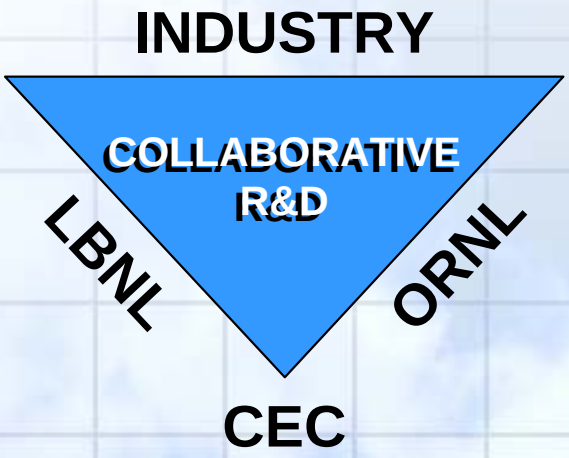
Market Deployment of Cool-Colored Roofing Materials

Project Advisory Committee (PAC) Meeting



Sponsored by the
California Energy Commission
(Project Manager: Chris Scruton)

March 15, 2007; Lawrence Berkeley National Laboratory, Berkeley, CA

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Project goals

- Help California utilities and public interest organizations develop incentive programs for residential cool roofs
- Help manufacturers of cool-colored materials deploy their products
- Measure the energy savings yielded by cool-colored roofing materials, and use these data to validate an energy savings calculator
- Educate consumers, contractors, engineers and architects by publicizing the results of the research

Project Advisory Committee (PAC) members

1. Asphalt Roofing Manufacturers Association (ARMA)
2. Cedar Shake and Shingle Bureau (CSSB)
3. Cool Roof Rating Council (CRRC)
4. Construction Engineering Research Lab (CERL/DOD)
5. Department of Energy (DOE)
6. Environmental Protection Agency (Energy Star/EPA)
7. EPA San Francisco Office
8. Florida Solar Energy Center (FSEC)
9. Pacific Gas and Electric Company (PG&E)
10. Roof Coating Manufacturers Association (RCMA)
11. Tile Roofing Institute (TRI)
12. Southern California Edison Company (SCE)

Industrial partners

- 3M Industrial Minerals
- Akzo Nobel Coatings
- American Rooftile Coatings
- BASF Industrial Coatings
- CertainTeed
- Custom-Bilt Metals
- Elk Corporation
- Ferro
- GAF
- Hanson Roof Tile
- ISP Minerals
- MCA
- MonierLifetile
- Owens Corning
- Steelscape
- Shepherd Color

Project team

- Lawrence Berkeley National Lab (LBNL)
  - Hashem Akbari (Project Director and Technical Lead) H_Akbari@LBL.gov
  - Paul Berdahl PHBerdahl@LBL.gov
  - Ronnen Levinson RMLevinson@LBL.gov
- Oak Ridge National Lab (ORNL)
  - André Desjarlais (Technical Lead) yt7@ORNL.gov
  - Bill Miller wml@ornl.gov

Technical tasks

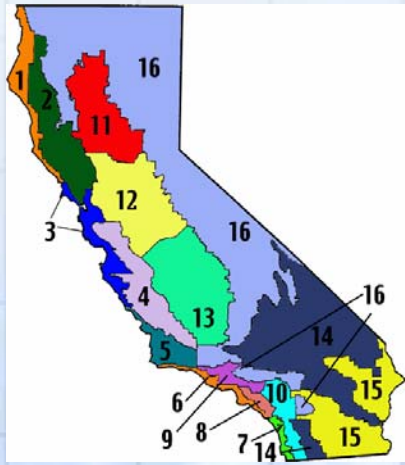
- 2.4 Help California utilities develop cool roofing programs for their residential customers
- 2.5 Help manufacturers of cool-colored materials deploy their products
- 2.6 Technology transfer activities

2.4 Help California utilities develop residential cool roofing programs

- Objective
  - Help California utilities develop cool roofing programs for their residential customers
- Deliverables:
  - Work with California utilities to help them develop incentive programs
  - Documented in quarterly progress reports
- Schedule: 08/20/2006 – 06/20/2008
- Funds expended: 20%

PG&E and SCE cool roof rebates

Roof Slope	Rebate Tier	Initial Solar Reflectance	Initial Thermal Emittance	Rebate [$/ft^2]
Low	N/A	≥ 0.70	≥ 0.75	$0.20
Steep	Tier 1	0.25 - 0.39	≥ 0.75	$0.10
	Tier 2	≥ 0.40	≥ 0.75	$0.20



- PG&E offers rebates in climate zones 2, 4, 11, 12, 13
- SCE offers rebates in climate zones 8, 9, 10, 13, 14, 15

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2.5 Help manufacturers of cool-colored materials deploy their products

- Objective: Continue working with roofing manufacturers to deploy and market their cool products
- Subtasks:
  - Enhance the solar reflectance of non-white roofing materials
  - Develop tools to measure solar reflectance for factory quality control
  - Correlate the solar reflectance of a shingle to that of its constituent granules
  - Develop industry-consensus energy-savings calculator
  - Conduct natural exposure testing in California
  - Conduct natural exposure testing at ORNL
  - Monitor building cooling energy use in Southern California to evaluate new cool-colored roofing materials for validation of the industry-consensus energy savings calculator

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2.5.1 Enhance the solar reflectance of non-white roofing materials

- Objective: Continue working with roofing manufacturers to enhance the solar reflectance of their products
- Deliverables:
  - Prototype cool-colored roofing products with increased solar reflectance
- Schedule: 07/20/2006 – 07/20/2008
- Funds expended: 10%

Ideas for increasing solar reflectance of asphalt shingles, wood shakes

- Granules & granule-surfaced shingles
  - Investigate cost, availability of whiter aggregate
  - Color shingles by applying a pigmented coating (sodium silicate or polymer) to shingle surfaced with bare granules
  - Others?
- Wood
  - Use clear surface coating (e.g., varnish) to protect wood roofing from UV damage (discoloration, loss of NIR reflectance)

Ideas for increasing solar reflectance of clay and concrete tile roofing

- Clay tiles
  - Characterize absorption, scattering coefficients of pigmented glazes to identify hot, cool coatings
  - Investigate effects of firing environment (e.g., O_2 availability) on chemistry, NIR reflectance of uncoated red clay tile
- Concrete tiles
  - Evaluate cost effectiveness of replacing gray cement with white cement for through-the-body application of cool color pigments
  - Compare cost and durability of coating technologies (polymer, cementitious) for surface coloring tiles

2.5.1 Status

- Collaboration with manufacturers to intensify over next six months
- We will work with partners to
  - Develop workplans
  - Prepare samples
  - Characterize performance
  - Improve prototypes

2.5.2 Develop tool to measure solar reflectance for factory quality control

- Objective: Develop instrument to measure product solar reflectance for quality control in roofing factories
- Deliverables:
  - A prototype instrument and protocol for measuring solar reflectance of variegated products in the factory
- Schedule: 07/20/2006 – 07/20/2008
- Funds expended: 5%

Our design goals for quality-control tool to check solar reflectance in factory

- Artificial illumination (to use indoors)
- Sample area ~ 0.5 - 1 m^2 (size of shingle board)
- Fast (< 1 min)
- Inexpensive (< $5K)
- Reasonably accurate (±0.05?)

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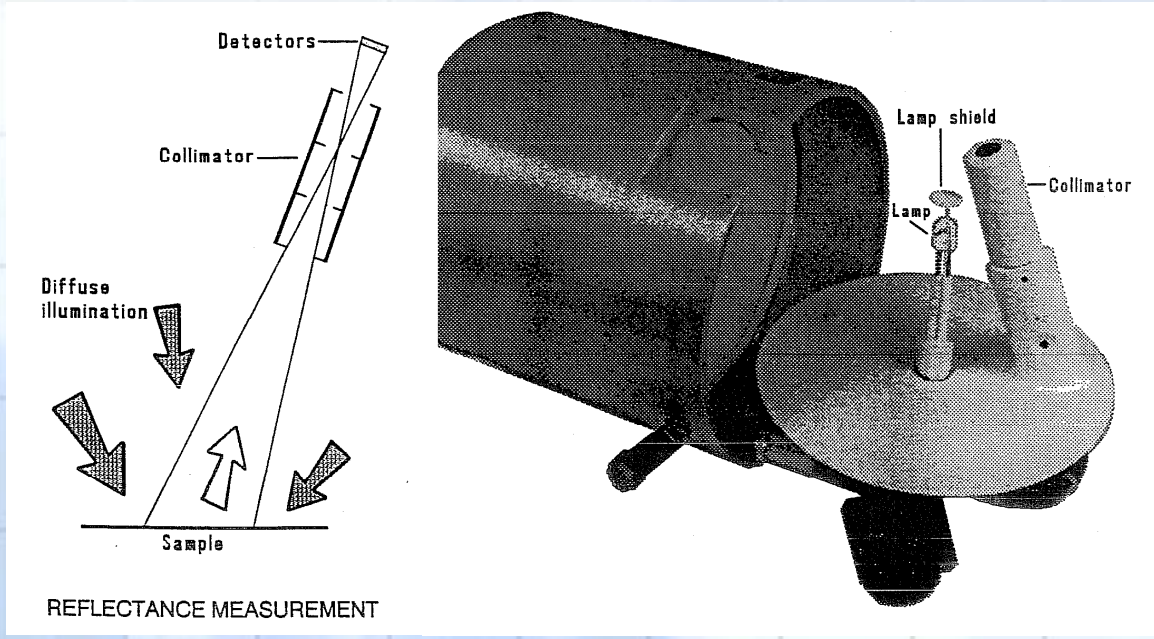
Reflectometer basics (Devices & Services Solar Spectrum Reflectometer)

