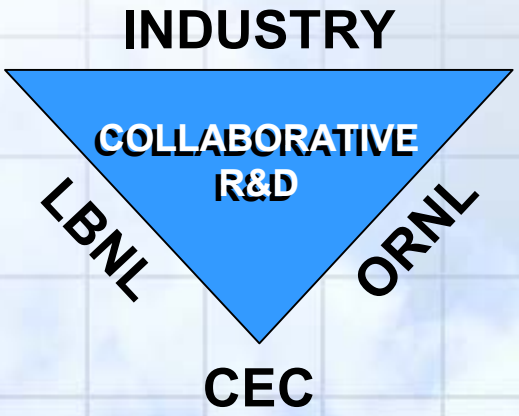
Development of Cool Colored Roofing Materials

Project Advisory Committee (PAC) Meeting



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

March 3, 2005; Custom-Bilt Metals, Chino, CA

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Project Goals

- Bring cool colored roofing materials to market
- Measure and document laboratory and *in-situ* performances of roofing products
- Accelerate market penetration of cool metal, tile, wood shake, and shingle products
- Measure and document improvements in the durability of roofing expected to arise from lower operating temperatures

Project Advisory Committee (PAC) Members

1. Asphalt Roofing Manufacturers Association
2. Bay Area Air Quality Management District
3. Cedar Shake and Shingle Bureau
4. Cool Metal Roofing Coalition
5. Cool Roof Rating Council
6. DuPont Titanium Technologies
7. Environmental Protection Agency (EPA)
8. EPA San Francisco Office
9. National Roofing Contractors Association
10. Pacific Gas and Electric Company (PG&E)
11. Tile Roofing Institute
12. Southern California Edison Company (SCE)

Industrial Partners (Welcome new partners)

- 3M
- Akzo Nobel
- American Roof Tile Coating
- BASF
- CertainTeed
- Custom-Bilt Metals
- Elk Corporation
- Ferro
- GAF
- Hanson Roof Tile
- ISP Minerals
- MCA
- Monier Lifetile
- Owens Corning
- Steelscape
- Shepherd Color

Project Team

- **LBNL**
  - Steve Wiel (Project Director) SWiel@LBL.gov
  - Hashem Akbari (Technical Lead) H_Akbari@LBL.gov
  - Paul Berdahl PHBerdahl@LBL.gov
  - Ronnen Levinson RMLevinson@LBL.gov
- **ORNL**
  - André Desjarlais (Technical Lead) yt7@ORNL.gov
  - Bill Miller wml@ornl.gov

Technical Tasks

- 2.4 Development of cool colored coatings
- 2.5 Development of prototype cool-colored roofing materials
- 2.6 Field-testing and product useful life testing
- 2.7 Technology transfer and market plan

2.4 Development of Cool Colored Coatings

- Objectives
  - Maximize solar reflectance of a color-matched pigmented coating
  - Compare performance of a coated roofing product (e.g., a shingle) to that of a simple smooth coating
- Subtasks
  - Identify & characterize pigments with high solar reflectance
  - Develop software for optimal design of cool coatings
  - Develop database of cool-colored pigments

2.4.1 Identify & Characterize Pigments w/High Solar Reflectance

- Objective: Identify and characterize pigments with high solar reflectance that can be used to develop cool-colored roofing materials
- Deliverables:
  - Pigment Characterization Data Report (**2 journal papers in press**)
- Schedule: 6/1/02 – 12/1/04 → 12/31/04
- Funds Expended 100%

Completed Study of Masstones (Pure Color Paints)

- Two articles (model, pigment survey) in press at *Solar Energy Materials & Solar Cells*
- Journal reviewer comments:
  - "Great work with extensive detail; I have not seen such detail on pigments since work in the 1960s by the arerospace companies. It is nice to see such a seminal work in one location and with one set of testing methodologies. Please publish."
  - "Very nice work, uniform and detailed—the beginnings of a handbook. Very valuable to my industry (paint formulation). If Elsevier puts together a Materials Property Handbook, the results of this work should be in it."

2.4.2 Develop a Computer Program For Optimal Design of Cool Coating

- Objective: Develop software for optimal design of cool coatings used in colored roofing materials
- Deliverables:
  - Computer Program
- Schedule: 11/1/03 – 12/1/04 ➠ 5/1/05
- Funds Expended 90%

Overview of Coating Formulation Software

- Tool to produce recipes for cool (solar reflective) coatings matching target color
- Components
  - pigment-mixture reflectance model
  - optimization algorithm
  - solar spectral optical properties of many pigments (LBNL Pigment Database)

Status of Coating Formulation Software

- Under development
  - pigment database complete
  - software & model being improved
  - alpha version to be released to partners in March 2005

2.4.3 Develop Database of Cool-Colored Pigments

- Objective
  - Develop a database that can be readily used by the industry to obtain characteristic pigment information for the design of cool-colored coatings
- Deliverables
  - Electronic-format Pigment Database
- Schedule: 6/1/03 – 6/1/05 ➠12/31/04
- Funds Expended 100%

