DEVELOPMENT OF COOL COLORED ROOFING MATERIALS

Project Advisory Committee (PAC) Meeting

A Collaborative R&D Between Industry

LBNL and **ORNL**

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

September 12, 2002; Sacramento, CA

UT-BATTELLE
Oak Ridge National Laboratory

Berkeley Lab

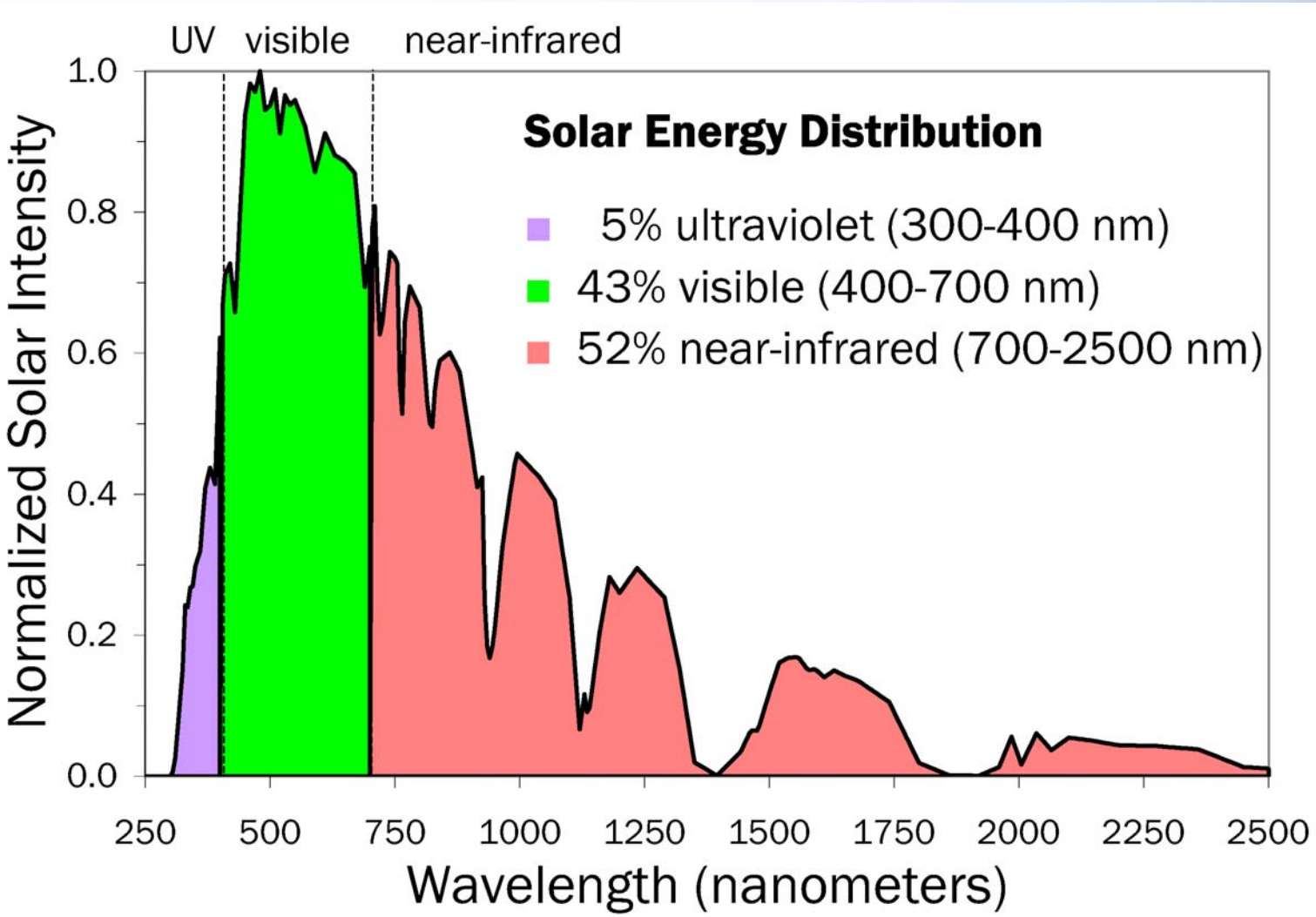
How Solar-Reflective Surfaces Save Energy, Improve Air Quality

- Direct Effect: reflective roofs
  - stay cool in the sun
  - reduce building air-conditioning use ~ 10%
  - may last longer (less thermal stress)
- Indirect Effect: cool reflective surfaces
  - transfer less heat to air
  - lower ambient air temperature ~ 2-3 ºF
  - reduce smog ~ 5%

Cool Roofing Material Availability

- Low-sloped roofs: many materials available
  - Coatings
  - Single-ply membranes
  - Painted metals
- Sloped roofs: limited material availability
  - Tiles
  - Metals
  - Shake
- Most sloped roofs use shingles (not cool)

Solar Energy Distribution



Cool and Standard Browns

- Cool brown 16 ºF cooler than standard brown

brown metal panel

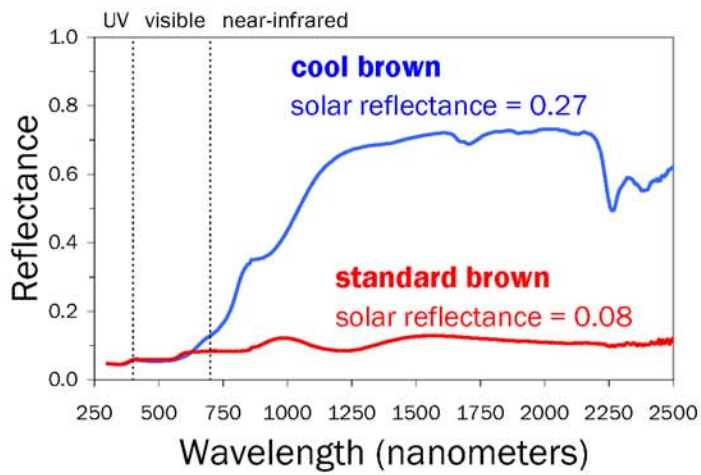
COURTESY BASF CORPORATION

cool

solar reflectance = 0.27
thermal emittance = 0.85
roof temp – air temp = 36ºC (65ºF)

standard

solar reflectance = 0.08
thermal emittance = 0.85
roof temp – air temp = 45ºC (81ºF)



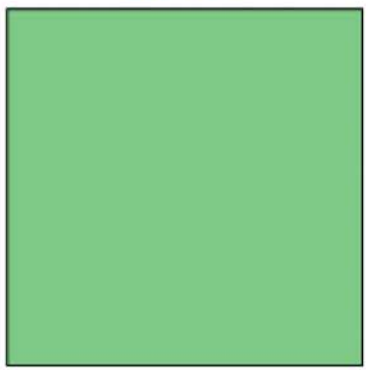
Cool and Standard Greens

- Cool green 12 ºF cooler than standard green

green metal panel

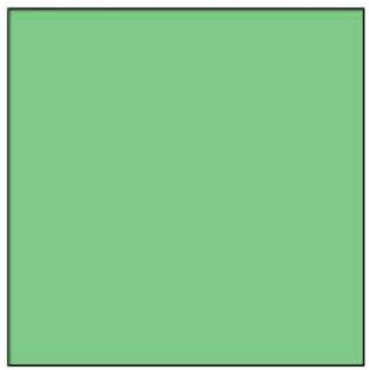
COURTESY BASF CORPORATION

cool

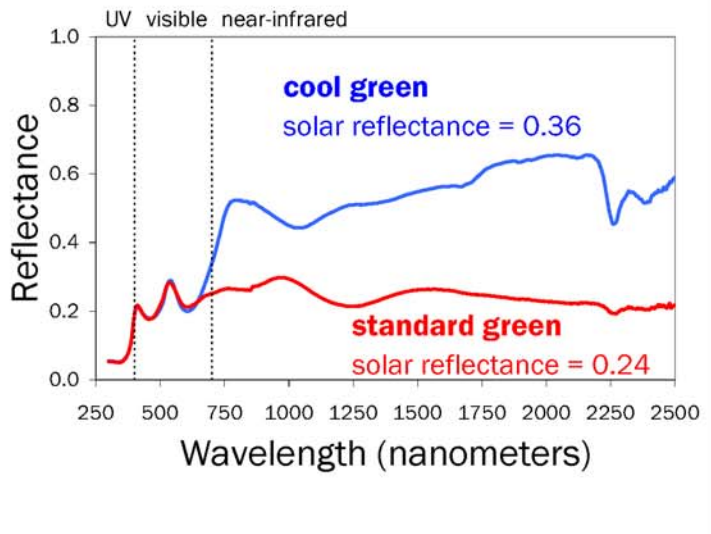


solar reflectance = 0.36
thermal emittance = 0.85
roof temp – air temp = 31ºC (56ºF)

standard



solar reflectance = 0.24
thermal emittance = 0.85
roof temp – air temp = 38ºC (68ºF)



Project Goal

- Bring cool colored roofing materials to the roofing market.
- Measure and document the laboratory and in-situ performance of roofing products
- Accelerate the 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. California Institute for Energy Efficiency
4. Cedar Shake and Shingle Bureau
5. Cool Roof Rating Council
6. Environmental Protection Agency (EPA)
7. EPA San Francisco Office
8. Habitat for Humanity
9. National Roofing Contractors Association
10. Roof Tile Institute

Industrial Partners

- **On Board**
  - **3M**
  - **BASF / Custom-Bilt Metals**
  - **Elk Manufacturing**
  - **Ferro**
  - **GAF**
  - **MCA**
  - **ISP Minerals**
  - **Shepherd Color Company**
- On List
  - American Roof Tile Coating
  - DuroLast
  - Rising and Nelson Slate
  - Transmet Corp.

Project Team

- LBNL
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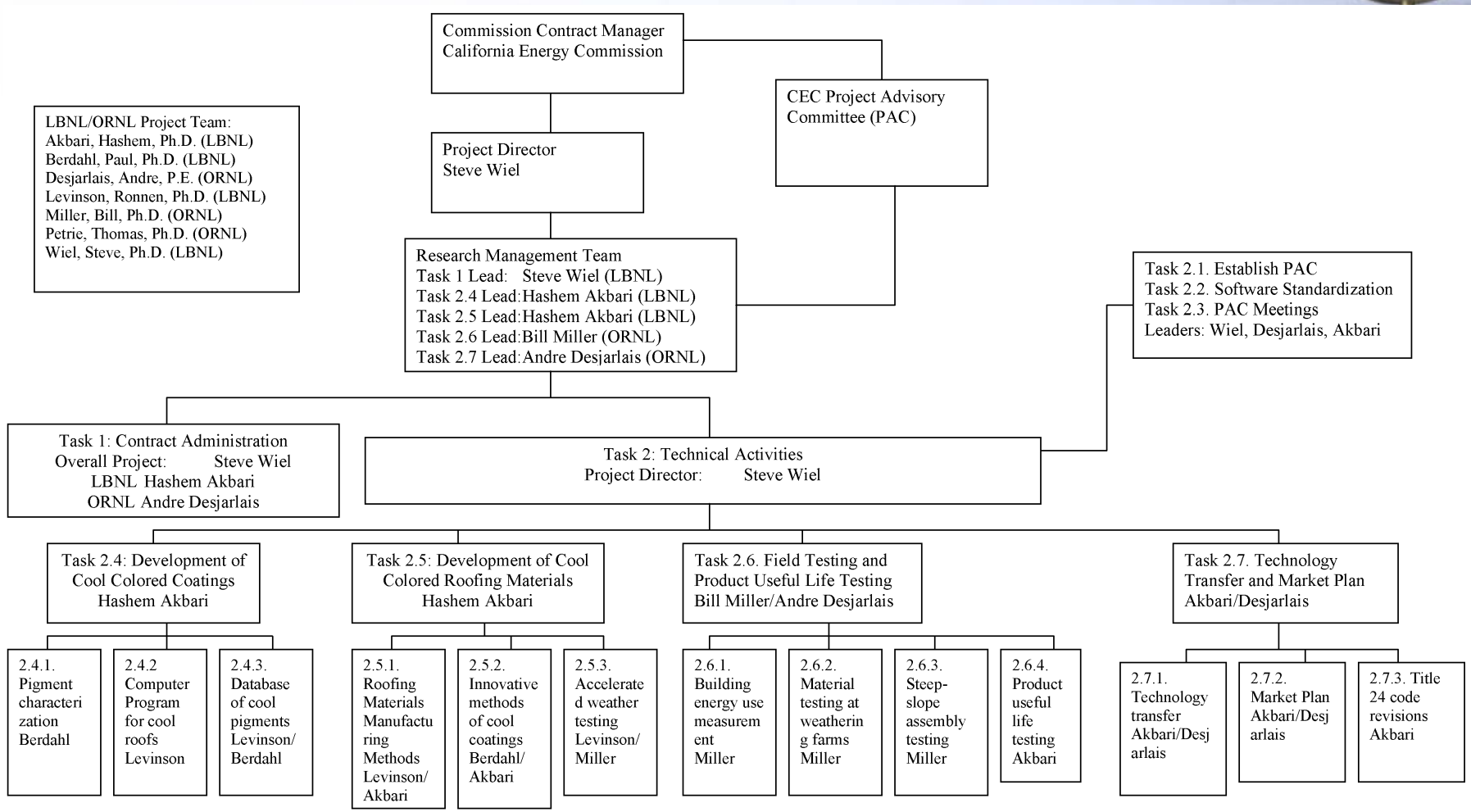
  - Bill Miller wml@ornl.gov