- Sample illuminated w/lamp light diffusely reflected from white cavity
- Reflected irradiance measured by one or more filtered detectors
- Lamp, white cavity, filtered detectors simulate pyranometer measurement of reflected sunlight



2.5.2 Status

- LBNL designing new reflectometer optimized for large (0.5 – 1 m^2) samples
- Current design potentially an order of magnitude less expensive than Devices & Services reflectometer
- Plan to build & test prototype over next 6 months

Bonus Topic

Measuring solar reflectance of roofing materials
for CRRC certification via method E1918A
(formerly “E1918M”)

Techniques for measuring solar reflectance

- Official ASTM methods
  - ASTM E903 for flat, small samples (~ 1 cm^2)
  - ASTM C1549 for flat, small samples (~ 2 cm^2)
  - ASTM E1918 for low- or high-profile, large samples (~ 10 m^2)
- CRRC-approved variation on C1549
  - CRRC Test Method #1 for flat, medium-sized samples (~ 1 m^2)
- New proposed method
  - E1918A (formerly "E1918M") for low or high-profile, medium-sized samples (~ 1 m^2)

Measuring the solar reflectance of tile assemblies to validate E1918A


CRRC01 - Gladding McBean Terracotta


CRRC02 - Gladding McBean #8 Mix


CRRC03 - US Tile Terracotta


CRRC04 - US Tile El Camino


CRRC05 - MCA Adobe White


CRRC06 - MCA Adobe Black


CRRC07 - Westile Grey Hawk


CRRC08 - Westile Paloma


CRRC09 - MonierLifetile Desert Sage


CRRC10 - Hanson Integrated Color


CRRC11 - Hanson Slurry


CRRC12 - Westile Pacific


CRRC13 - Westile Grey Hawk Slurry


CRRC14 - MonierLifetile Rio Grande

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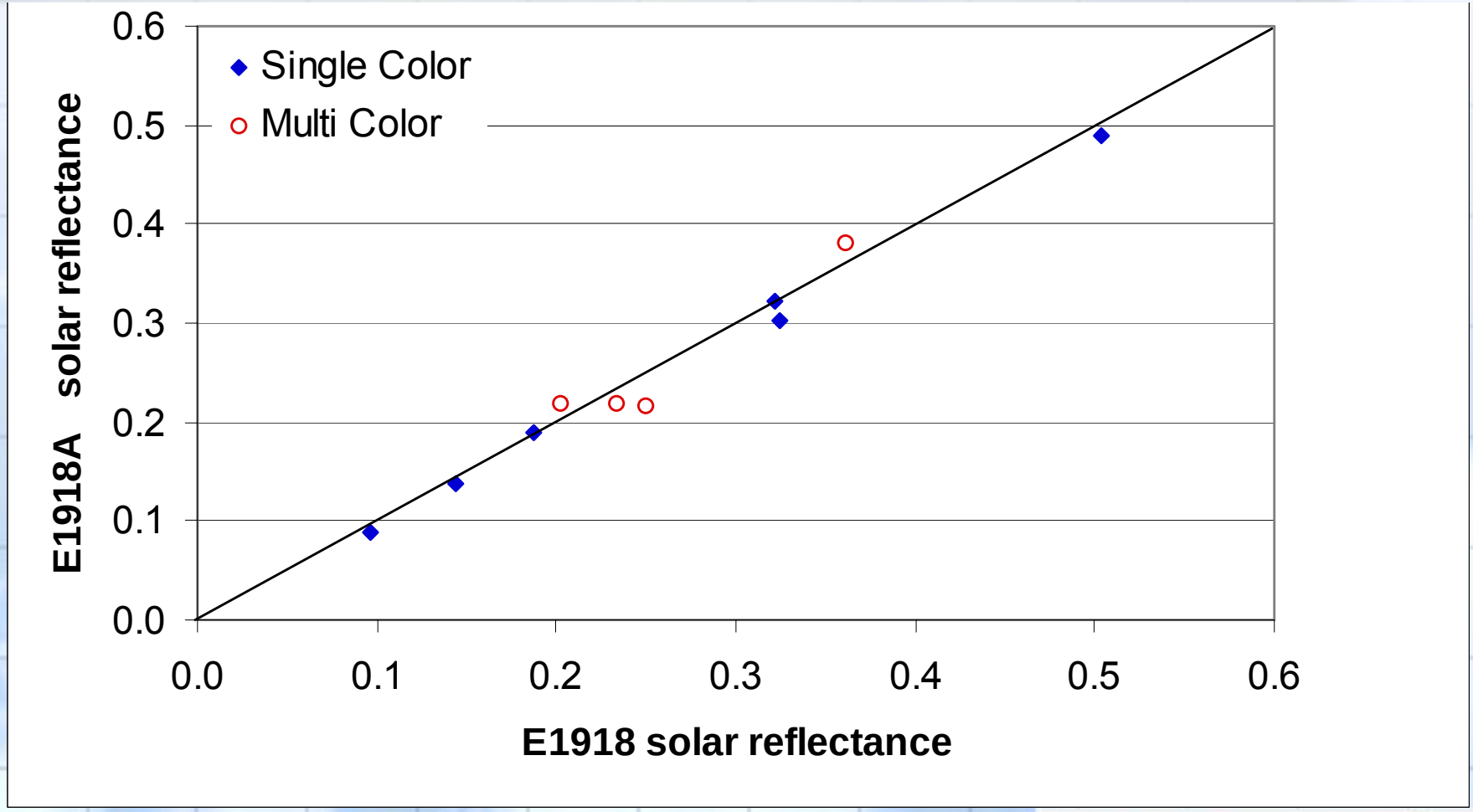
Solar reflectance of tile assemblies: E1918A (1 m^2) vs. E1918 (10 m^2)



2.5.3 Correlate the solar reflectance of a shingle to that of its constituent granules

- Objective: Relate the solar reflectance of a roofing shingle to that of its granules
- Deliverable:
  - A technique for correlating the reflectance of a cool-colored shingle to that of its surface granules
- Schedule: 07/20/2006 – 07/20/2008
- Funds expended: 30%

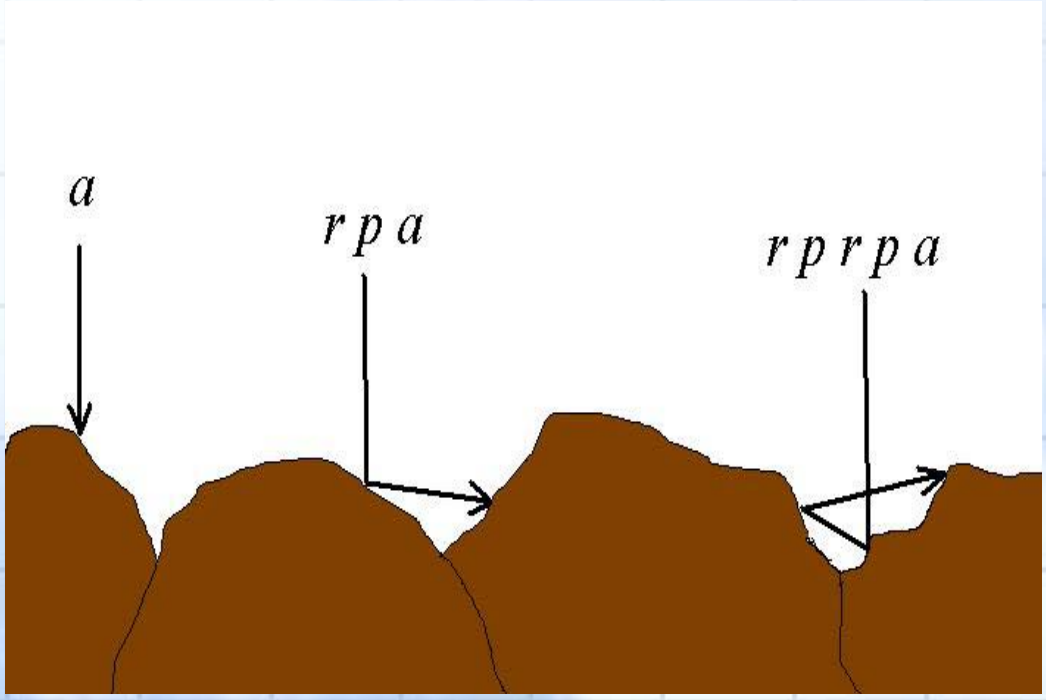
Effects of surface roughness on solar reflectance