Database Now Online

- User-friendly database online at **http://CoolColors.LBL.gov/LBNL-Pigment-Database/database.html**
  - images and charts available to public
  - spectral datafiles encrypted
  - datafile password available from Ronnen

LBNL Pigment Database: Contents

- Describes 87 pigments
  - masstones (pure colors)
  - tints (mixtures with white)
  - nonwhite mixtures
- Pigment details
  - name, chemistry, particle size, concentration, solar spectral properties, photographs, LBNL commentary
- Browsable web pages
  - images, charts, tables, text
- Machine-readable datafiles
  - matrices of spectral data

[R03] Red Iron Oxide (iii)

Paint Code	**R03**
Paint Name	Red Iron Oxide (iii)
Pigment Name	Ferro Red V-13810 (PR 101)
Color Family	Red/Orange
Color Subfamily	iron oxide red
Mean Particle Size (microns)	0.27
Dry Film PVC	3%
Pigment Datasheet	available
Paint Datasheet	unavailable
LBNL Commentary	available

Masstone and Mixtures with White (Tints)

[R03] Red Iron Oxide (iii) +
[W03] Titanium White (i)

image over white				
image over black				
spectral datafile	R03 masstone	R03 tint 1:4	R03 tint 1:9	W03 masstone

guide to reading spectral datafiles

Mixtures with Nonwhite Colors

[R03] Red Iron Oxide (iii) +
[B16] Iron Titanium Brown Spinel (i)

image over white			
image over black			
spectral datafile	R03 masstone	R03+B16 mixture 1:1	B16 masstone

guide to reading spectral datafiles

LBNL Pigment Database: Applications

- Identifying hot, cool pigments
  - Avoiding hot pigments as important as including cool pigments
  - User-friendly database easy to browse
- Formulating cool nonwhite coatings
  - Database includes tables of solar spectral radiative properties usable in LBNL and proprietary coating formulation tools

2.5 Develop Prototype Cool-Colored Roofing Materials

- Objective: Work with manufacturers to design innovative methods for application of cool coatings on roofing materials
- Subtasks:
  - Review of roofing materials manufacturing methods
  - Design innovative engineering methods for application of cool coatings to roofing materials
  - Accelerated weathering testing

2.5.1 Review Roofing Materials Manufacturing Methods

- Objective: Compile information on roofing materials manufacturing methods
- Deliverables:
  - Methods of Fabrication and Coloring Report (prepared on July 1, 2003)
- Schedule: 6/1/02 – 6/1/03
- Funds Expended 100%

Updated and Finalized the Roofing Manufacturing Report

- Technical report in press
  - Akbari H., R. Levinson, and P. Berdahl. 2004. A review of methods for the manufacture of residential roofing materials. Berkeley, CA; Lawrence Berkeley National Laboratory Report LBNL-55574.
- Report to be serialized in *Western Roofing Insulation & Siding* (spring 2005)

2.5.2 Design Innovative Engineering Methods for Application of Cool Coatings To Roofing Materials

- Objective: Work with manufacturers to design innovative methods for application of cool coatings on roofing materials
- Deliverables:
  - Summary Coating Report
  - Prototype Performance Report
- Schedule: 6/1/02 – 12/1/04 ➠ 5/1/05
- Funds Expended 95%

Engineering Methods: Partners' Presentations

- 3M
- Elk Corporation
- ISP Minerals
- Ferro
- Shepherd Color
- Steelscape/BASF/Custom-Bilt
- American Rooftile Coatings

2.5.3 Accelerated Weathering

- Objective: Identify latent material defects early by accelerated weathering
- Deliverables:
  - Accelerated Weathering Testing Report
- Schedule: 11/1/02 – 6/1/05 ➠ 10/1/05
- Funds Expended 40%

Two Review Articles in Preparation

- Accelerated testing of roofing materials (Task 2.5.3)
- Weathering of roofing materials (Task 2.6.4)
- Tutorial information
- Providing a bibliography to our industry partners so they can help us fill the gaps

Outline: Accelerated Testing of Roofing Materials

- Useful provided weathering is "understood"
- Equipment used: UV, moisture, cyclic heating
- Summary of literature
  - Polymer coatings on various substrates
  - Inorganic and organic pigments
  - Asphalt-based materials
  - Tiles
  - Wood shakes
- Case studies (Ferro/BASF data and others)

Outline: Weathering of Roofing Materials

- Environmental stresses include UV, heat, moisture, wind, hail, freeze-thaw, SO_2, NO_2, biological growth, …
- Photooxidation of polymers, asphalt, organic pigments
- Some corrosion chemistry (metal, cement, asphalt,...), efflorescence
- Mechanical stresses – wind, differential thermal expansion – need for structural flexibility