Project Management



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 coated roofing product (e.g. shingle) to that of simple smooth coating
- Subtasks
  - Identify and characterize pigments with high solar reflectance
  - Develop a computer program for optimal design of cool coatings
  - Develop a 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
- Schedule: 6/1/02 – 12/1/04

Pigment Characterization

- LBNL has characterized pigments used in 51 single-pigment paints (artist-color acrylics, BASF PVDFs)
  - 9 blues
  - 8 reds
  - 7 greens
  - 7 blacks
  - 7 yellows
  - 5 browns
  - 3 whites
  - 2 violets
  - 2 oranges
  - 1 gold

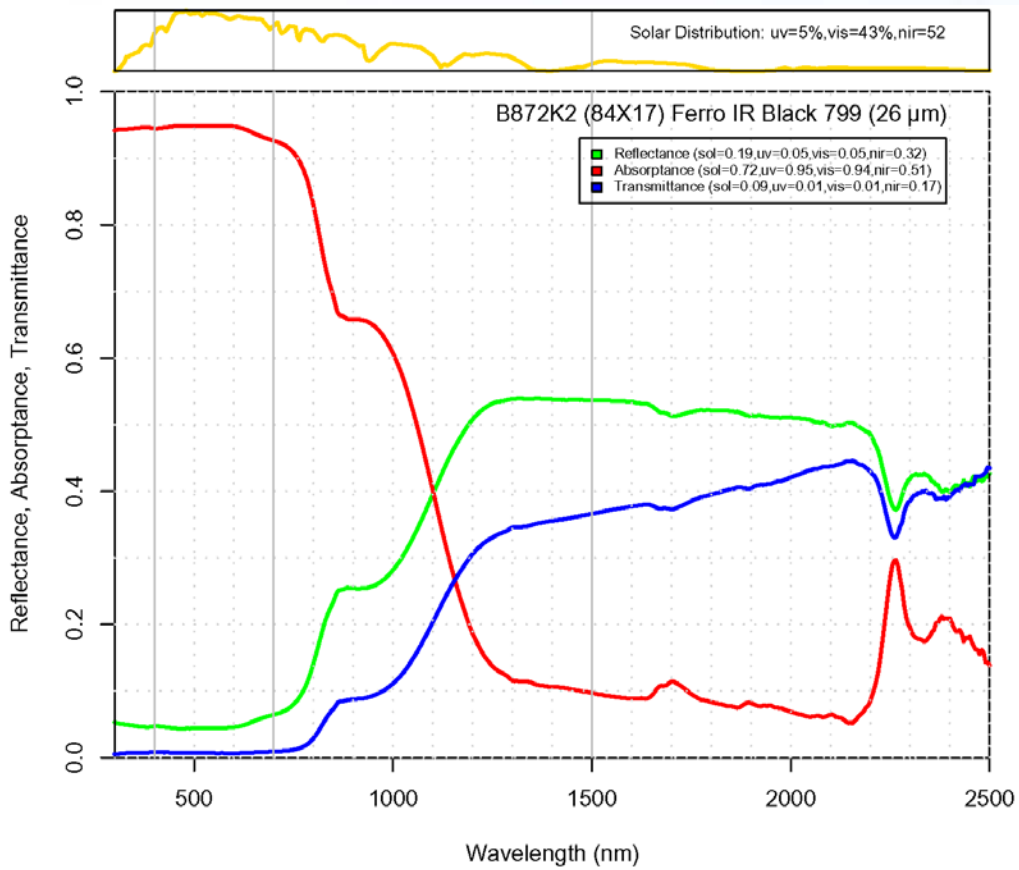
Eight Reds

B815R65 Red Iron Oxide (I)
B815R66 Red Iron Oxide (II)
B835R4 Monstral Red
LM38 Interference Red
LM108 Acra Burnt Orange
LM112 Acra Red
LM294 Naphthol Red Light
LM335 Red Oxide

Some BASF Single-Pigment Paints (25-µm Film Over Opaque White)

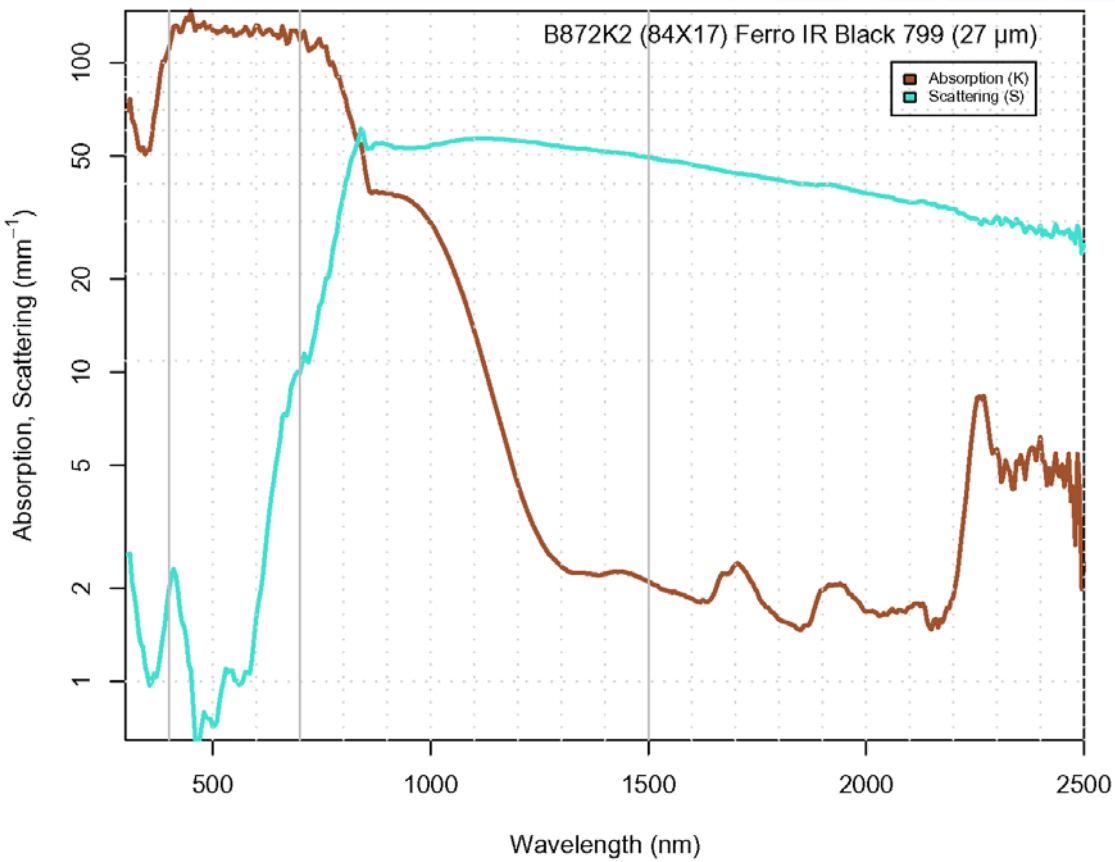
Paint Film Properties

- Paint films characterized by thickness, reflectance, absorptance, transmittance



Pigment Properties

- Pigments characterized by absorption, scattering coefficients (Kubelka-Munk theory)

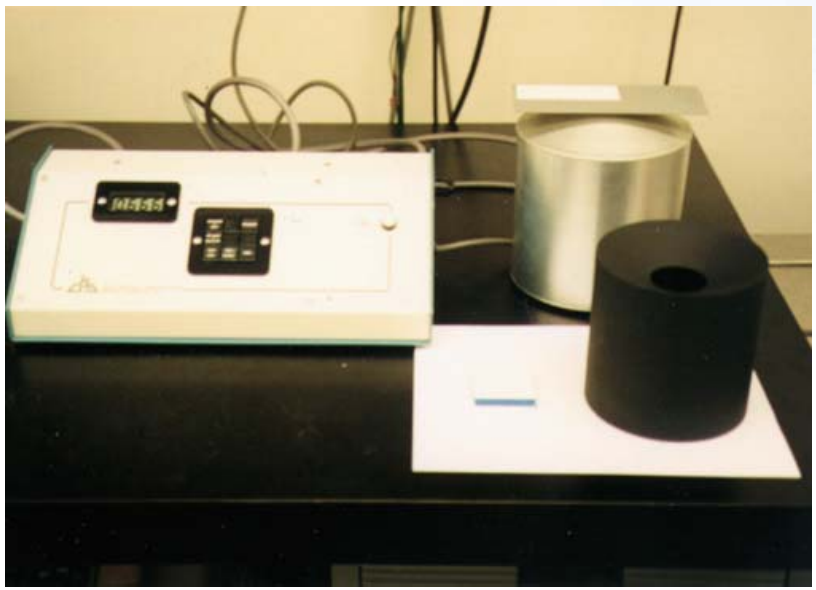


Spectrometer for Spectral Reflectance, Transmittance

- UV-VIS-NIR instrument (Perkin-Elmer Lambda 19) with integrating sphere
- Accurate laboratory measurement

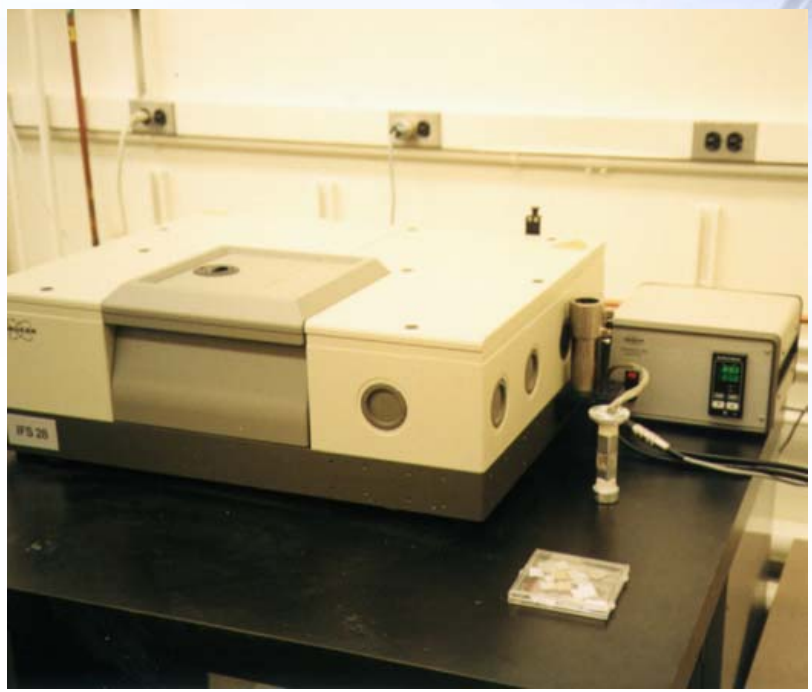
Solar Reflectance Instrumentation

- Solar Spectrum Reflectometer (Devices & Services Company)
- Quick measurement over overall solar reflectance
- Laboratory instrument sometimes used in field



Fourier-Transform Infra-Red (FTIR) Spectral Emissometer

- Based on commercial Bruker IFS 28 FTIR spectrometer
- Spectral distribution of emittance (5 to 40 micrometers)
- Set-up unique in U.S.