- Method to connect “macro” shingle reflectance *R* to “micro” granule reflectance *r*
  - Corresponding absorptances are
    “macro” absorptance $A = 1 - R$
    “micro” absorptance $a = 1 - r$
- Techniques for using reflectances of monocolor shingles to compute reflectance of blends

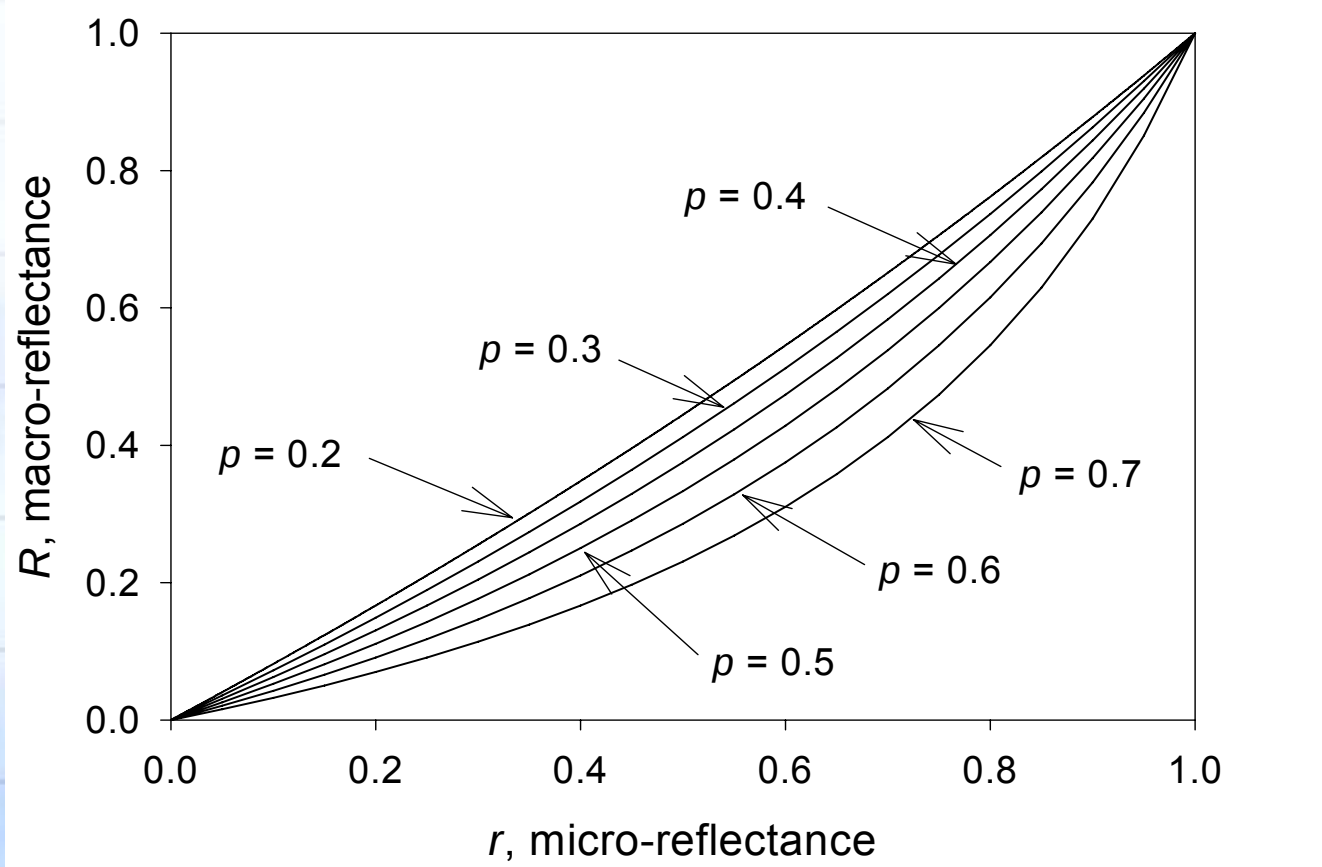
Mathematical connection between “macro” and “micro” parameters

- Let p be the probability that a scattered photon encounters the surface again
- $A = a + (p\,r)\,a + (p\,r)^2\,a + \ldots$
- $A = a\,/\,(1 - p\,r)$
- $R = r\,(1 - p)/(1 - p\,r)$
- We estimate p from the ratio of footprint area (F) to surface area (S)

  $p = 1 - F/S$



Macro-reflectance *R* as a function of micro-reflectance *r*



Asphalt shingle, $p \approx 0.5$
Curved roof tile, $p \approx 0.2$

Estimating reflectance of shingle surfaced with blended granules

- Simplest method: linearly combine *macro* reflectances
  - $R = \Sigma_i w_i R_i$
  - w_i is the fraction of granule type i
- Refined method: linearly combine *micro* reflectances
  - $r = \Sigma_i w_i r_i$
  - $R = r (1 - p)/(1 – p r)$
- Methods allow accurate estimates of blended shingle reflectance (error < 0.01)
  - need monocolor shingle reflectances R_i
  - need granule fraction w_i
- Refined method easy to implement, often unnecessary
  - evaluates limitations of linear method

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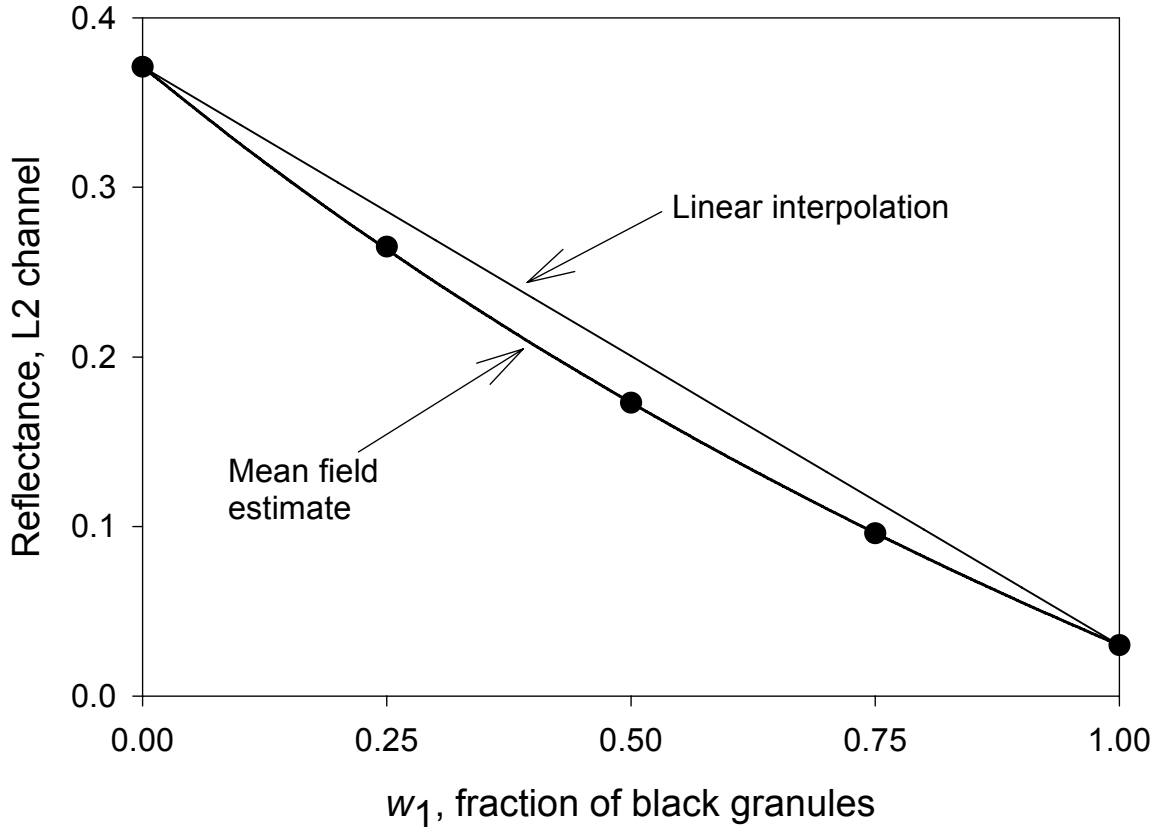
Reflectance of blends: measured and computed