2.6 Field-testing and Product Useful Life Analysis

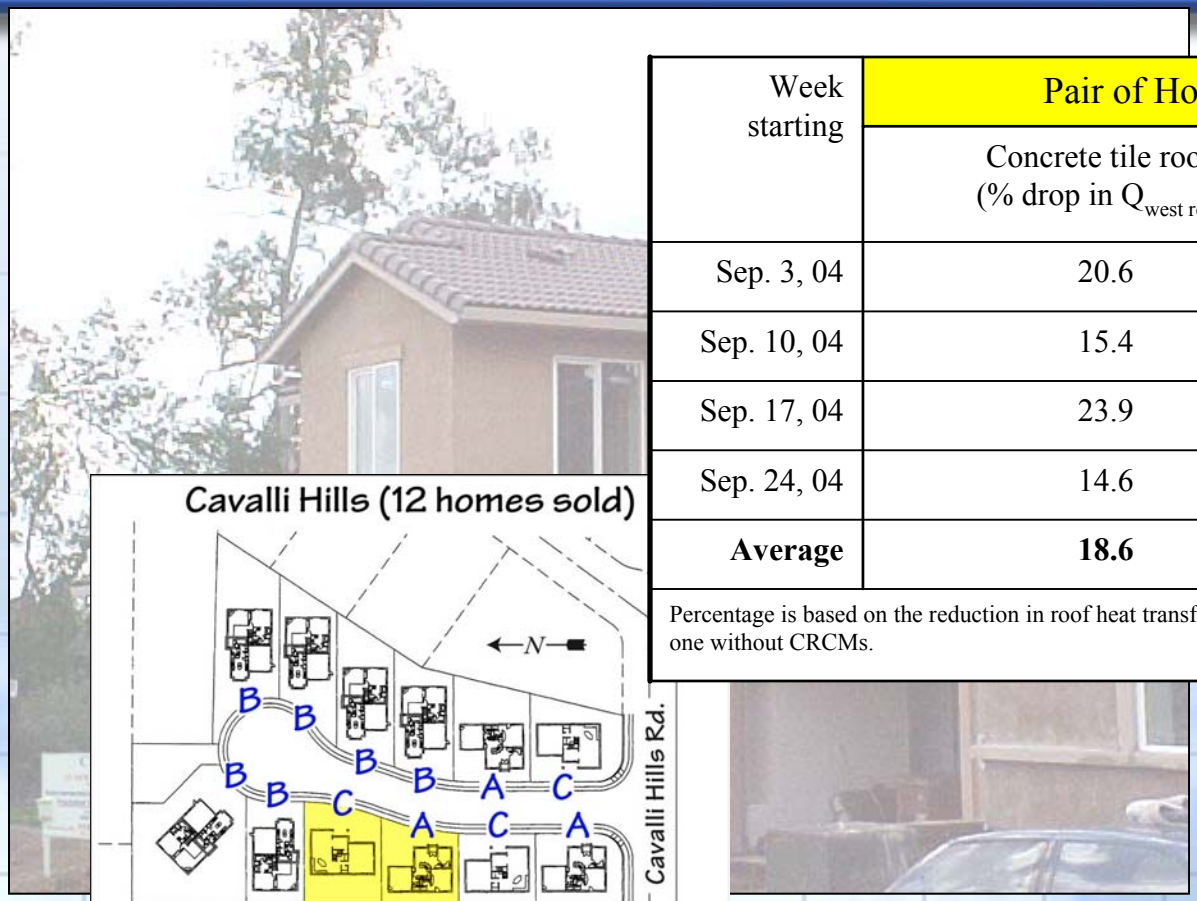
- **Objective:** Demonstrate, measure and document the building energy savings, improved durability and sustainability of Cool Roof Color Materials (CRCMs)

- Subtasks:
  - Building energy-use measurements at California demonstration sites
  - Materials testing at weathering sites in California
  - Steep-slope assembly testing at ORNL
  - Product useful life testing

2.6.1 Building Energy-Use Measures at California Demonstration Sites

- **Objective:** Setup residential demonstration sites; measure and document the energy savings of CRCMs
- Deliverables:
  - √ Site Selection: Cavalli Hills, Fair Oaks,CA
    Redding, CA
    Martinez, CA
  - √ Site Test Plan
  - – Test Site Report
- Schedule: 10/1/02 – 10/1/05 ➠ 10/1/06
- Funds Expended 85 %

Cavalli Hills Demonstrations Continue to Show Positive Benefits of CRCMs



Week starting	Pair of Homes with and without CRCMs	
	Concrete tile roofs (% drop in $Q_{west\ roof}$)	Painted Metal Roofs (% drop in $Q_{south\ roof}$)
Sep. 3, 04	20.6	35.5
Sep. 10, 04	15.4	35.9
Sep. 17, 04	23.9	38.0
Sep. 24, 04	14.6	34.4
Average	**18.6**	**36.0**

Percentage is based on the reduction in roof heat transfer during the sunlit hours for a roof with CRCM as compared to one without CRCMs.