Emissometer

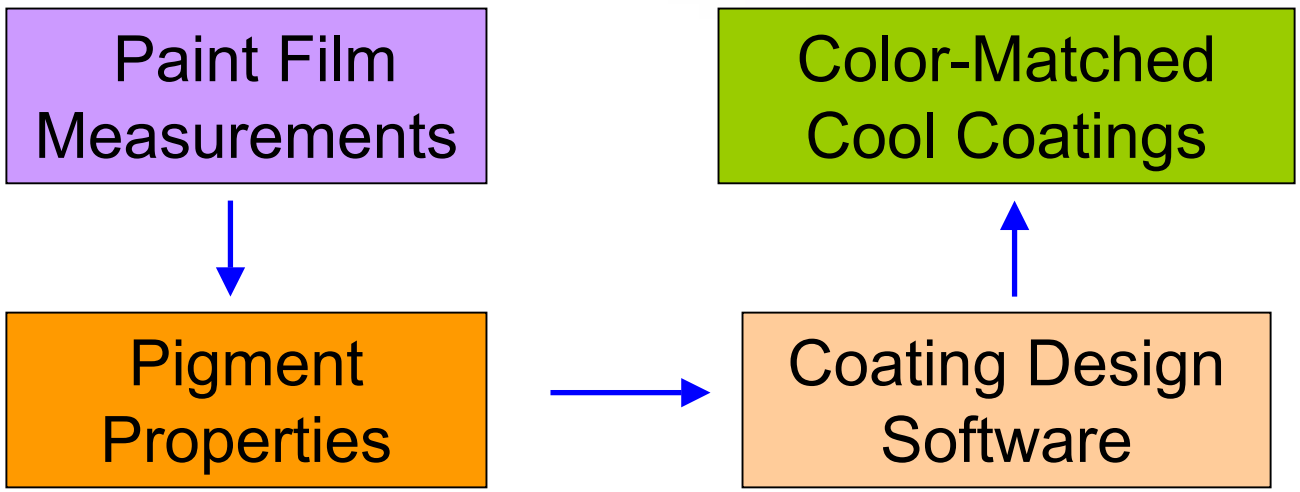
- Overall emittance (Devices & Services, Company)
- Compares emittance to high and low standards

2.4.2 Develop a Computer Program For Optimal Design of Cool Coatings

- Objective: Develop a computer program for optimal design of cool coatings used in colored roofing materials
- Deliverables:
  - Computer Program
- Schedule: 11/1/03 – 12/1/04

Coating Design Software

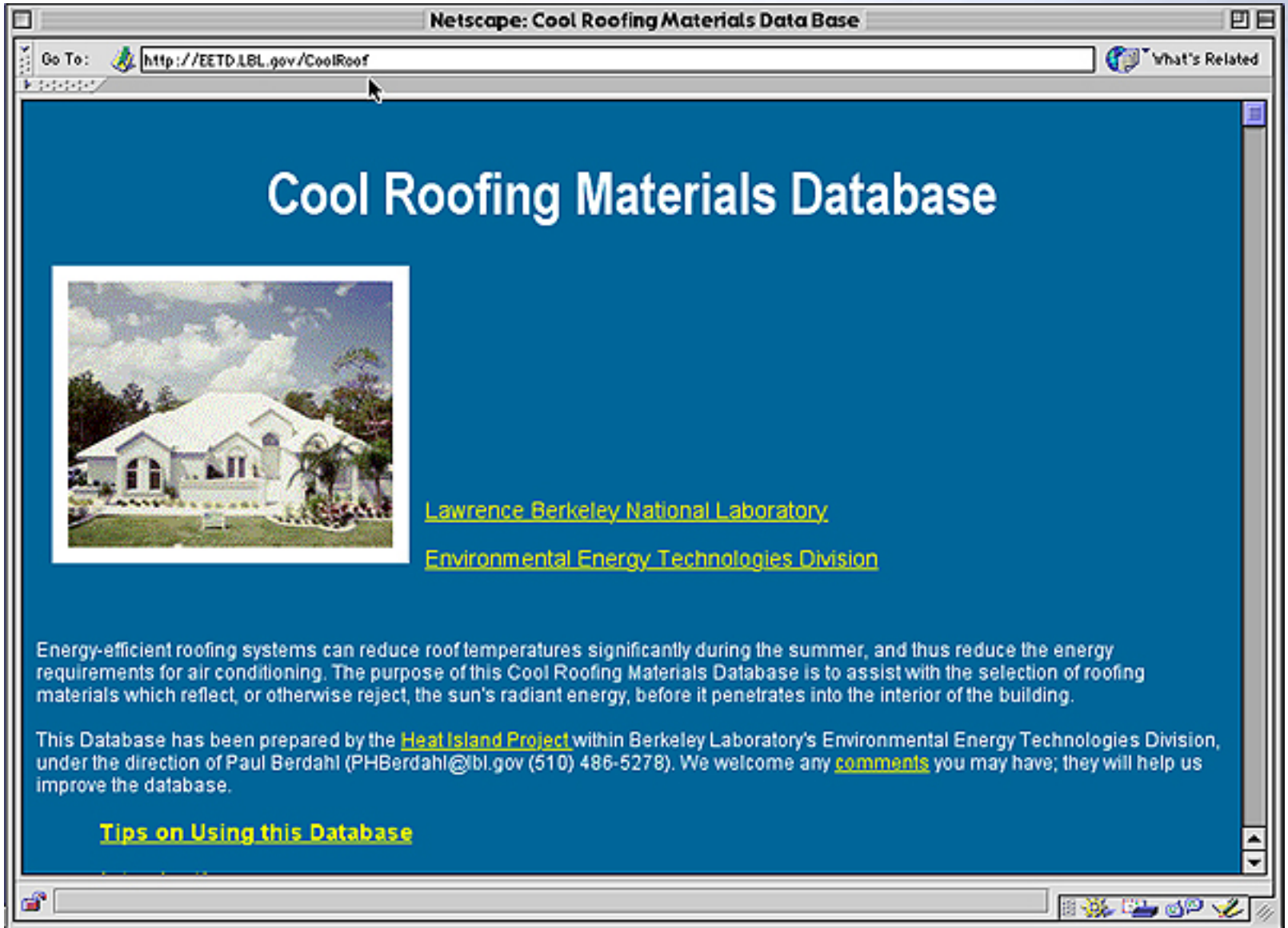
- Estimate coating reflectance from pigment properties (absorption & scattering), film geometry (mixing & layering)
- Recommend pigments & geometry to match color, maximize solar reflectance



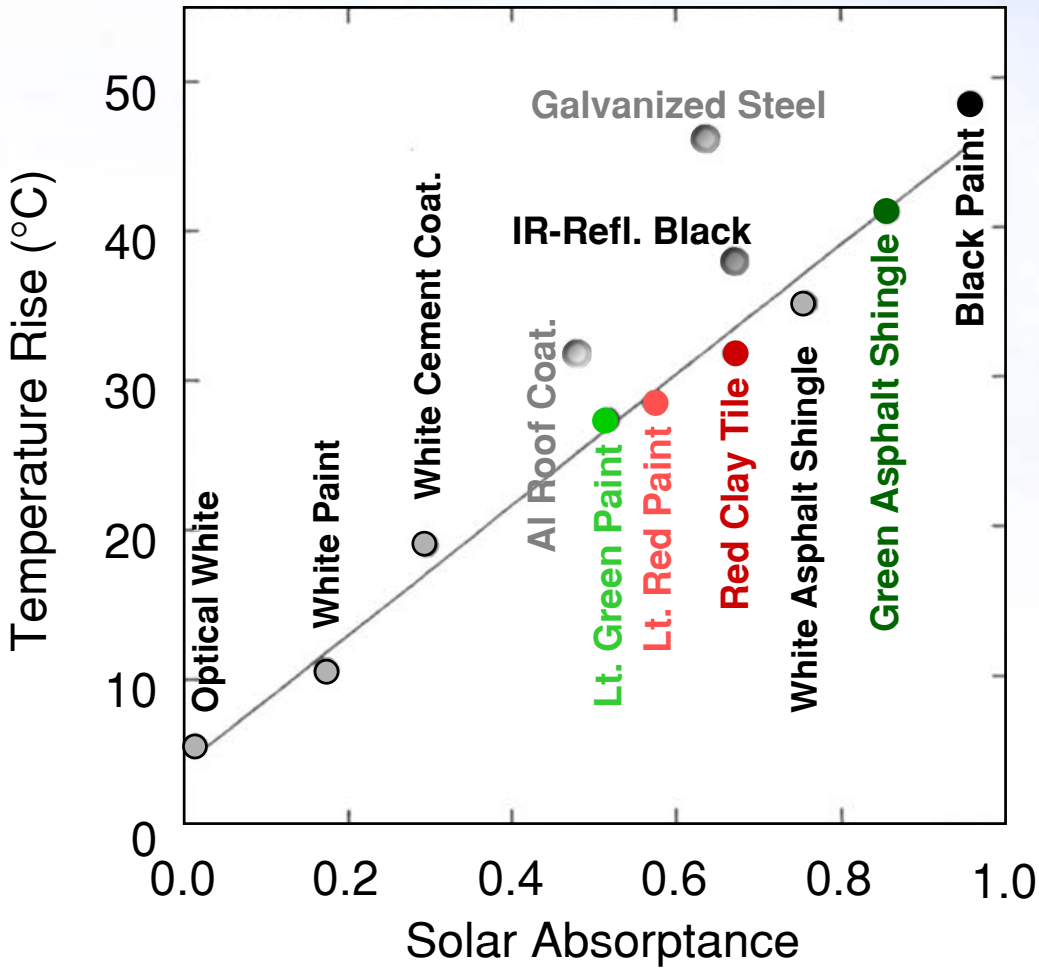
2.4.3 Develop a Database of Cool-Colored Pigments

- 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

LBNL's Cool Roofing Material Database



Temperature Rise of Various Roofing Materials in Sunlight



2.5 Development of 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 of Roofing Materials Manufacturing Methods

- Objective: Compile information on roofing materials manufacturing methods
- Deliverables:
  - Methods of Fabrication and Coloring Report
- Schedule: 6/1/02 – 6/1/03