Blend	Solar reflectance	Simplest method	Refined method
Weathered wood-Standard	0.106	0.105	0.102
Weathered wood-Cool	0.280	0.286	0.284
Black & White 50:50	0.144	0.160	0.145

- Excellent agreement for commercial-type blends
- Refined method better for “salt and pepper” blend

Mixtures of high and low reflectance granules permits measurement of small non-linearity

Curve fitting yields $p = 0.54$, close to the expected value



Asphalt shingle reflectance - future work and acknowledgement

- Publish current results
- Estimate reflectance changes due to granule loss
  - If 5% granule loss, how much reflectance loss?
- Examine how texture (granule orientation due to rolling process) affects reflectance
- Perform 3 year natural exposure testing
  - Interpret results in terms of weathering, granule loss, soiling

3M provided cost-sharing, in-kind support, guidance, technical advice, and samples for this work

2.5.4 Develop industry-consensus energy-savings calculator

- Objective: Develop a web-based calculator (and a PC-based version) with which consumers, contractors and distributors can estimate the cooling energy savings and peak demand reduction achieved by installing cool roofing on specific buildings
- Deliverables:
  - Industry-consensus energy calculator
- Schedule: 07/20/2006 – 07/20/2008
- Funds expended: 5%

Energy-savings calculator

- Methodology
  - Developed by LBNL and ORNL
  - Approved by CEC, EPA, and DOE
  - Will be presented to a national advisory committee
- New calculator will replace existing DOE and EPA calculators

Technical approach

- Use hourly building energy simulation models and building prototypes
- Use advanced algorithms to calculate heat transfer through the roof
  - Existing residential- and commercial-building roof algorithms
  - New algorithms developed in this program
  - Fully documented algorithms
- Integrate the adopted algorithms in hourly simulation models
- Use EnergyPlus or DOE2
- Use MICROPAS if source code is available AND we conclude MICROPAS is suitable
- Evaluate and modify available prototypes

Technical approach (continued)

- Perform parametric simulations of hourly heating- and cooling-energy use for all climate regions in California (and, with DOE funding, for all climate regions in the U.S.)
- Parameters:
  - roof thermal resistance
  - roof solar reflectance
  - roof thermal emittance
  - heating and cooling systems
  - heating and cooling fuels
- Tabulate annual heating energy use, annual cooling energy use, and peak electricity demand
- Regress annual energy consumption and peak demand to climate parameters
- Use regression results to develop the web-based model

Calculator inputs

- Building type
- Roof type
- Roof insulation
- Heating energy system
- Cooling energy system
- Duct systems (location)
- Days of operation per week
- Daily HVAC operation schedule
- Solar reflectance and thermal emittance of existing roof
- Solar reflectance and thermal emittance of proposed roof
- Cost of electricity (both kWh and peak demand charges)
- Cost of natural gas

Calculator outputs

- Annual cooling energy use and savings
- Annual heating energy use and penalties
- Peak electricity demand and savings
- Net annual cost savings (or penalties)

2.5.5 Conduct natural exposure testing in California

- Objective: Conduct natural exposure testing of currently tested roofing samples and new roofing materials
- Deliverables:
  - A technical report summarizing the results of the exposure testing
- Schedule: 07/20/2006 – 07/20/2009
- Funds expended: 2%

Least area needed for accurate measurement of solar reflectance

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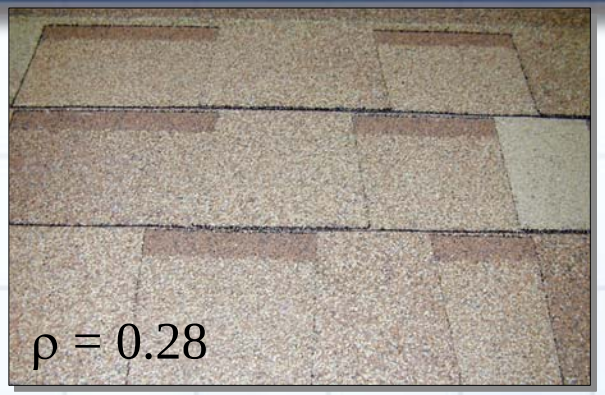
Cool-color asphalt shingles under exposure at weathering sites

A. Cool Color Shingle



B. Cool Color Shingle

C. Cool Color Shingle

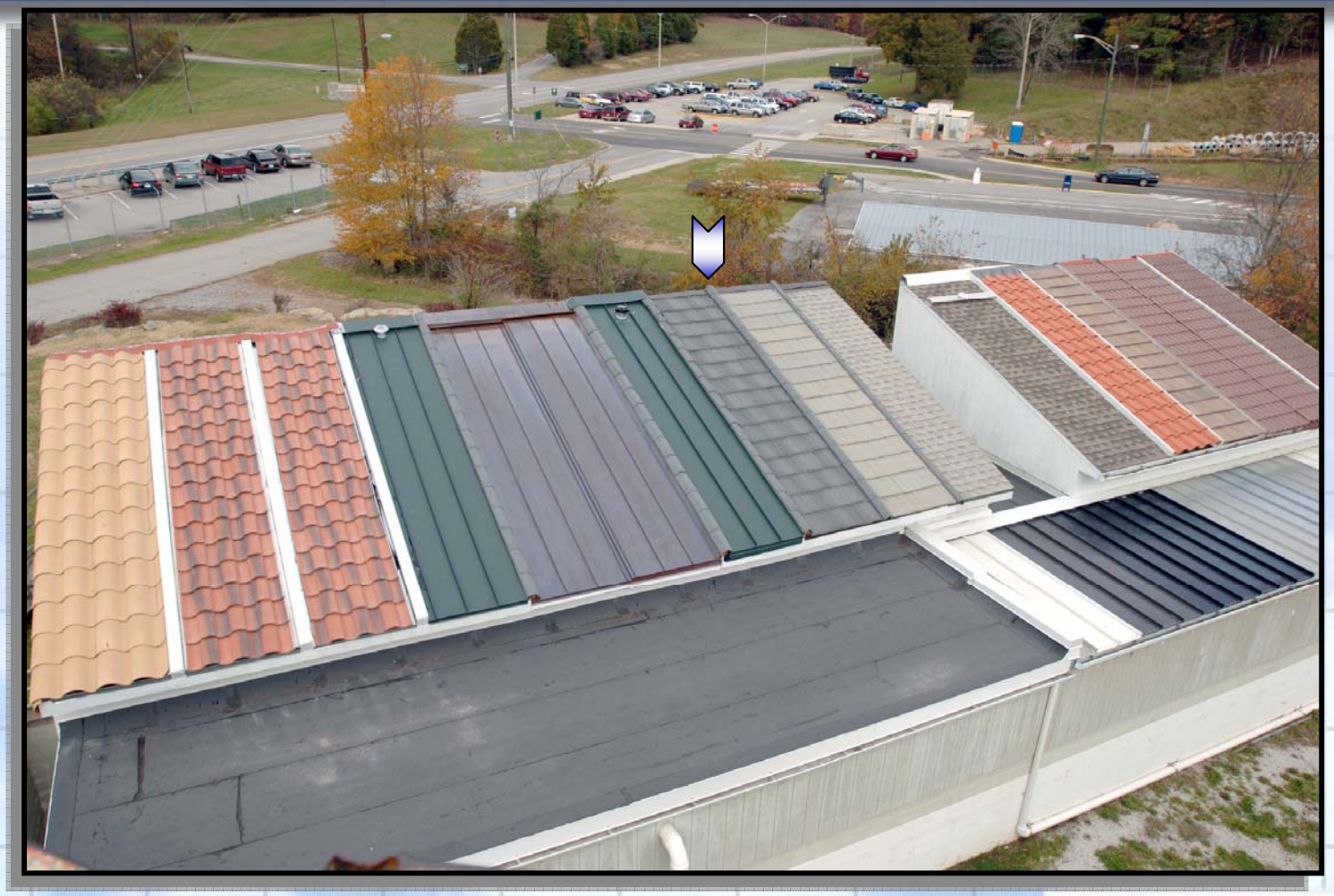
D. Conventionally Pigmented Shingle

E. Cool Color Shingle

2.5.6 Conduct field exposure testing at ORNL

- Objective: Conduct field exposure testing of new cool roofing materials at ORNL
- Deliverables:
  - Use data to validate industry-consensus energy savings calculator
  - A technical report summarizing the results of field exposure testing at ORNL
- Schedule: 07/20/2006 – 07/20/2009
- Funds expended: 12%