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Demonstration Homes Provided by Elk Corp and Ochoa & Shehan Custom Homes

2605 Eel Street, Redding CA

2605 Loggerhead St., Redding CA

East TN Field Data Comparing Shingle (SR 0.26) to Shingle (SR 0.09)

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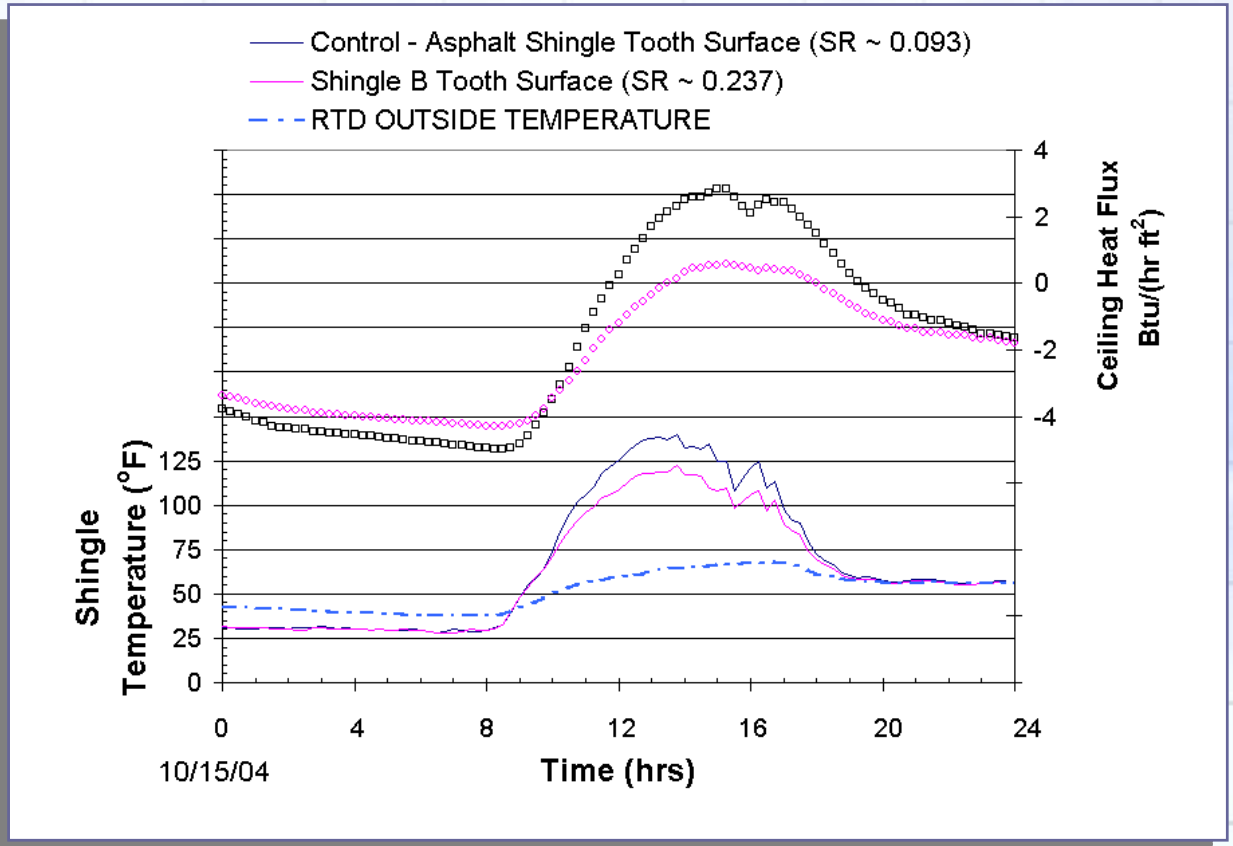
CRCM Shingle Drops Surface Temperature ~11°C (20°F) and Reduced Heat Flux by ~75%



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2.6.1 Next Steps

- **Establish Demonstration Sites**

  One Pair of Composition shingles **Redding, CA**

  - DAS on line April, 2005

  Second Pair of Composition shingles **Martinez, CA**

- **Report on Demonstration Sites 10/01/06**

2.6.2 Materials Testing at Weathering Sites in California

- **Objective:** Document the change in reflectance and emittance for roof products having Cool Roof Color Materials

- Deliverables:
  - Weathering Studies Report
- Schedule: 10/1/02 – 10/1/05 ➠ 10/1/06
- Funds Expended 70 %