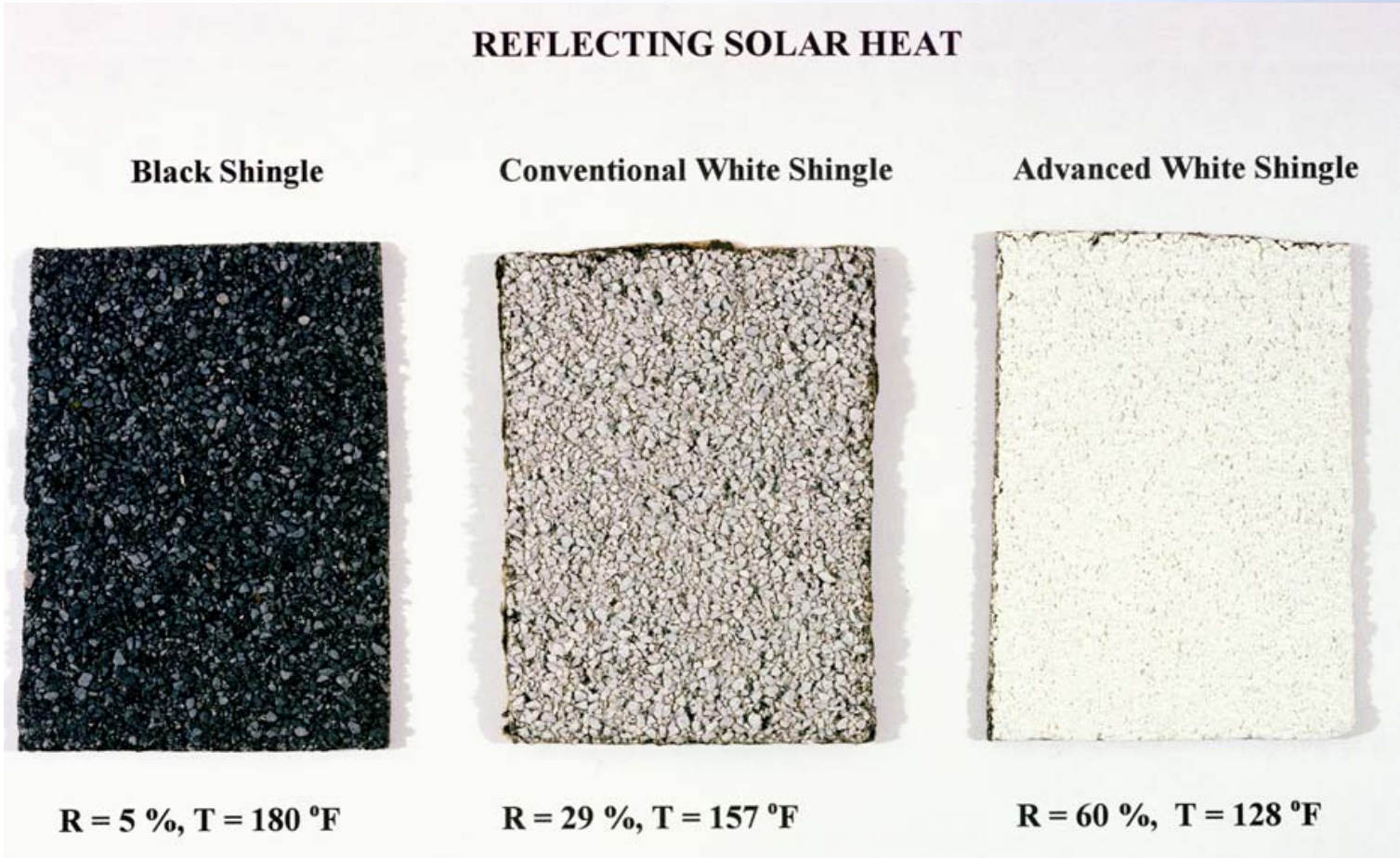
Focus: Application of Cool Colors to Roofing Products

- Metal roofing
- Clay roof tiles
- Concrete roof tiles
- Wood shakes
- Asphalt shingles (granules)

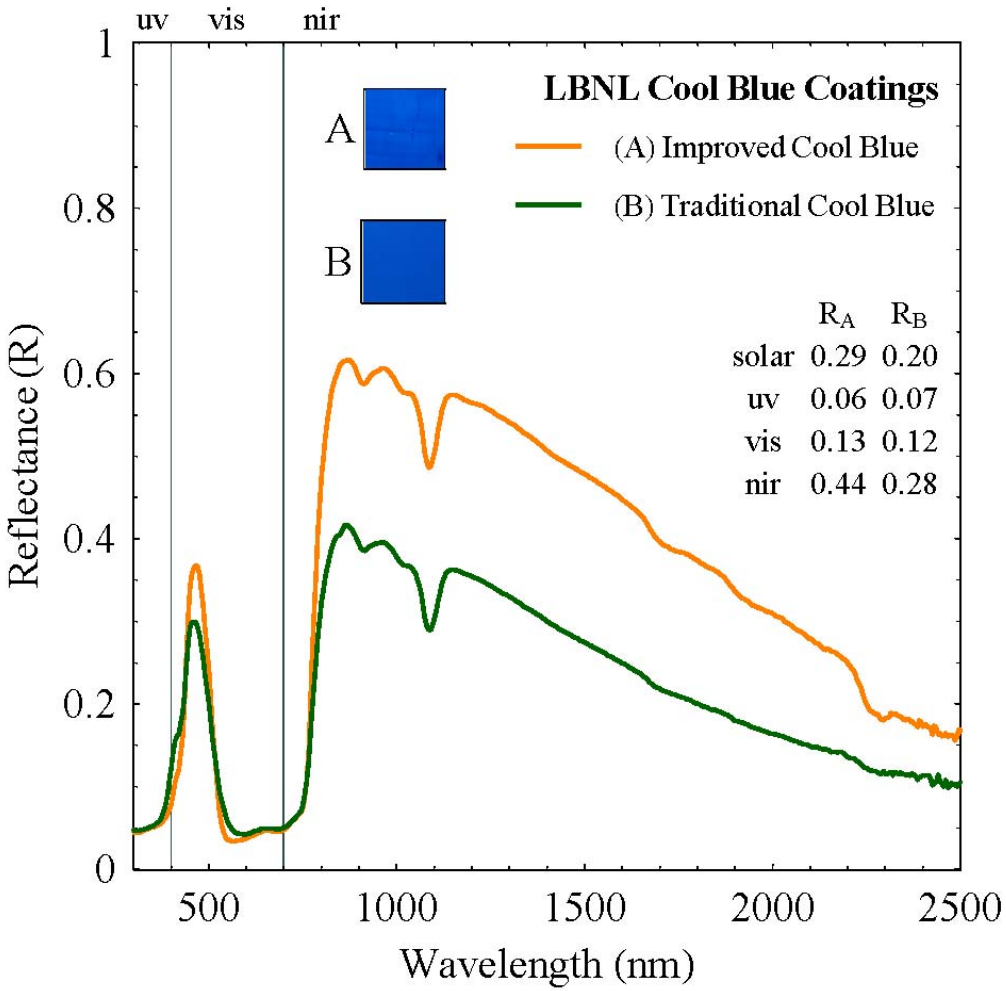
2.5.2 Design Innovative Engineering Methods for Application of Cool Coatings To Roofing Materials

- 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

ISP/LBNL Shingle With Whiter Roofing Granules



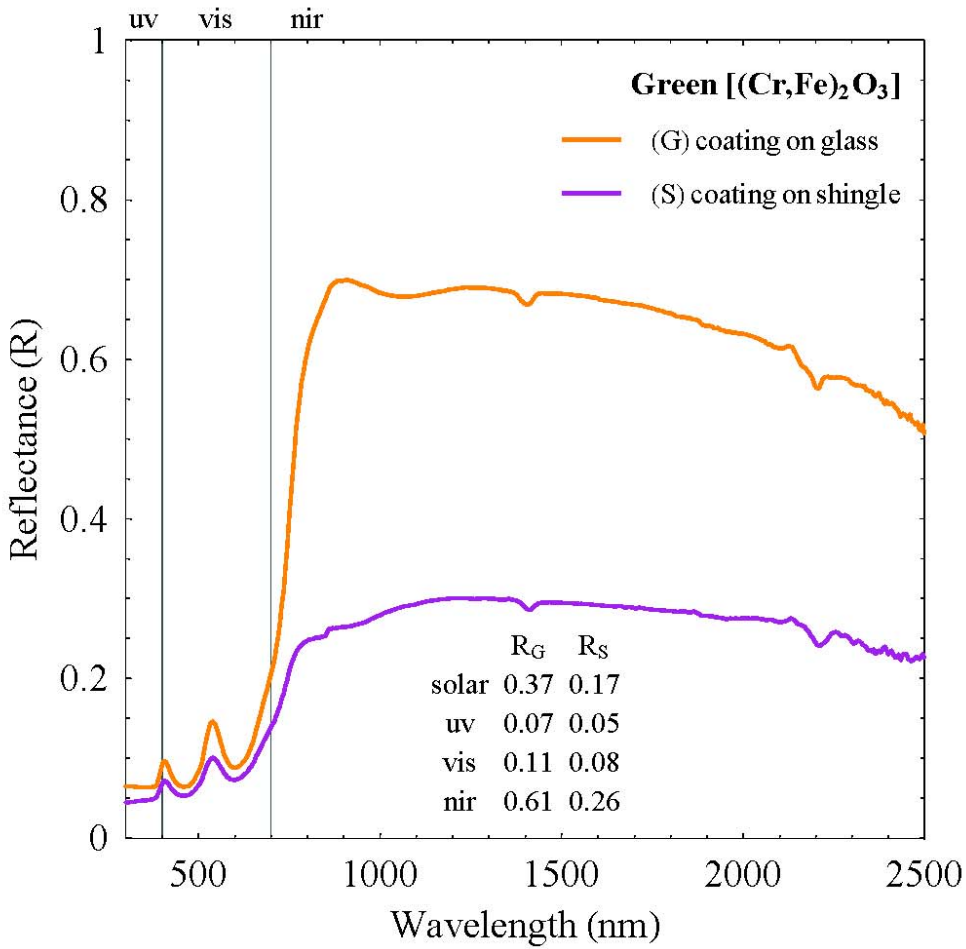
Improvement in Solar Reflectance: LBNL Results



Near-Infrared Reflectances

- **standard blue ~ 0.15**
- **traditional cool blue = 0.28**
- **improved cool blue = 0.44**

From Cool Pigments to Cool Shingles: a Difficult Problem



(G) coating on glass

(S) coating on shingle

2.5.3 Accelerated Weathering Testing

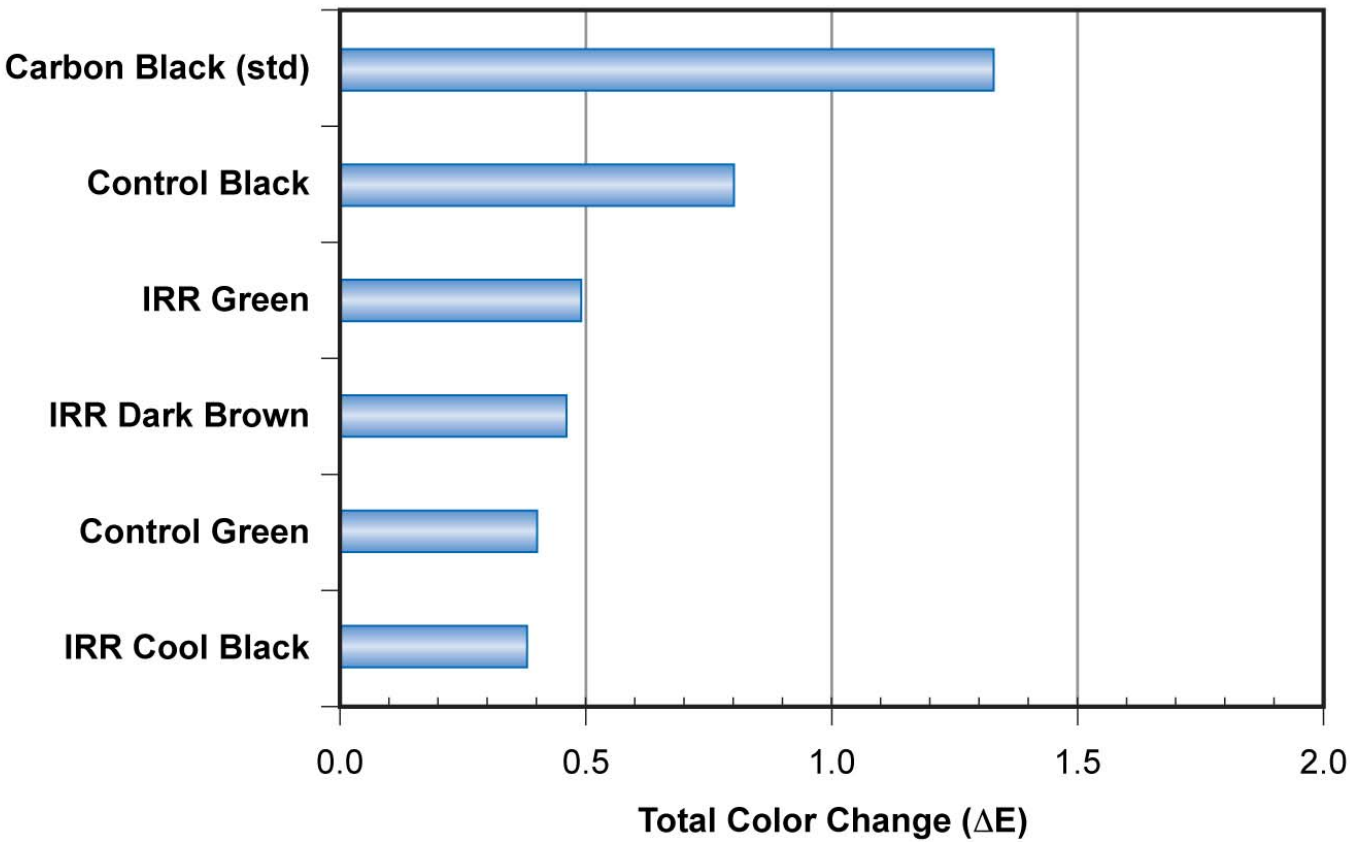
- Objective: Identify latent materials defects early by accelerated weathering tests
- Deliverables:
  - Accelerated Weathering Testing Report
- Schedule: 11/1/02 – 6/1/05