ESRA has standing-seam metal, stone-coated metal, clay tile and concrete tile roofs



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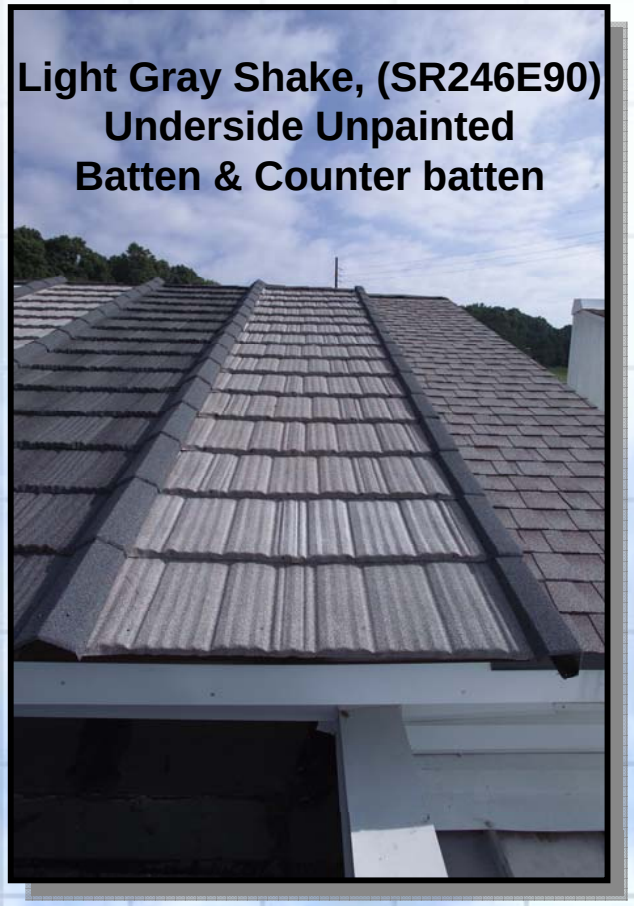
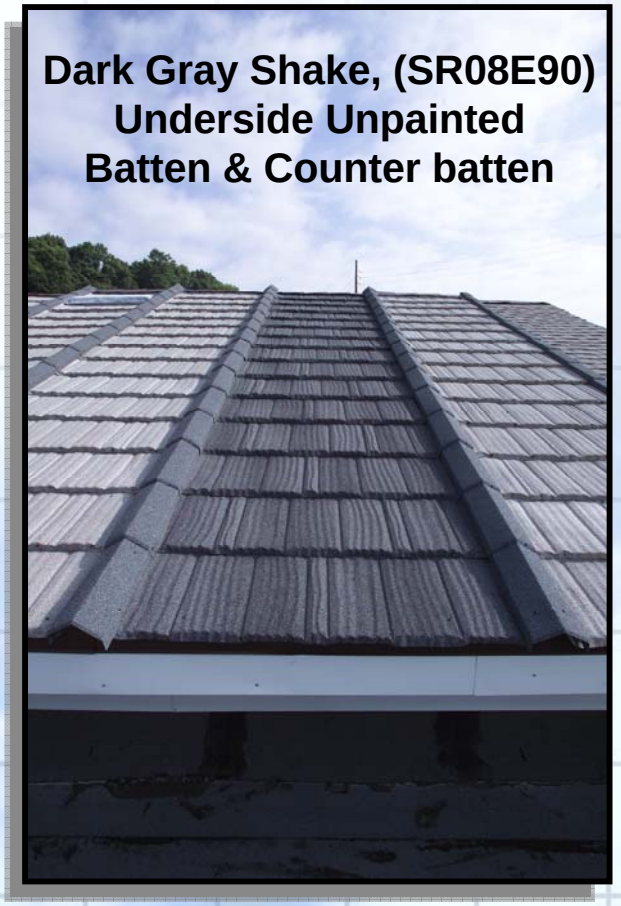
Medium-profile concrete tile with and without cool color pigments

Same setup used at Fair Oaks Demonstration

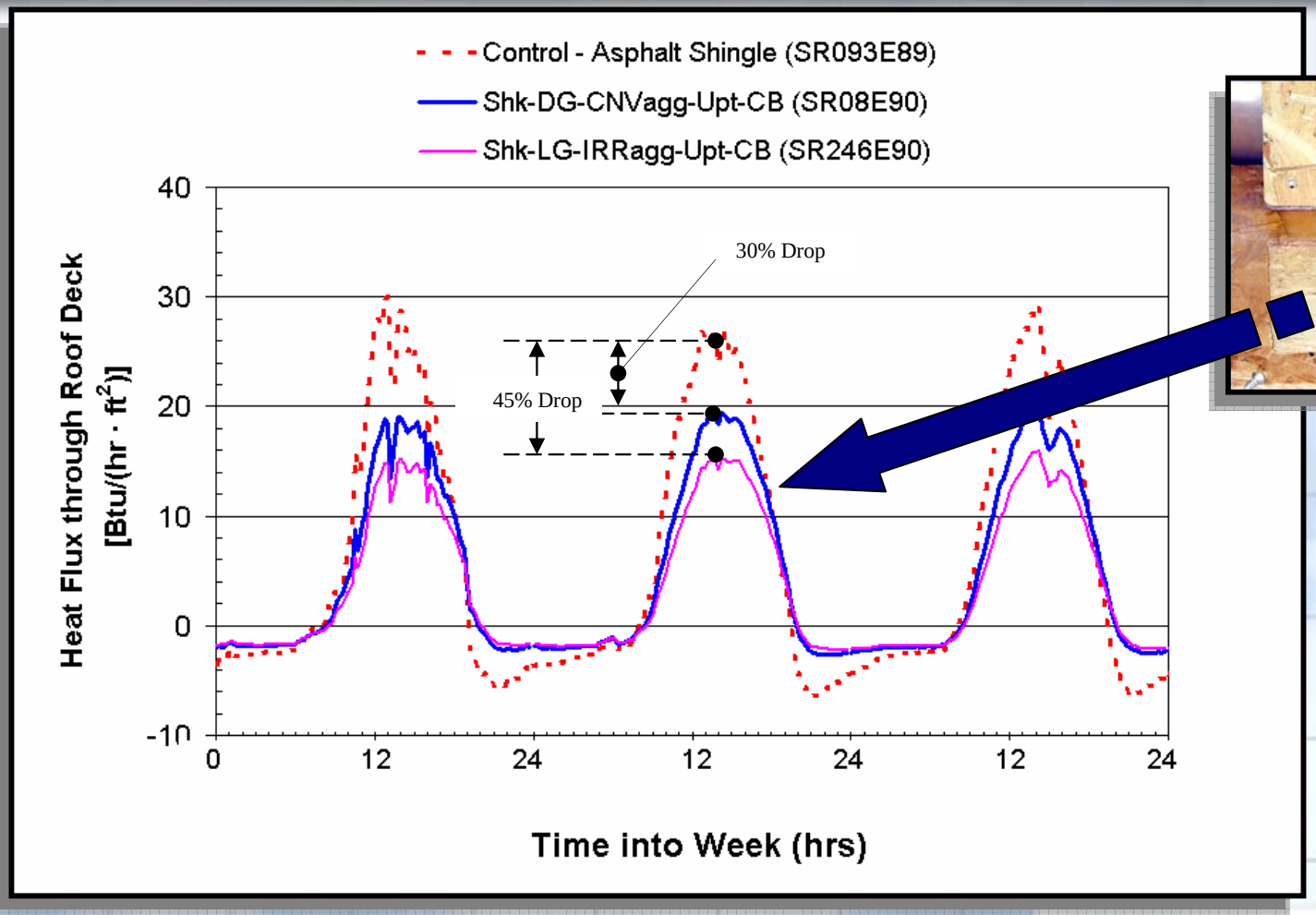
Solar reflectance and above-sheathing ventilation (ASV) effects