Concrete and Clay tile and Painted Metals under exposure

Clay and Painted Metal exposed for 1½ years

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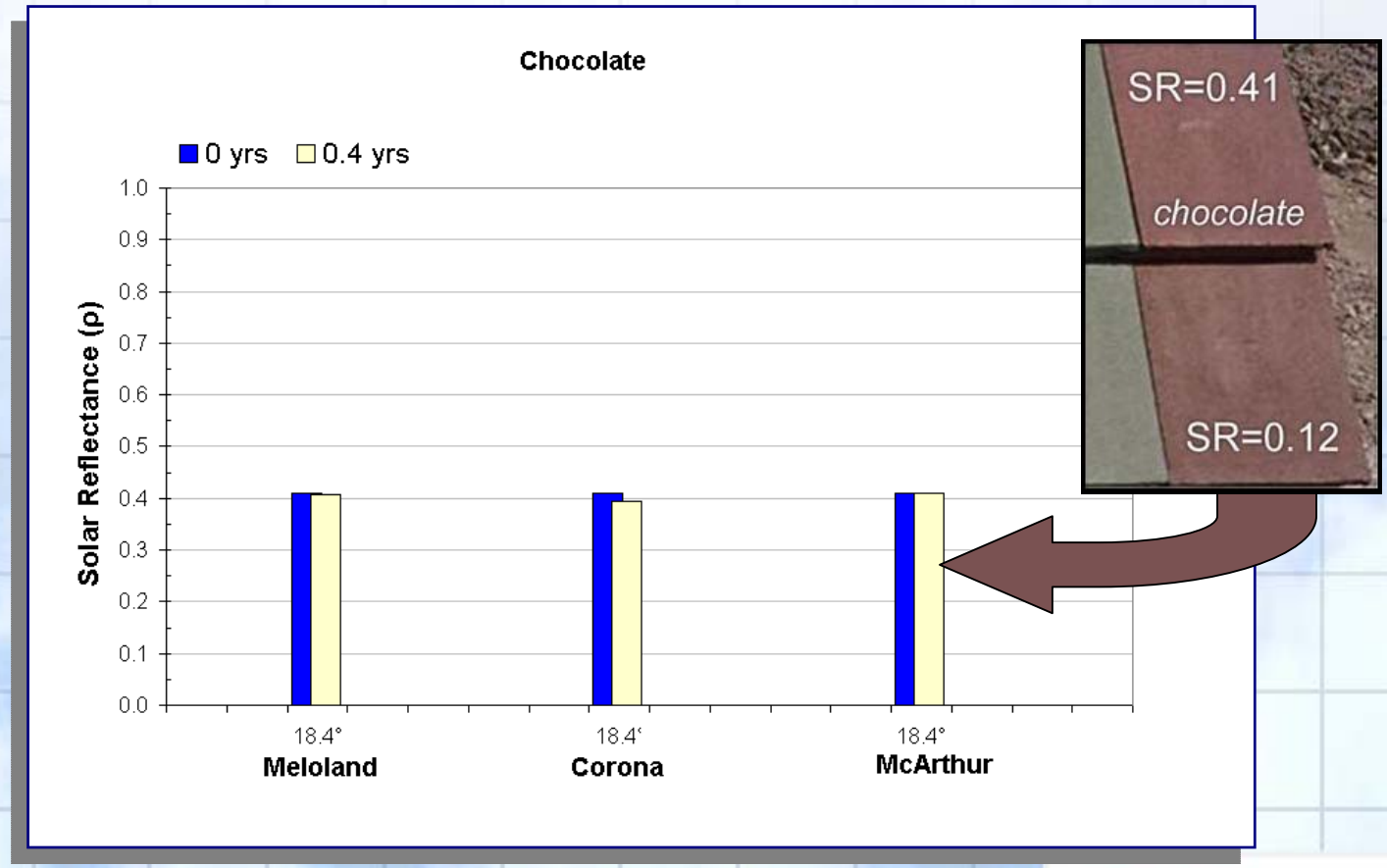
Concrete Tile Coatings under exposure at all seven weathering sites