Plans

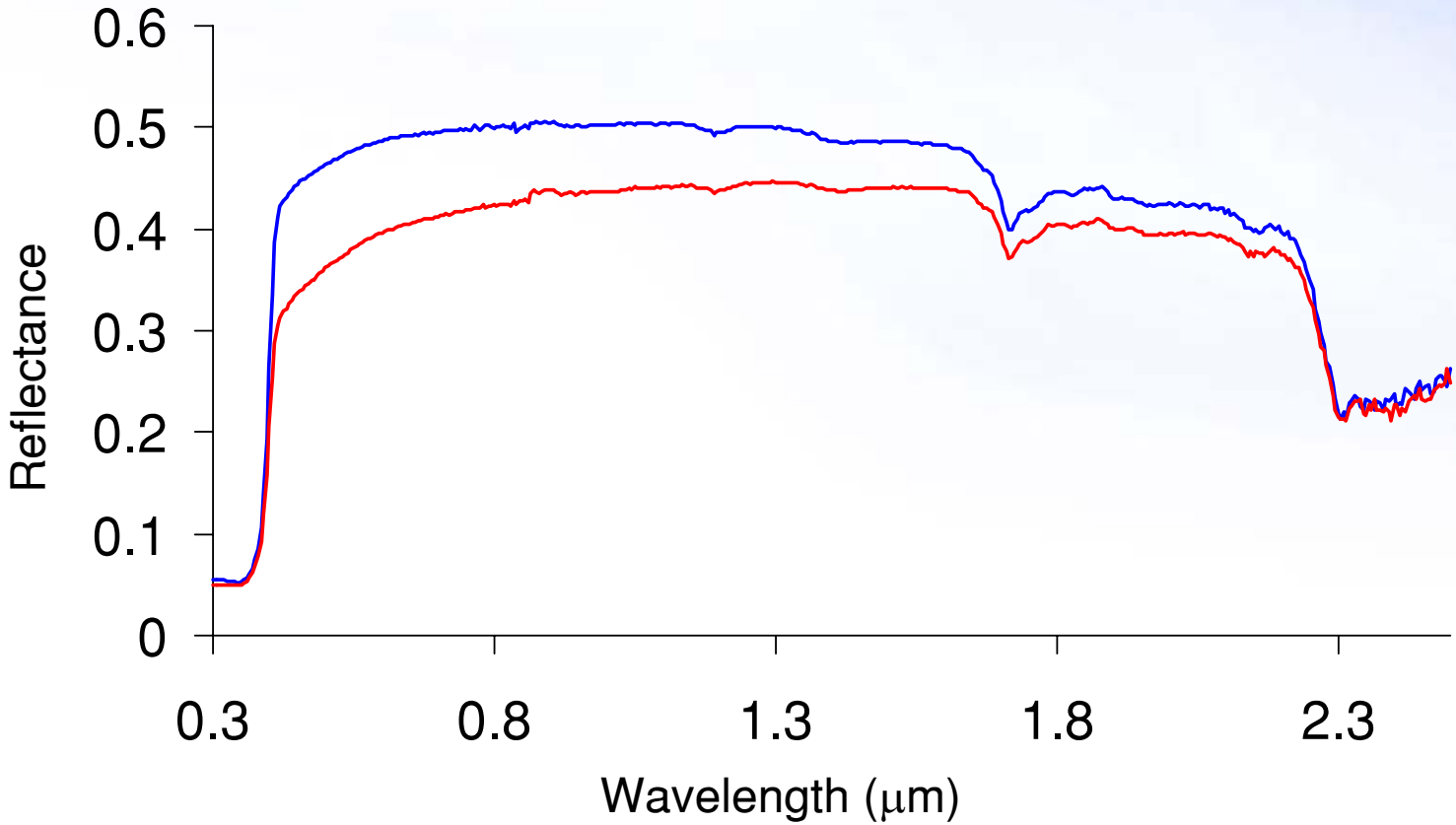
- High-degree of dynamic interactions with industrial partners
- Accelerated testing via weatherometer (exposure to cycles of light, moisture, and dry heat)
- Check for color-stability and integrity
- Tests are conducted for several prototype roofing materials

Natural Sunlight Exposure

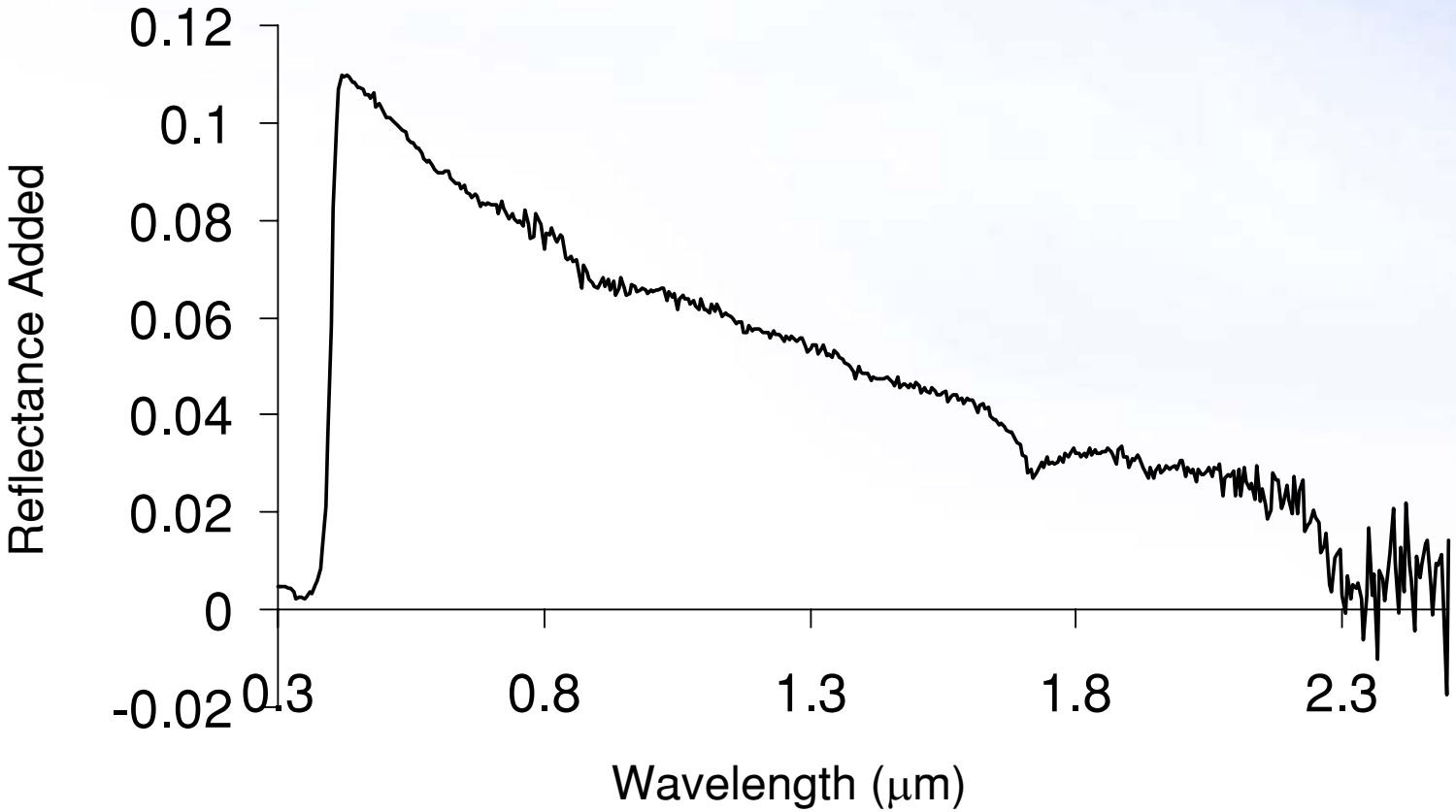
- Preliminary Florida exposure for 1 year
- IRR colors show better fade resistance than painted metal test standards



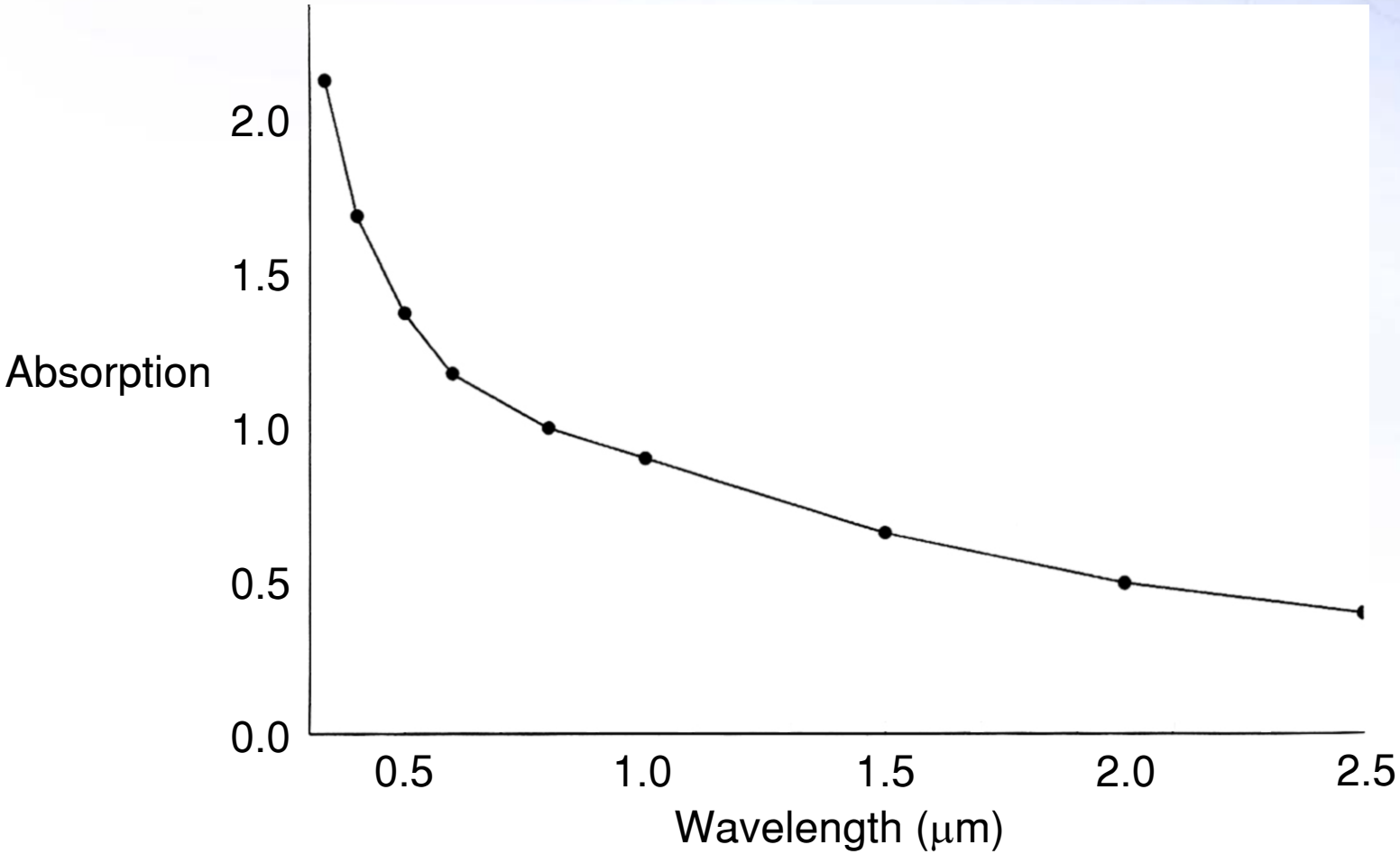
Reduction of Reflectance: Membrane Reflectance Before and After Washing