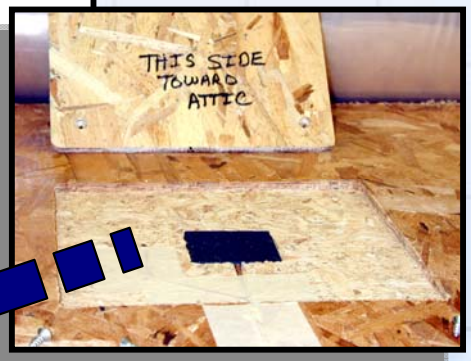




Batten and counter batten roof construction

ASV reduced heat flow crossing deck by 30% of asphalt shingle



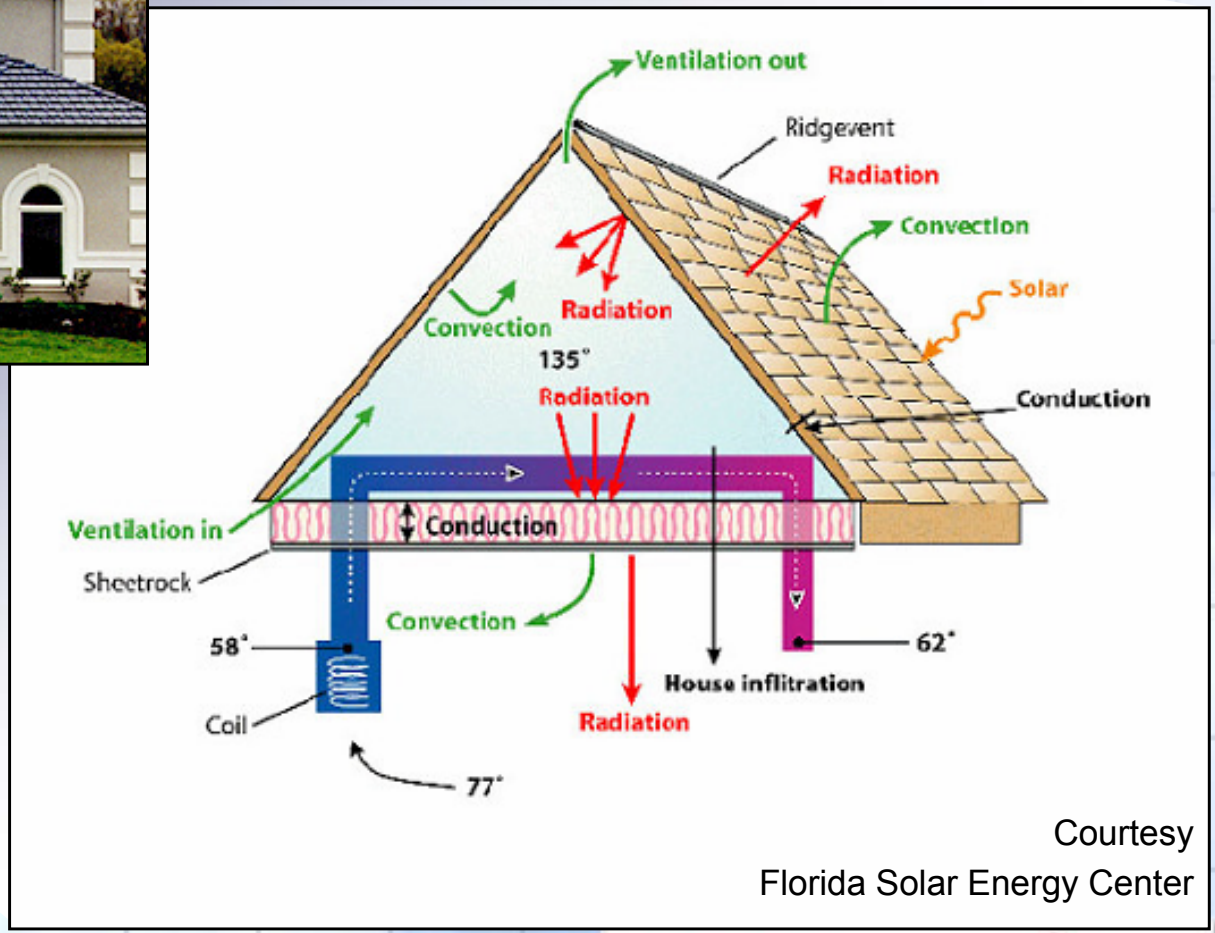


August 2005

AtticSIM *(Attic Simulation)* model

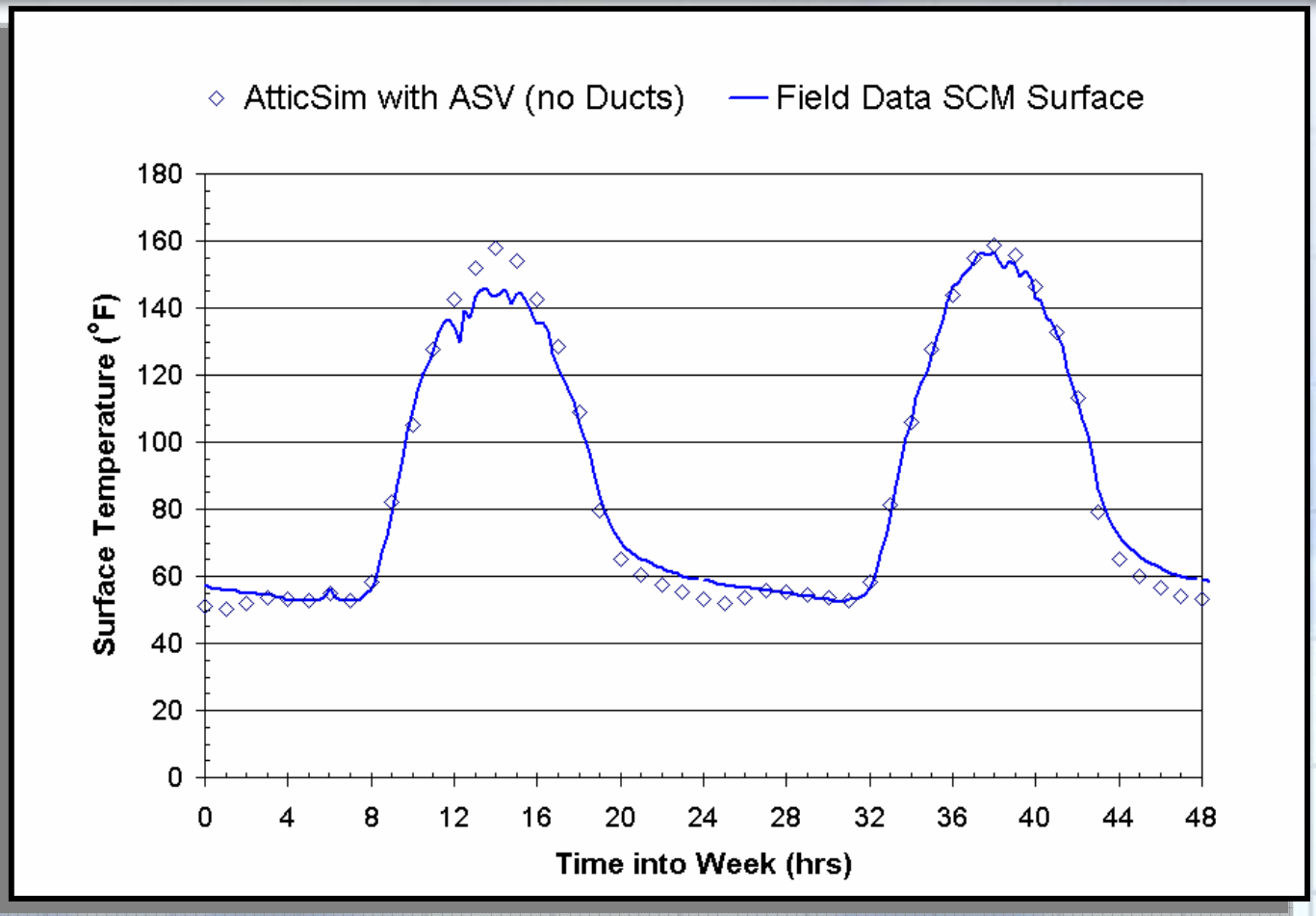
ASTM C 1340-99 Standard For Estimating Heat Transfer through Ceilings Under Attics