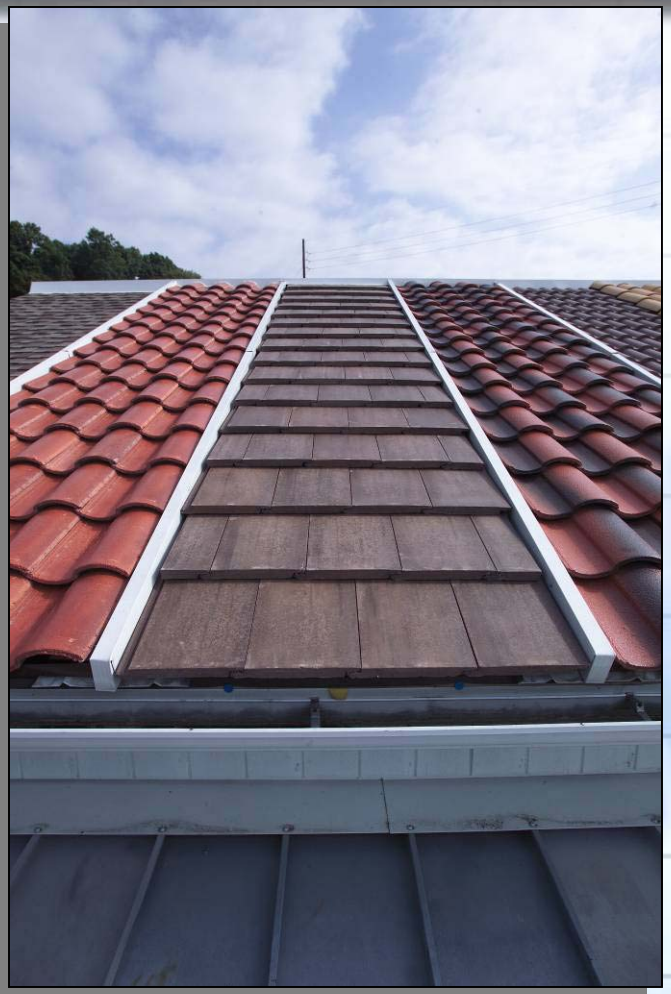


2.6.3 Steep-slope Assembly Testing at ORNL

- **Objective:** Field test Cool Roof Color Materials on the Envelope Systems Research Apparatus (ESRA) to document the effect of reflectance and emittance weathering on thermal performance
- Deliverables:
  - Attic Model Validation
  - Steep Slope Assembly Test Report
  - Presentation at the Pacific Coast Builders Conference
- Schedule: 10/1/02 – 10/1/05
- Funds Expended 70 %

Tile Roofs Being Field Tested for the Tile Roofing Institute

MonierLifetile Concrete Slate Tile Installed on Batten and Counter Batten, Standard Color



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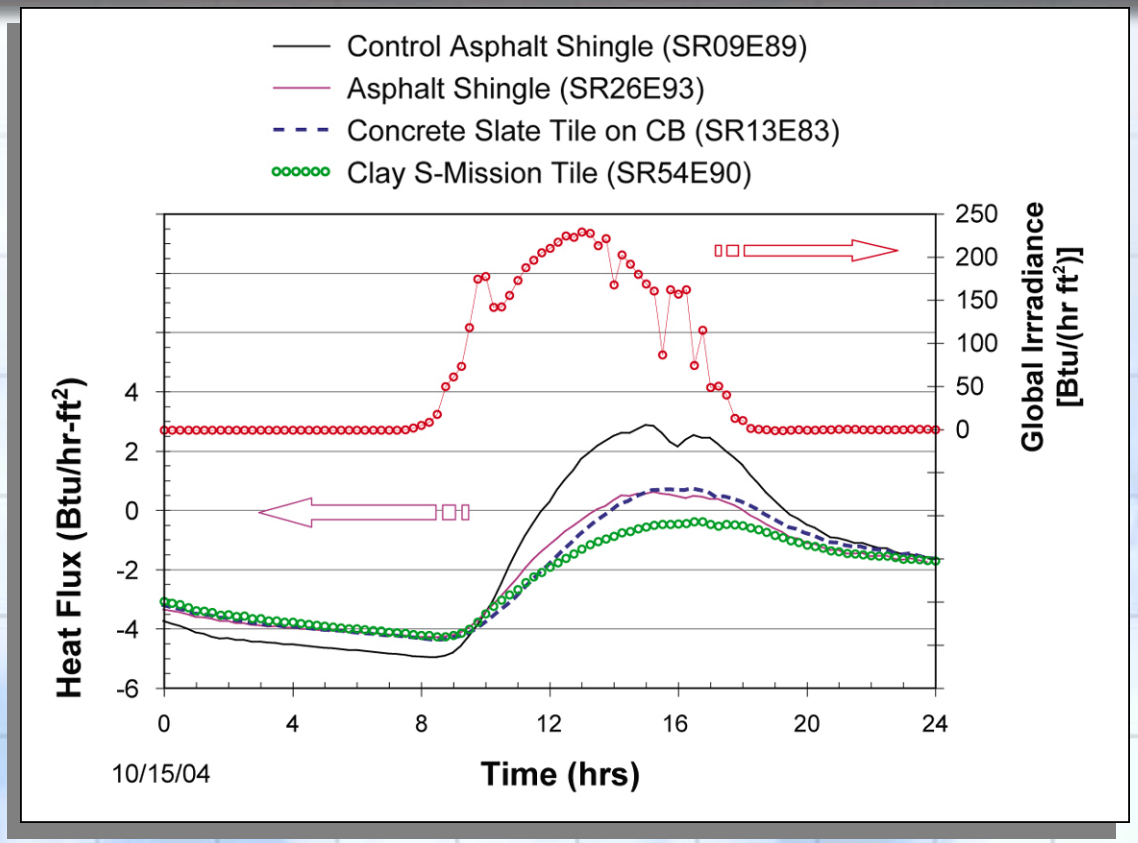
Concrete Slate Tile Yields Comparable Performance to Asphalt Shingle with CRCMs