Difference in Spectral Reflectance Before and After Washing



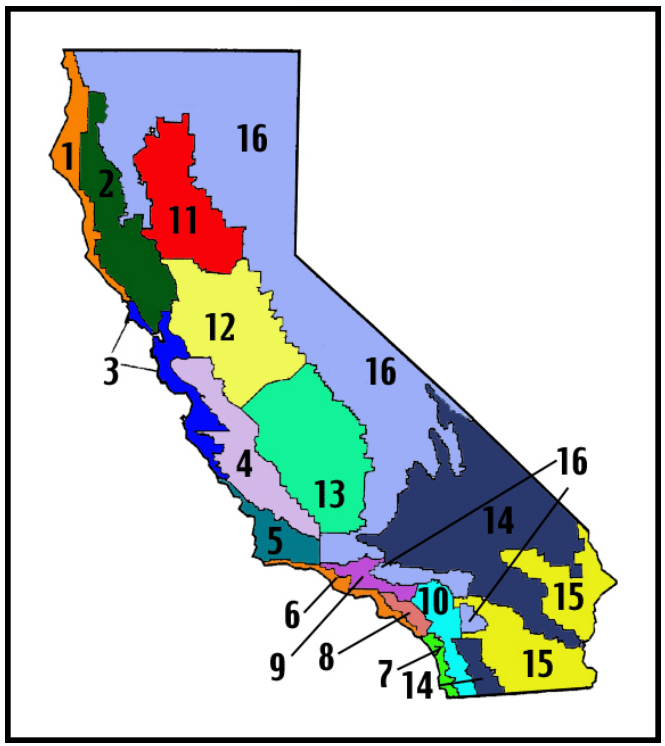
Spectrum of Black Carbon Absorption



2.6 Field-testing and Product Useful Life Testing

- Objective: Demonstrate, measure and document the building energy savings, improved durability and sustainability of cool colored roofing materials
- Subtasks:
  - Building energy-use measurements at california demonstration sites
  - Materials testing at weathering farms in california
  - Steep-slope assembly testing at ORNL
  - Product useful life testing

Cool Colored Roofing Materials Study



- **Demonstration sites**
  - Setup and Instrument Eight Test Roofs in Sacramento, California
  - Setup and Instrument ESRA Test Stand at BTC
  - Field exposure sites in California

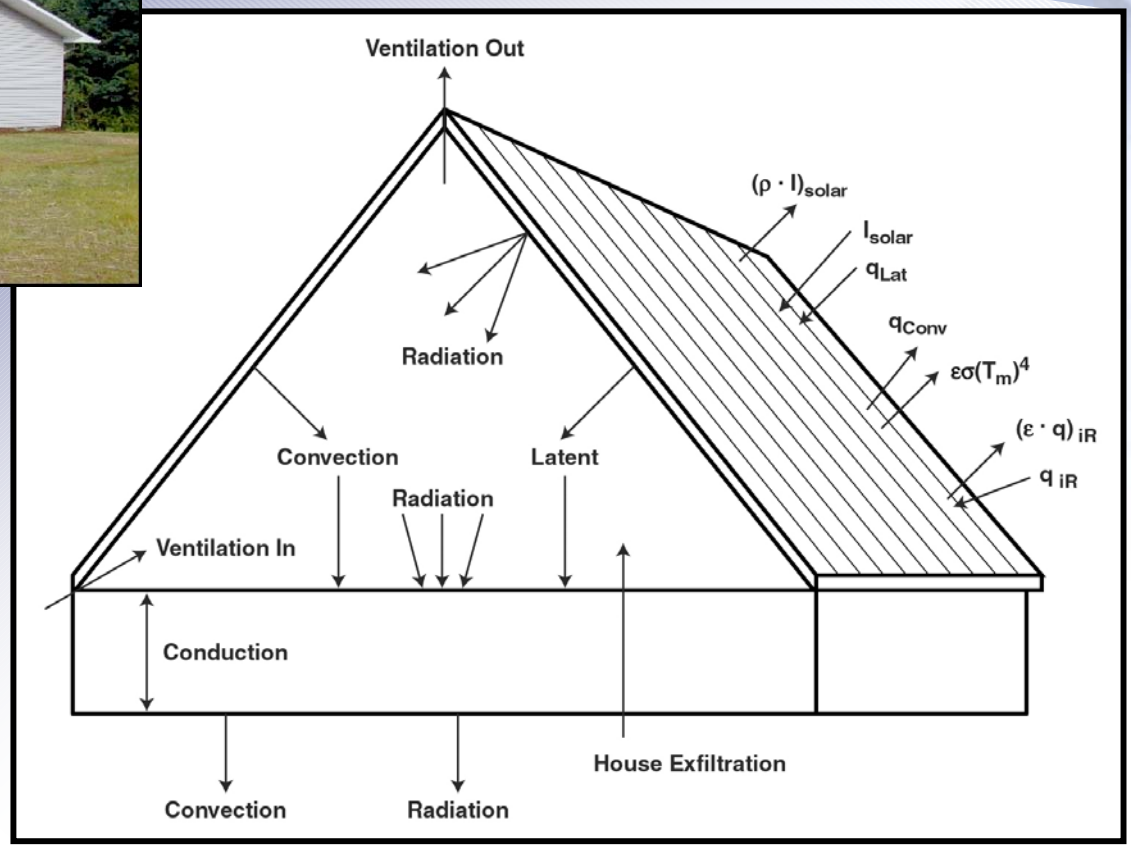
2.6.1 Field-testing and Product Useful Life Testing

- Objective: Setup residential demonstration sites, measure and document the energy savings of cool pigmented roof materials
- Deliverables:
  - Demonstration Site Test Plan
  - Test Site Report
- Schedule: 6/1/02 – 10/1/05

Habitat For Humanity

- Side-by-side performance monitoring of up to eight test homes

AtticSIM *(Attic Simulation)* Model



Effect Of Climate

- Exercise models for unoccupied houses with simple operation in various climates
- Use California sizes for air conditioners and electrical resistance heaters

2.6.2 Materials Testing at Weathering Farms in California

- Objective: Document the change in reflectance and emittance for roof products having cool color pigments
- Deliverables:
  - Weathering Studies Report
- Schedule: 6/1/02 – 10/1/05

