8; Duct Leakage 4%	12	6	4	3
Seal Attic Floor No Ceiling Leak	22	8	4	3
Radiant Barrier (underside of rafters)	19	16	19	17
Code Insulation	98	45	29	30
SR40 Shingle	44	55	[illegible]	NA
SR25 Shingle	87	110	NA	NA
Medium Profile Concrete Tile Ecoset System.	67	54	65	58
Insulated and ventilated roof	91	70	81	76
SR 25 Metal Roof with 1½-inch airspace Low-e in airspace Without removal of shingles	124	93	103	98
High Profile Clay Tile EcoSet System	132	109	134	120

[1] ASHRAE 90.2-2007 [8].
[2] Energy Information Agency (2008)
[3] Costs based on EIA 2008 data for electricity and natural gas.

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Retrofit Options Based on Pre-1990 Home

HVAC Duct in Attic

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Retrofit	\$Note 3 per square [100 square feet (9.3 m^2)]					yrs
Base Retrofit: SR10 Shingle 10% Duct Leakage. Ceiling Leak induces 1.3 ACH to House	$13.22	$27.70	$44.04	$56.25		
Retrofit Option: Radiant Barrier (foil-faced OSB)	$11.04	$25.12	$41.81	$53.71	$10.0	5
Retrofit Option: Repair Ducts R_{US}-8; Duct Leakage 4%	$9.68	$20.33	$32.83	$40.41	$40.0	6
Retrofit Option: Seal Attic Floor No Ceiling Leak	$11.78	$23.53	$36.37	$46.28	$30.0	9
Retrofit Option: Eliminate Ducts. No Duct Leakage	$4.31	$10.61	$18.32	$21.84	$450.0	28
Retrofit Option: Sealed Attic Icynene Foam Insulation (R_{US}-20)	$6.36	$10.84	$15.48	$18.57	$425.0	30
Retrofit Option: Code Insulation	$12.52	$26.20	$41.64	$52.63	$65 $103	51
Retrofit Option: Medium Profile Concrete Tile with Ecoset System. Insulated Gables	$10.84	$24.78	$41.62	$53.54	$150.0	61
Retrofit Option: Insulated and ventilated roof	$10.19	$23.77	$40.66	$52.63	$260.0	79