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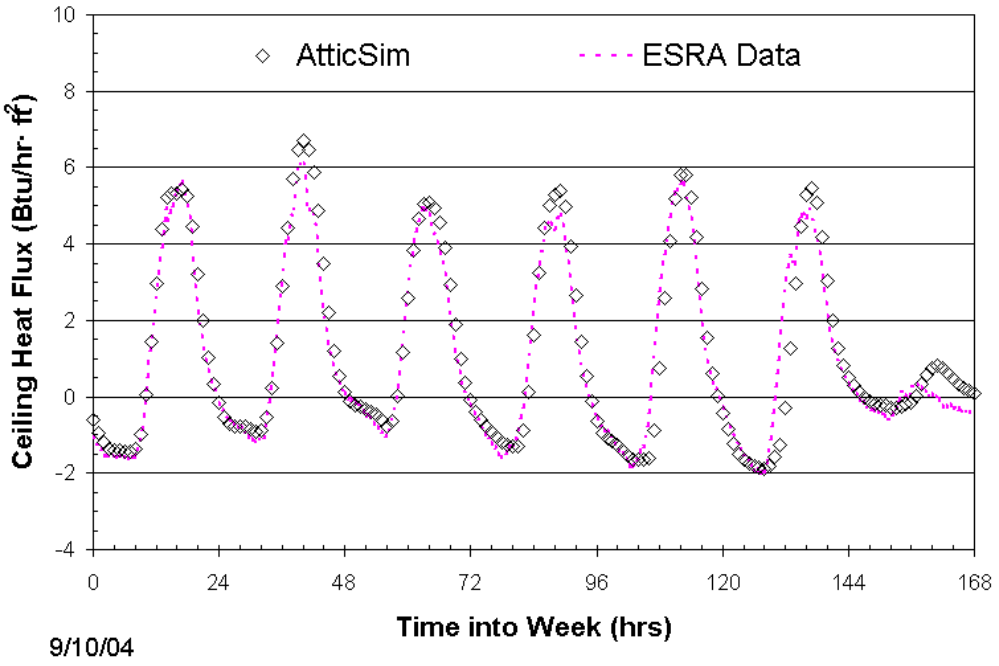
AtticSim Validation against Asphalt Shingle (SR09E89) Attic Assembly



2.6.3 Next Steps

- **Validation of AtticSim code**
  - Direct nailed shingle steep-slope assembly
  - Concrete Tile with venting between deck and roof tile
- **Completion Milestone of 10/01/05 for CEC and Tile Roofing Institute (TRI)**