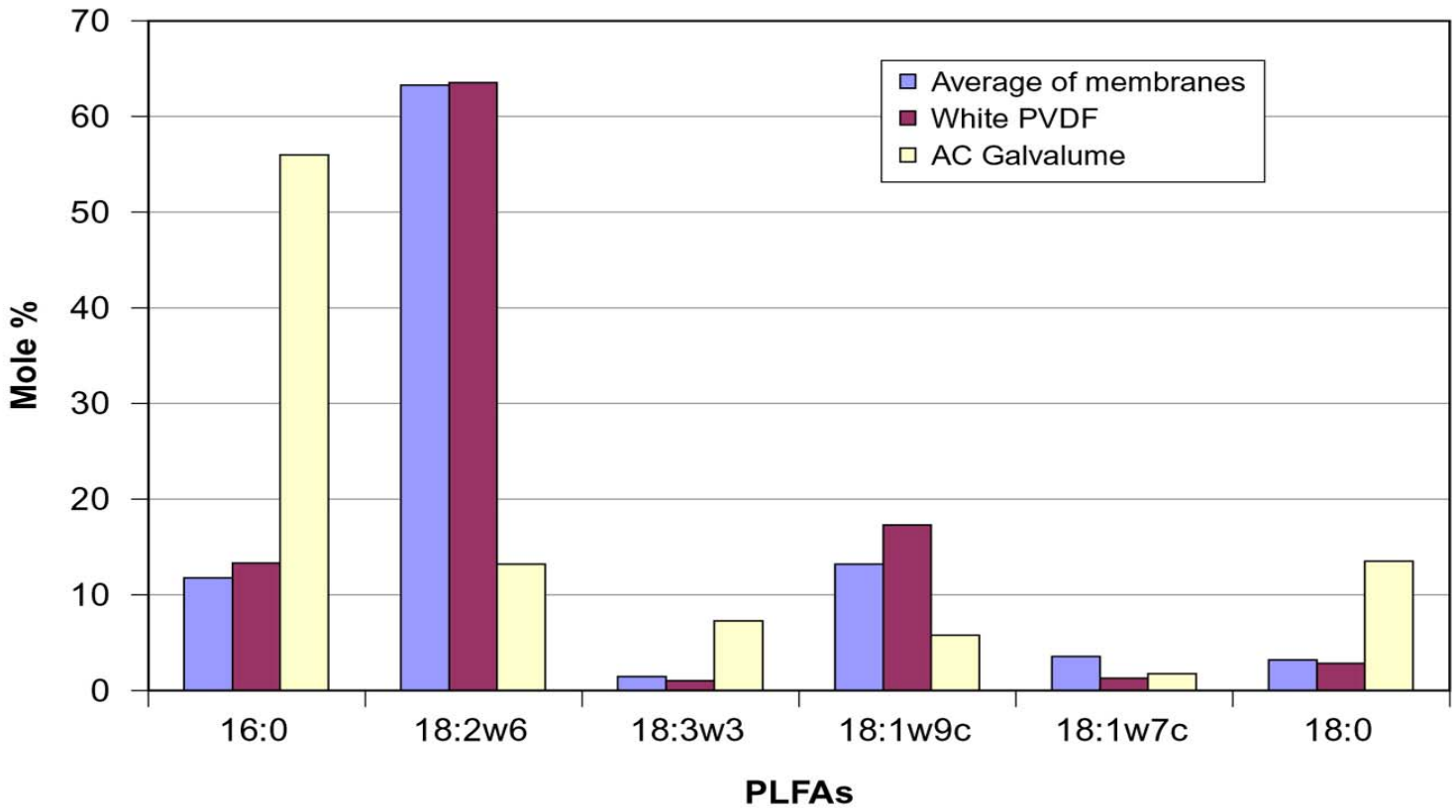
Weathering Sites

- Ft. Lauderdale, FL
- Nova Scotia, Canada
- Bethlehem, PA

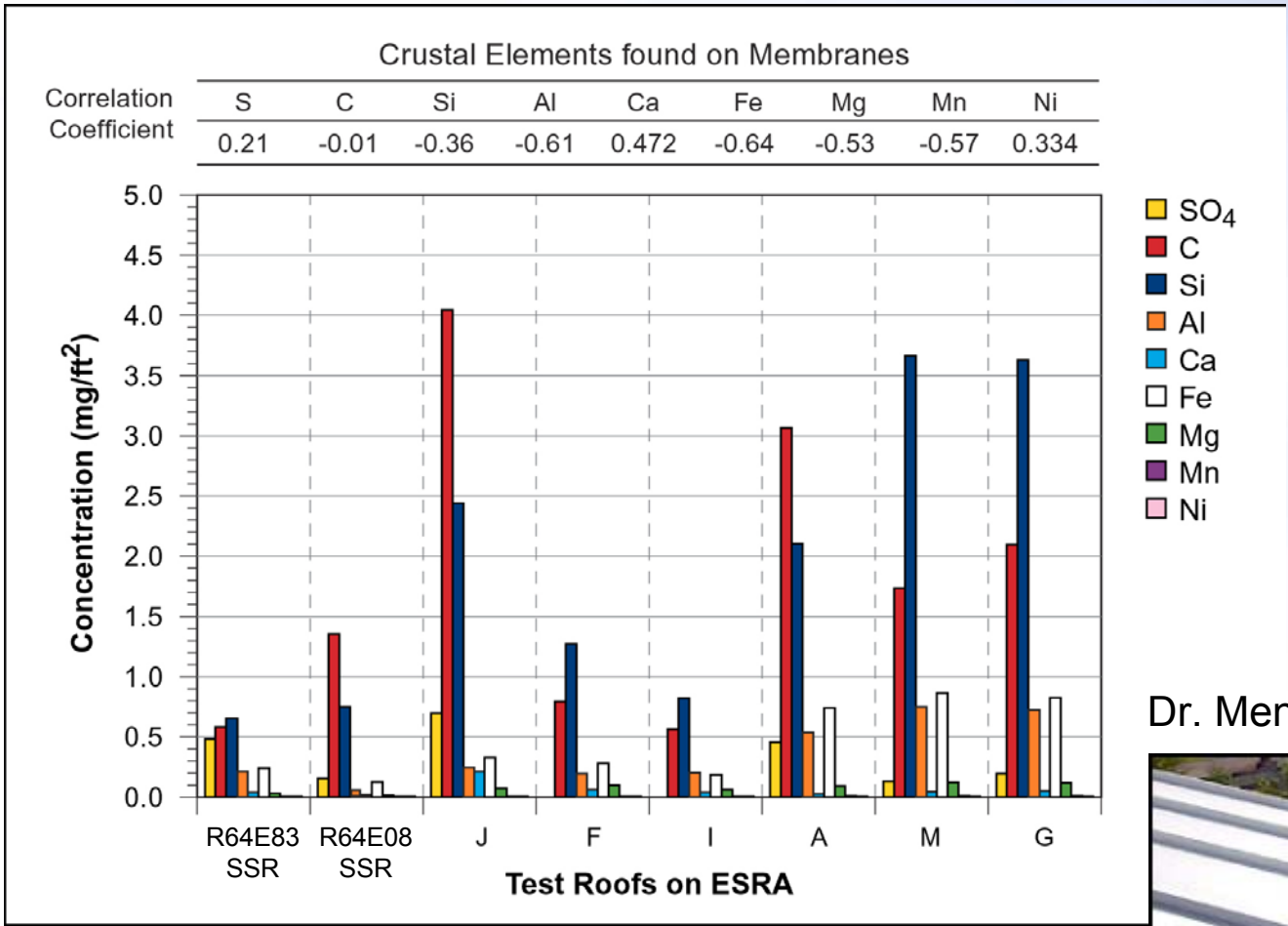
- Monroeville, PA

Biomass As Measured By PLFA

- Community Biomass range 10^6 to 10^8 cells per ft^2
- Grassland soils contain significantly more bacteria than fungi

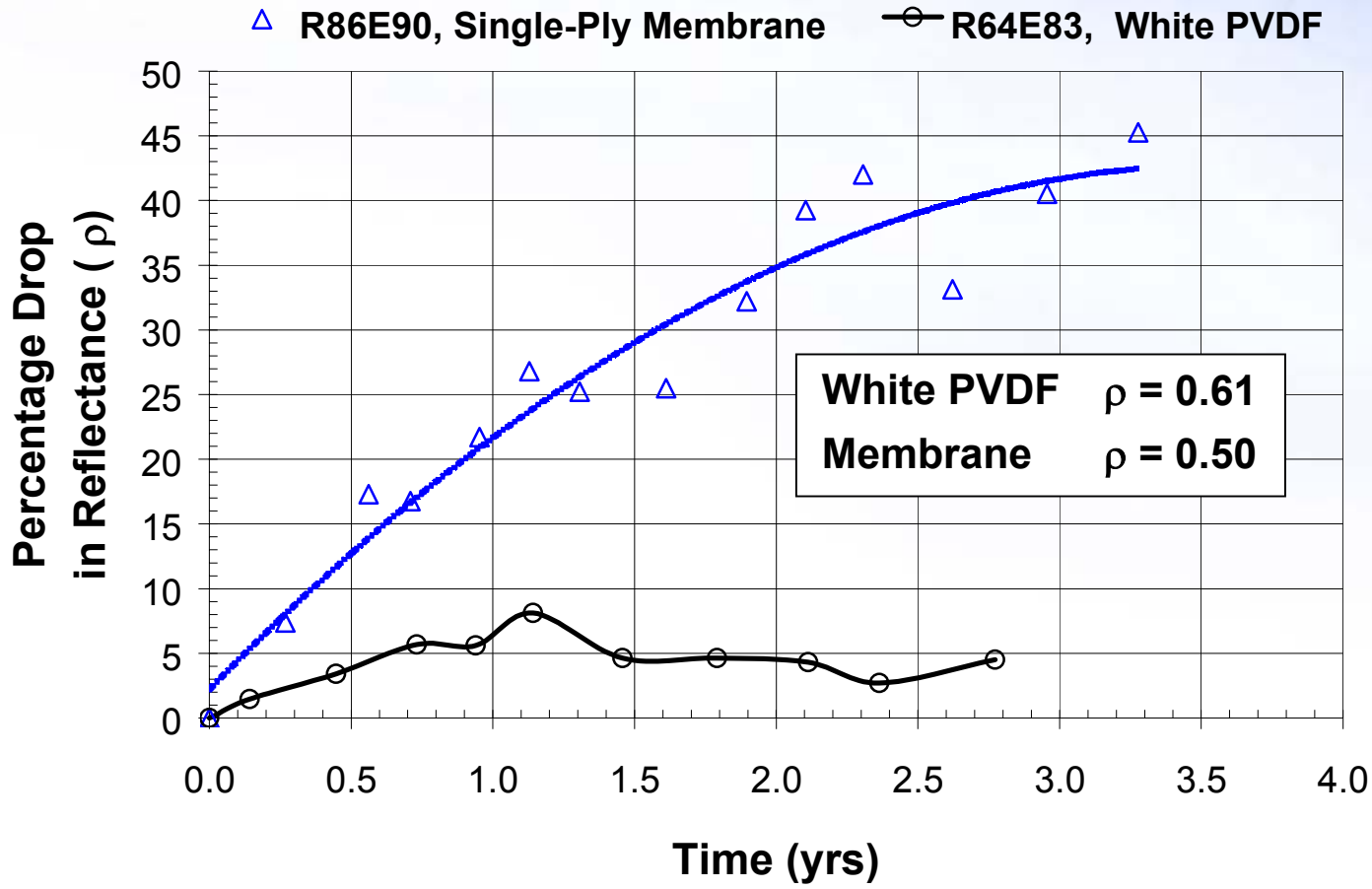


Crustal Elements (DUST) Drive The Drop In Reflectance



Dr. Meng-Dawn Cheng

White Polyvinylidene Fluoride (PVDF) Has Higher Reflectance After 2 Yrs



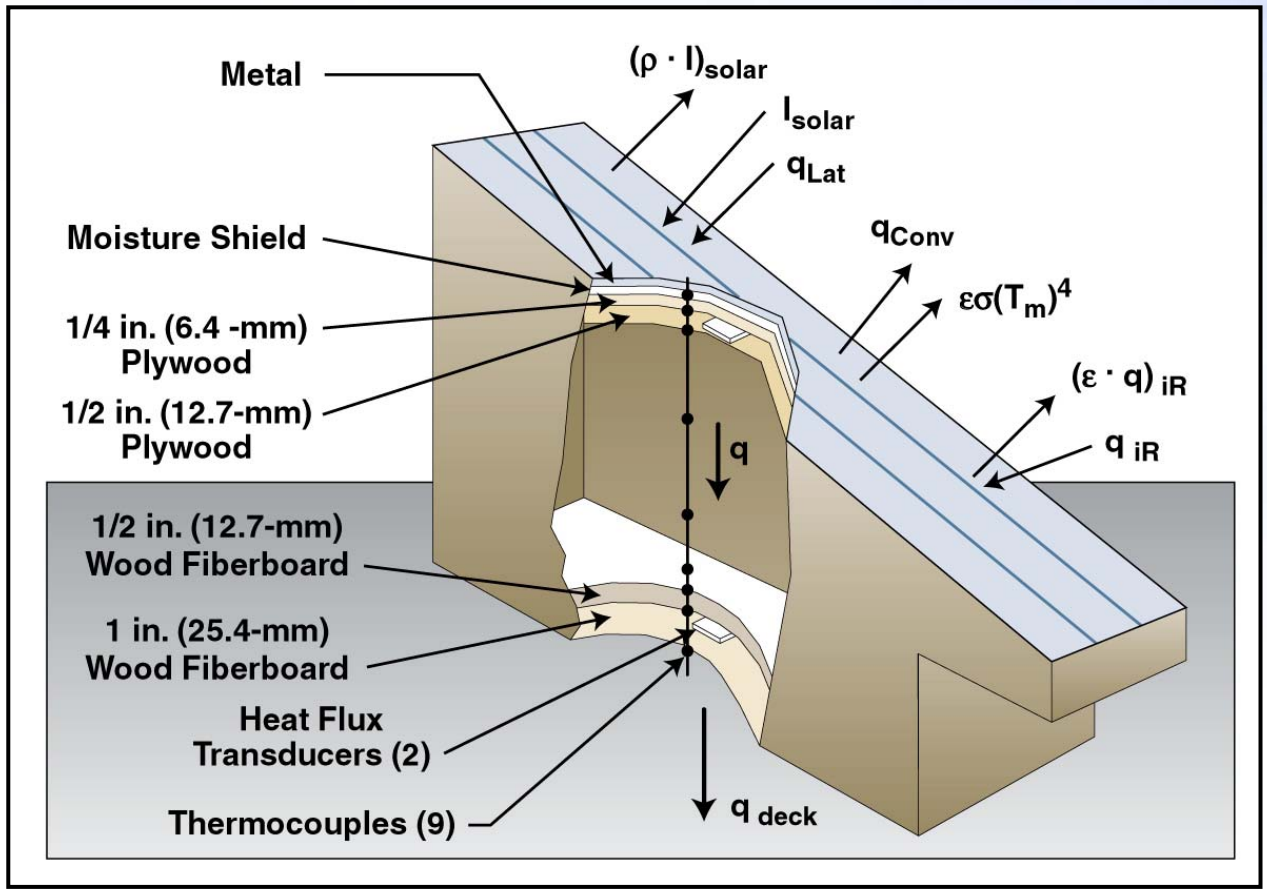
2.6.3 Steep-slope Assembly Testing at ORNL

- Objective: Select appropriate cool color pigments, apply them to roofing materials and field test the roof products on the Envelope Systems Research Apparatus (ESRA) to document the effect of reflectance and emittance weathering on the thermal performance of the cool pigment roof systems
- Deliverables:
  - Whole-Building Energy Model Validation
  - Presentation at the Pacific Coast Builders Conference
  - Steep Slope Assembly Test Report
- Schedule: 6/1/02 – 10/1/05