Roof Energy Balance

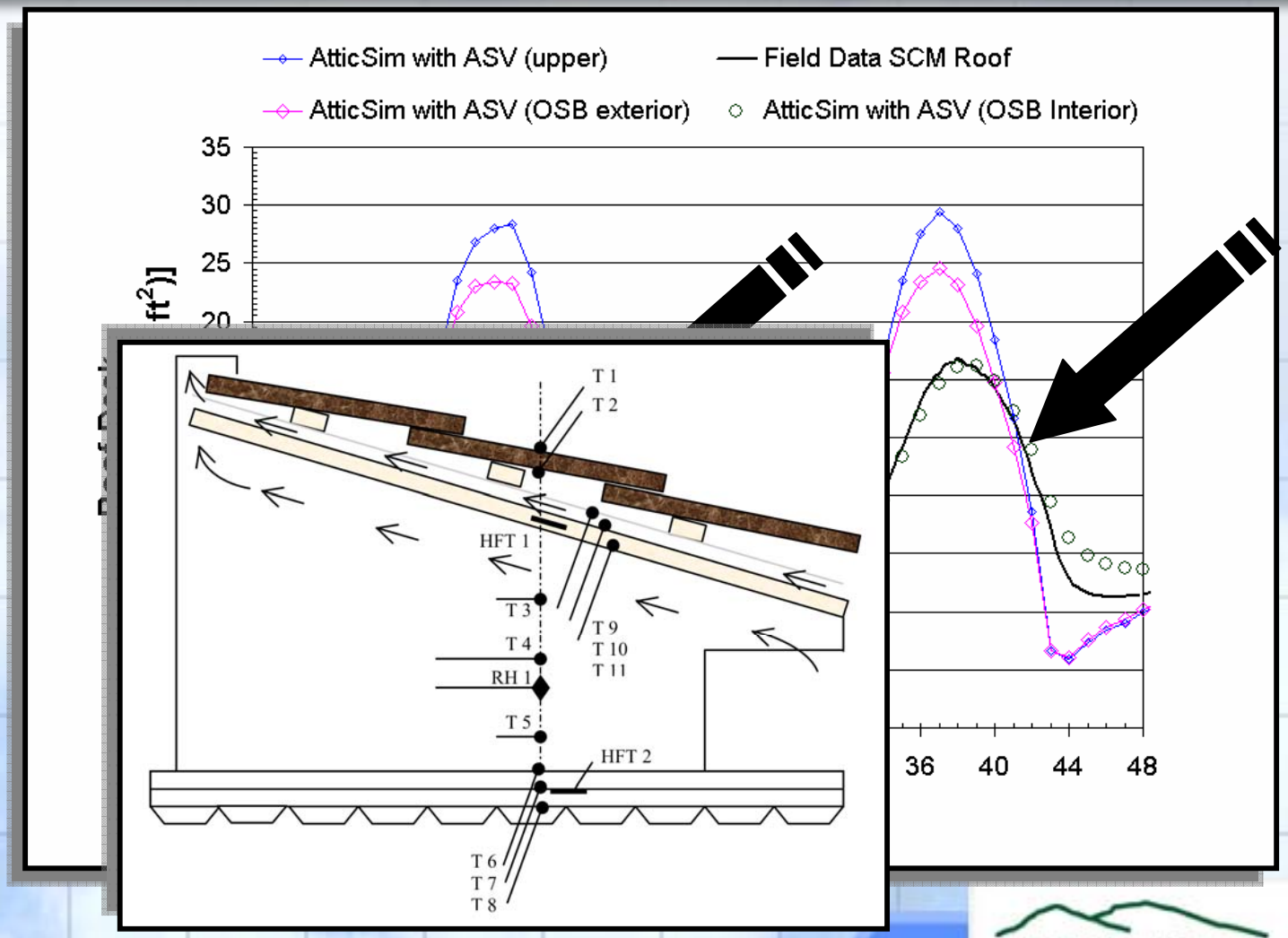


Courtesy
Florida Solar Energy Center

AtticSim prediction of SR25E90 roof surface temperature

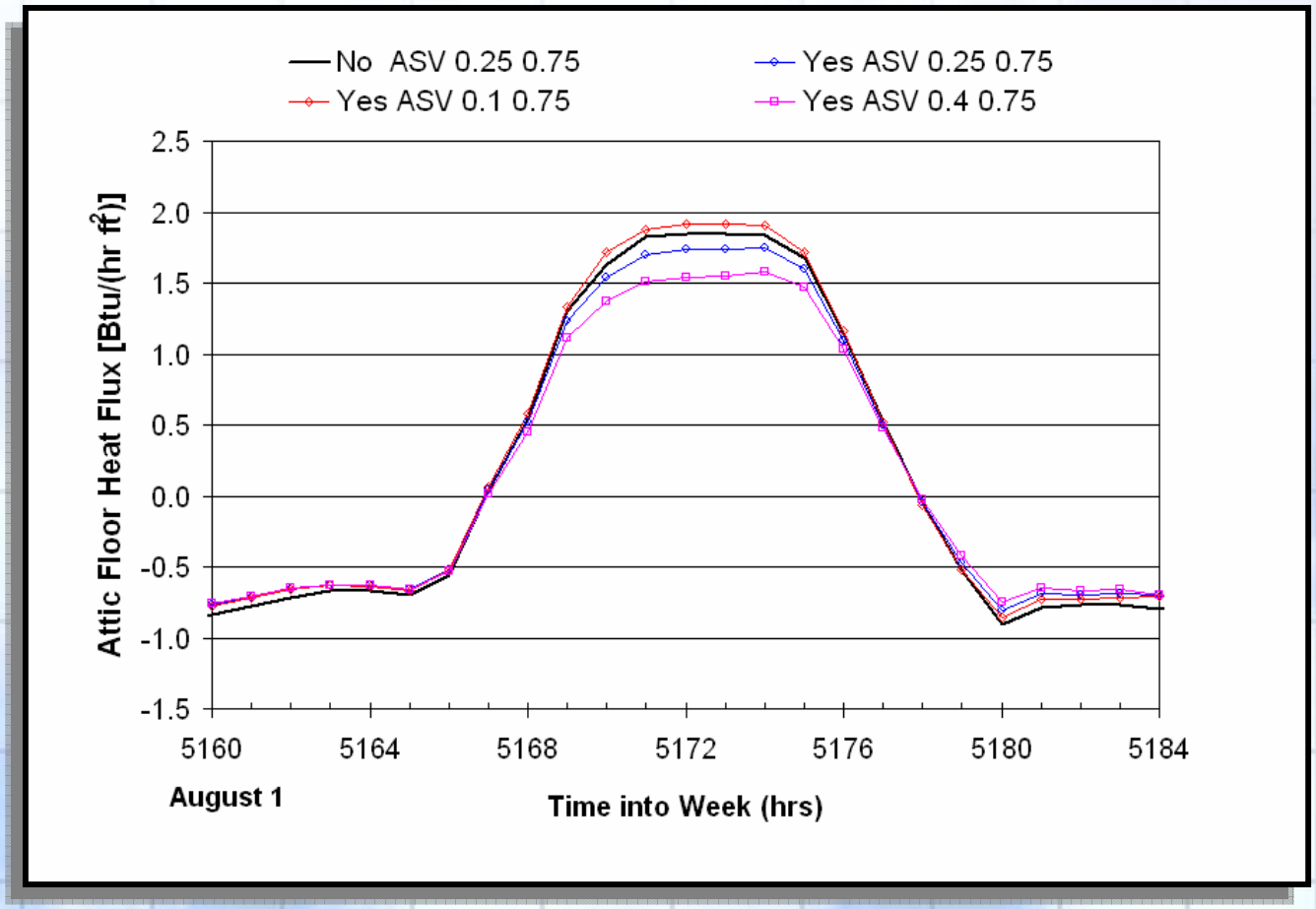


AtticSim predicts above-sheathing ventilation (ASV)