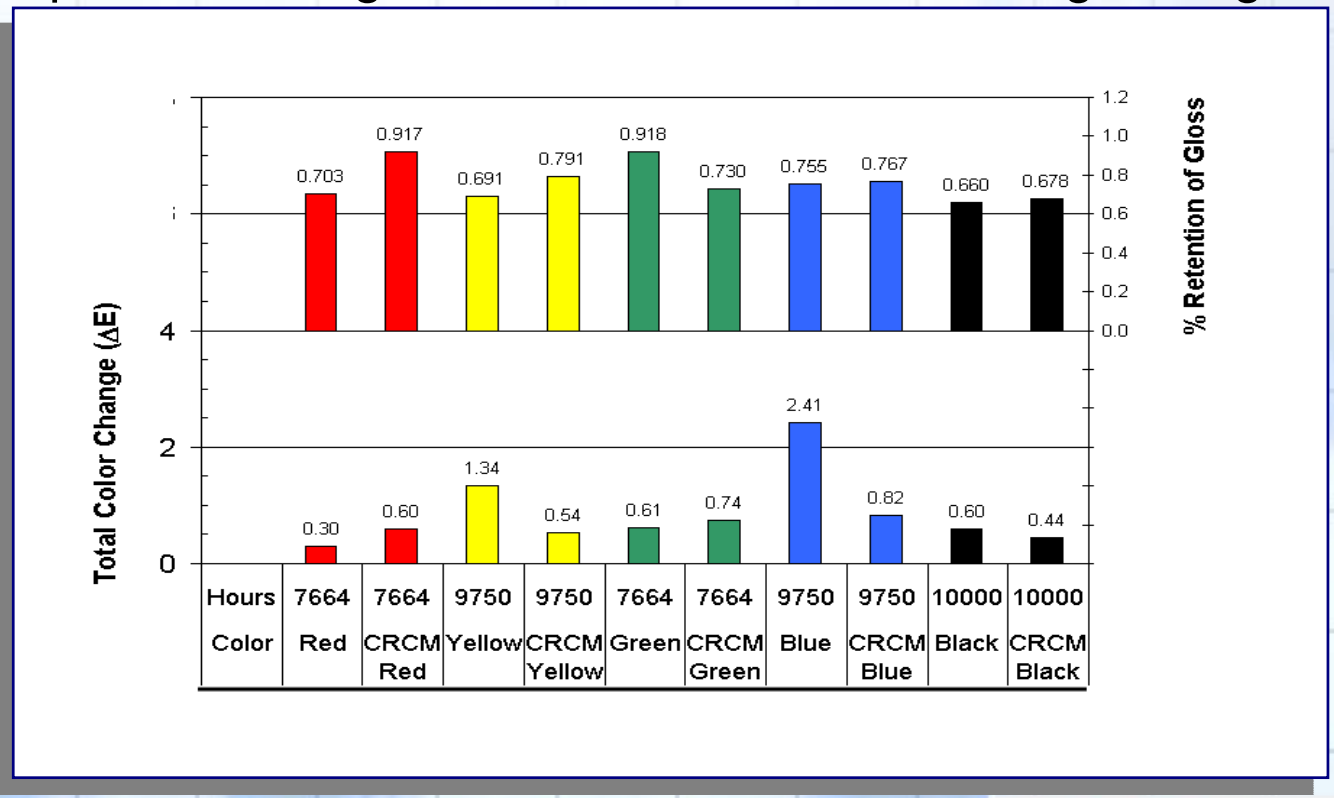
2.6.4 Product Useful Life

- Objective: Investigate the effect of reflectance on the useful life of roofing products and measure the pertinent mechanical and rheological properties to assess the sustainability of the different roofing products
- Deliverables:
  - Solar Reflectance Report
- Schedule: 5/1/04 – 6/1/05➠10/1/05
- Funds Expended 40 %

2.6.4 Product Useful Life Analysis

Fade Resistance & Gloss Retention of Painted Metals

- QUV exposure testing of standard vs CRCM coatings using QUV 313B



BASF

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2.6.4 Next Steps

- Mechanical Property Testing of Shingles
  - Natural exposure at demo field sites
    - » Weathered at Redding demo site (2 yrs)
  - New shingles with CRCMs
    - » Weatherometer testing (partners)

2.7 Tech Transfer

- Akbari, H. 2005. Heat island reduction: an effective air pollution control strategy paying for itself in energy cost savings. A presentation at the Sierra club meeting, Stockton, CA, Jan. 24.
- Akbari, H., A.A. Berhe, R. Levinson, S. Graveline, A.H. Delgado, and R.M. Paroli. 2005. Aging and weathering of cool roofing membranes. To be published at the RCI Foundation conference, “Cool Roofs: Cutting through the glare.” Atlanta GA. May 12-13.
- Akbari, H. and André Desjarlais. 2005. Cooling down the house: Residential roofing products soon will boast *cool* coatings. To be published in *Professional Roofing*.
- Levinson, R., P. Berdahl, and H. Akbari. 2005. Solar spectral optical properties of pigments. To be published at the RCI Foundation conference, “Cool Roofs: Cutting through the glare.” Atlanta GA. May 12-13.

2.7 Tech Transfer (Continued)

- Levinson, R., P. Berdahl, and H. Akbari. 2005. Solar spectral optical properties of pigments—Part I: model for deriving scattering and absorption coefficients from transmittance and reflectance measurements. *Solar Energy Materials & Solar Cells* (in press).
- Levinson, R., P. Berdahl, and H. Akbari. 2005. Solar spectral optical properties of pigments—Part II: survey of common colorants. *Solar Energy Materials & Solar Cells* (in press).
- Miller, W.A. 2005. Experimental analysis of the natural convection effects observed within the closed cavity of tile roofs. To be published at the RCI Foundation conference, “Cool Roofs: Cutting through the glare.” Atlanta GA. May 12-13.

2.7 Tech Transfer (Continued)

- Akbari, H. 2004. Cool colored roofs to save energy and improve air quality. A presentation at the CONSTRUCTION CHEMICALS OUTLOOK *2004.* Philadelphia, PA. Dec. 9-10.
- Akbari, H. 2004. Cool colored materials for roofs. Presented at the Emerging Technologies in Energy Efficiency-Summit 2004. Hilton San Francisco • San Francisco, CA October 14-15.
- Akbari, H. 2004. Mitigating summer heat islands. Presented at an ICLEI-sponsored conference, San Diego, CA, Sep. 30.
- Akbari, H., R. Levinson. 2004. Coatings for cool vehicles. A presentation at the Ford Motor Company, Detroit, MI. Nov. 18.
- Miller, W. A., Desjarlais, A.O., Akbari, H., Levinson, R., Berdahl, P. and Scichili, R.G. 2004. Special IR reflective pigments make a dark roof reflect almost like a white roof. In Thermal Performance of the Exterior Envelopes of Buildings, THERM IX, Clearwater, FL., Dec.

THANKS TO ALL OF YOU

Industrial Partners & PAC Members for PIER Cool Roofs Project

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Cool Colors Project Website

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

http://CoolColors.LBL.gov