Above-sheathing ventilation (ASV) nearly equivalent to 15 points of SR

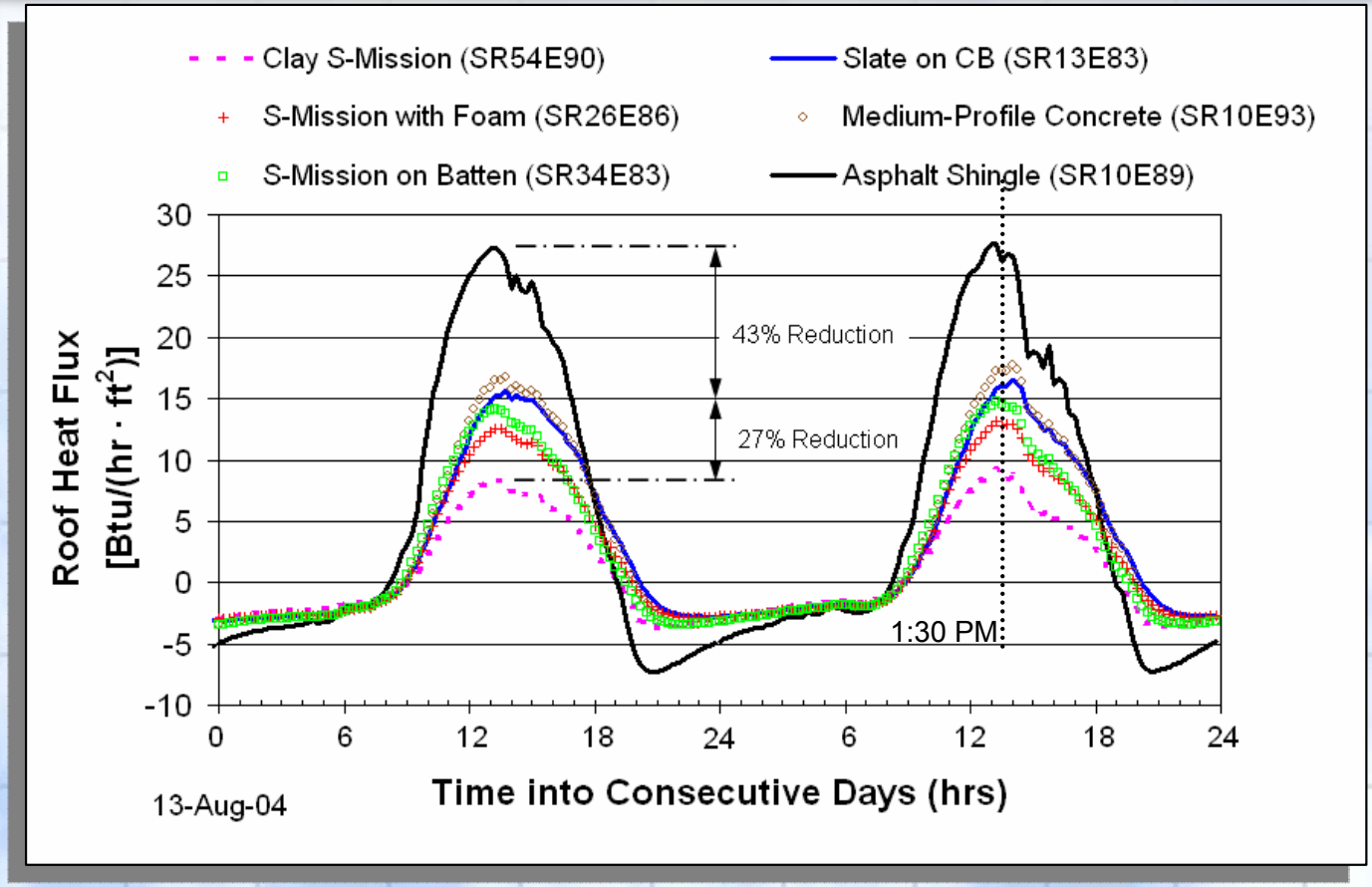
Zone 12: Attic Contains R-38 Insulation and AC Ducts with R-6 Insulation



Underside Emittance = 0.90

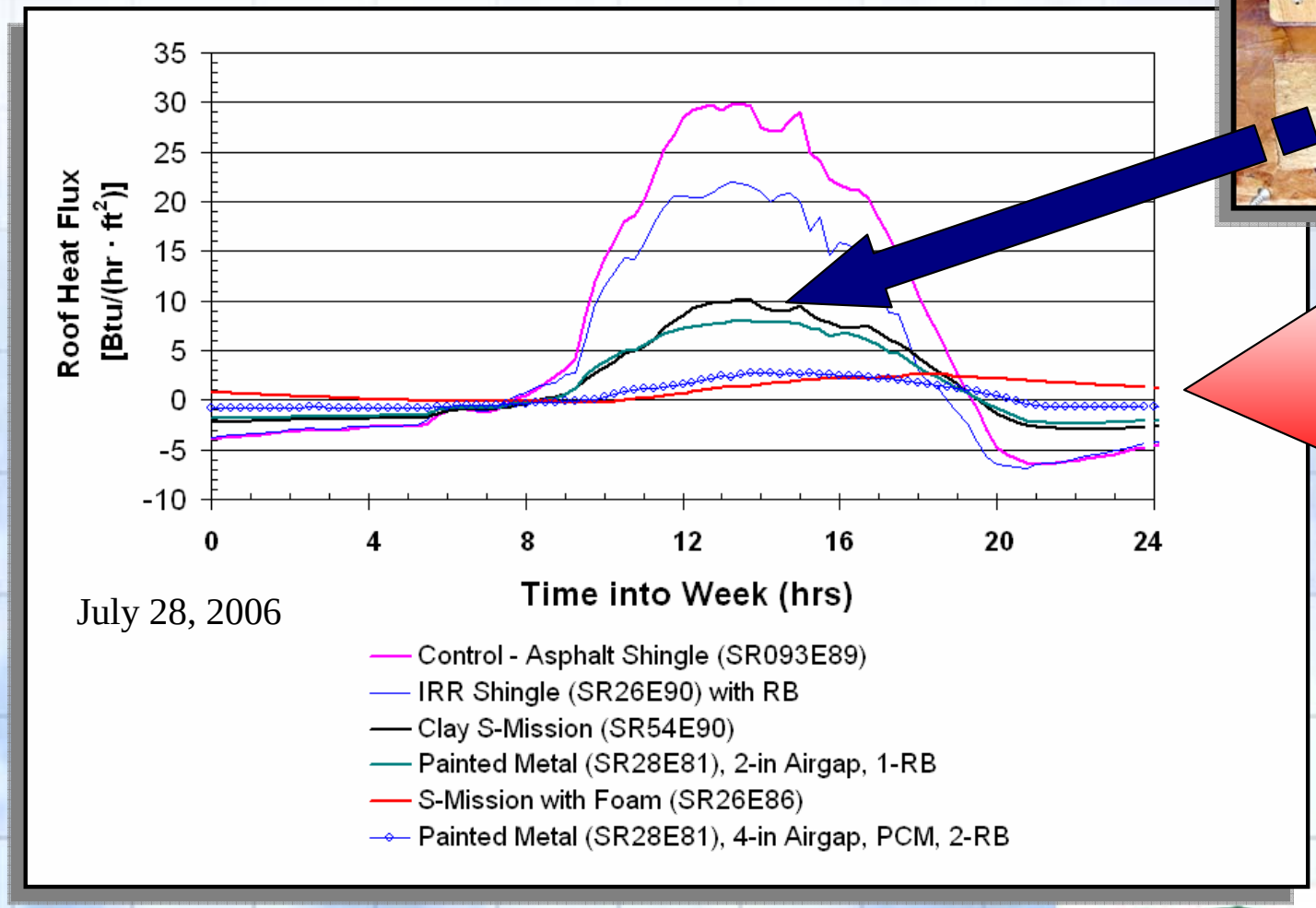
Metal, clay and concrete tile and shingle roofs — summer comparisons

S-Mission tiles have lowest heat transfer penetrating the roof deck



Cool colors, above-sheathing ventilation, radiant barrier, phase change materials, above deck insulation

ECOSET SYSTEM



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2.5.7 Carry out field experiments in S. CA to validate the energy savings calculator

- Objective: Carry out field experiments to evaluate new cool-colored roofing materials in Southern California for validation of the industry-consensus energy savings calculator
- Deliverables:
  - Comparison of validated steep-slope roof calculator to demonstration data
  - A technical report summarizing the results of the field experiments and comparison of the energy-savings calculator
- Schedule: 07/20/2006 – 07/20/2009
- Funds expended: 0%

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Southern CA field experiments at Fort Irwin, CA

Located in the High Mojave Desert

Excellent Demonstration Opportunity

Army must provide safe, secure, reliable, environmentally compliant, and cost-effective energy and water services to soldiers and their families, civilians and contractors on Army installations.

Clark Pinnacle is building some 200+ private dwellings

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2.6 Technology transfer activities

- Objective: Make the knowledge gained, experimental results and lessons learned available to key decision-makers
- Deliverables:
  - Publish results in trade magazines and academic journals
  - Participate in building-product exhibitions
  - Develop a brochure summarizing the research results and characterizing the benefits of cool colored roofing materials
- Schedule: 07/20/2006 – 07/20/2008
- Funds expended: 10%

Technology transfer

- Published 5 papers in journals, conference proceedings, magazines (see handouts)
  - *Construction & Building Materials*
  - *Solar Energy Materials & Solar Cells*
  - *Interface*
  - *15th Symposium Improving Buildings Systems in Hot & Humid* Climates
- HGTV interviewed Miller about cool roofs field tested on ESRA (broadcast in March)
- KQED-FM radio program *Quest* interviewed Akbari about heat islands and cool roofs on 16 Feb 2007
  - http://www.kqed.org/quest/radio/view/82
- Akbari presented cool roofs at Green Technologies Demonstration for Governor's inauguration on 4 Jan 2007 (photo at right)

Schedule of PAC meetings

	Date	Location
PAC-1	Sep. 7, 2006	CEC
PAC-2	**Mar. 15, 2007**	**LBNL**
PAC-3	Sep. 6, 2007	Southern CA
PAC-4	Mar. 6, 2008	ORNL
PAC-5	Sep. 4, 2008	?
PAC-6	Mar. 5, 2009	?

Cool colors project website

- Project information (including copies of this presentation) available online at

  http://CoolColors.LBL.gov