Our Test Facilities

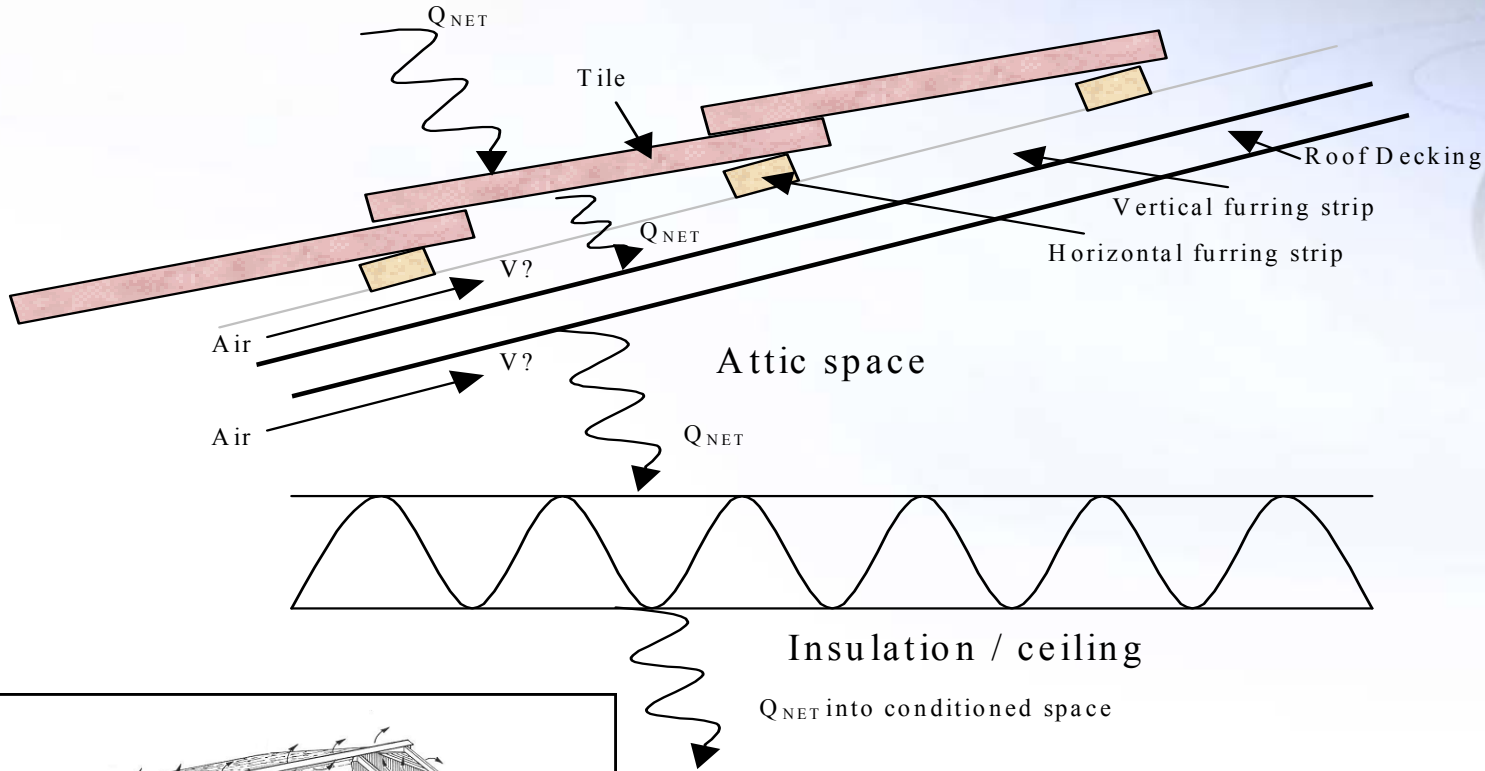
- Some Sixty Roofs Under Evaluation
- Residential & Commercial Markets
- AISI, MCA, NamZAC, NCCA, MBMA, SPRI and RCMA

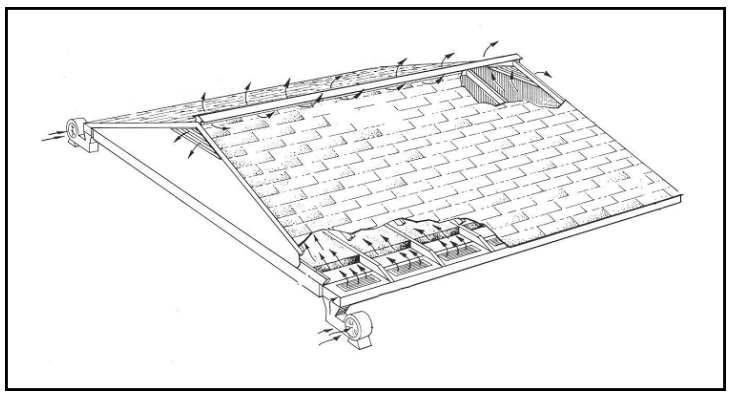
Steep-Slope Roof Assembly



Flurry of Activity to Finish before Hurricane Irene Hit

Key Issue: Venting between Roof Deck and Tile or Metal Roof





2.6.4 Product Useful Life Testing

- 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 Test Report
- Schedule: 5/1/04 – 6/1/05

Hypothesis:Cool roofing materials last longer

- Perform accelerated testing of roofing materials of the same color (cool vs. standard)
- Primary focus on shingles and wood shakes
- In collaboration with industry, develop required ASTM standards

2.7 Technology Transfer and Market Plan

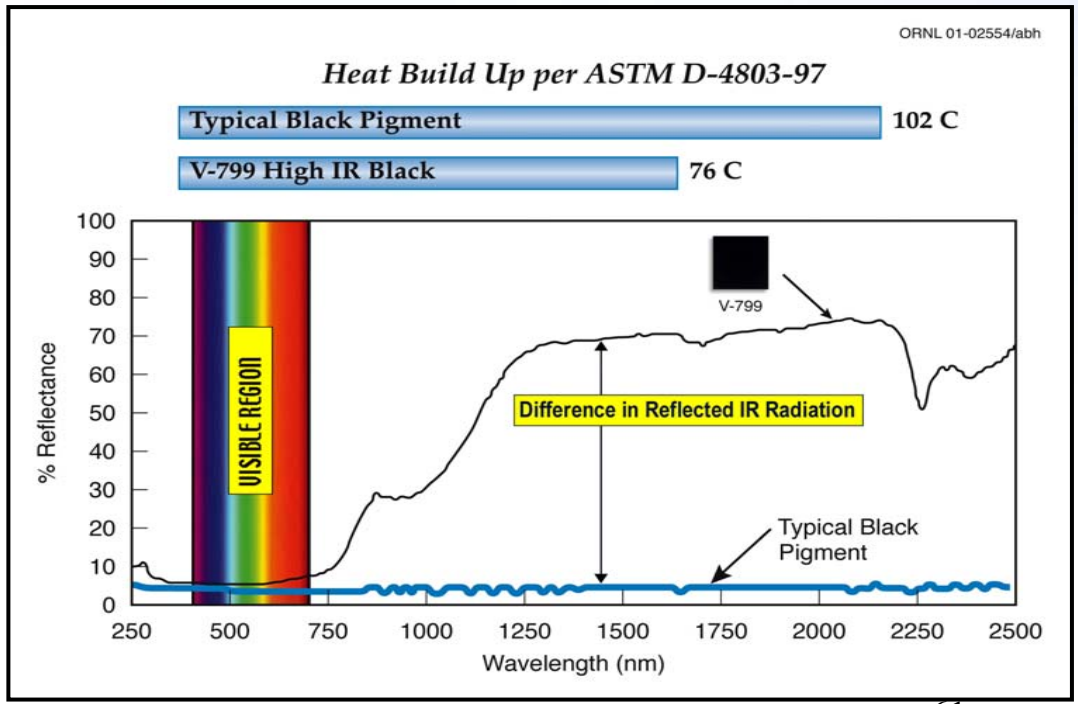
- Objective: Make cool-colored roofing materials a market reality within three to five years
- Subtasks:
  - Technology Transfer
  - Market Plan
  - Title 24 Code Revisions

2.7.1 Technology Transfer

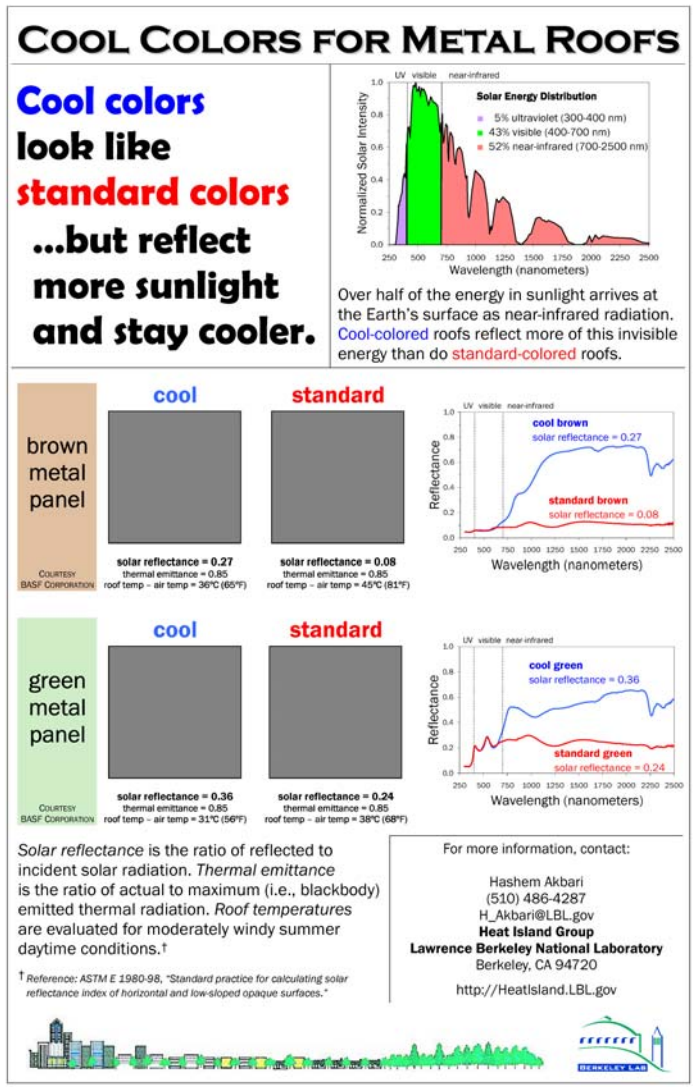
- Objective: Support the roofing industry by promoting and accelerating the market penetration of cool color pigmented roof products
- Deliverables:
  - Publication of results in industry magazines and refereed journal articles
  - Participation in buildings products exhibition, such as the PCBC
  - Brochure summarizing research results and characterizing the benefits of cool colored roofing materials
- Schedule: 6/1/03 – 6/1/05

Publications

- Miller, W.A., Desjarlais A.O., Loye, K.T. and Blonski, R.P. “Cool Color Roofs with Complex Inorganic Color Pigments.” in American Council for an Energy-Efficient Economy, proceedings of 2002 ACEEE Summer Study on Energy Efficiency in Buildings.



Brochure



Cool Colors for Metal Roofs

Cool colors look like standard colors ...but reflect more sunlight and stay cooler.

Over half of the energy in sunlight arrives at the Earth's surface as near-infrared radiation. Cool-colored roofs reflect more of this invisible energy than do standard-colored roofs.

	cool	standard
brown metal panel	solar reflectance = 0.27 thermal emittance = 0.85 roof temp – air temp = 36°C (65°F)	solar reflectance = 0.08 thermal emittance = 0.85 roof temp – air temp = 45°C (81°F)
green metal panel	solar reflectance = 0.36 thermal emittance = 0.85 roof temp – air temp = 31°C (56°F)	solar reflectance = 0.24 thermal emittance = 0.85 roof temp – air temp = 38°C (68°F)

Courtesy BASF Corporation

Solar reflectance is the ratio of reflected to incident solar radiation. *Thermal emittance* is the ratio of actual to maximum (i.e., blackbody) emitted thermal radiation. *Roof temperatures* are evaluated for moderately windy summer daytime conditions.†

† *Reference: ASTM E 1980-98, "Standard practice for calculating solar reflectance index of horizontal and low-sloped opaque surfaces."*

For more information, contact:

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2.7.2 Market Plan

- Objective: Develop and initiate actions to facilitate the market adoption of cool-colored roofing products
- Deliverables:
  - Market Plan(s)
- Schedule: 5/1/05 – 6/1/05

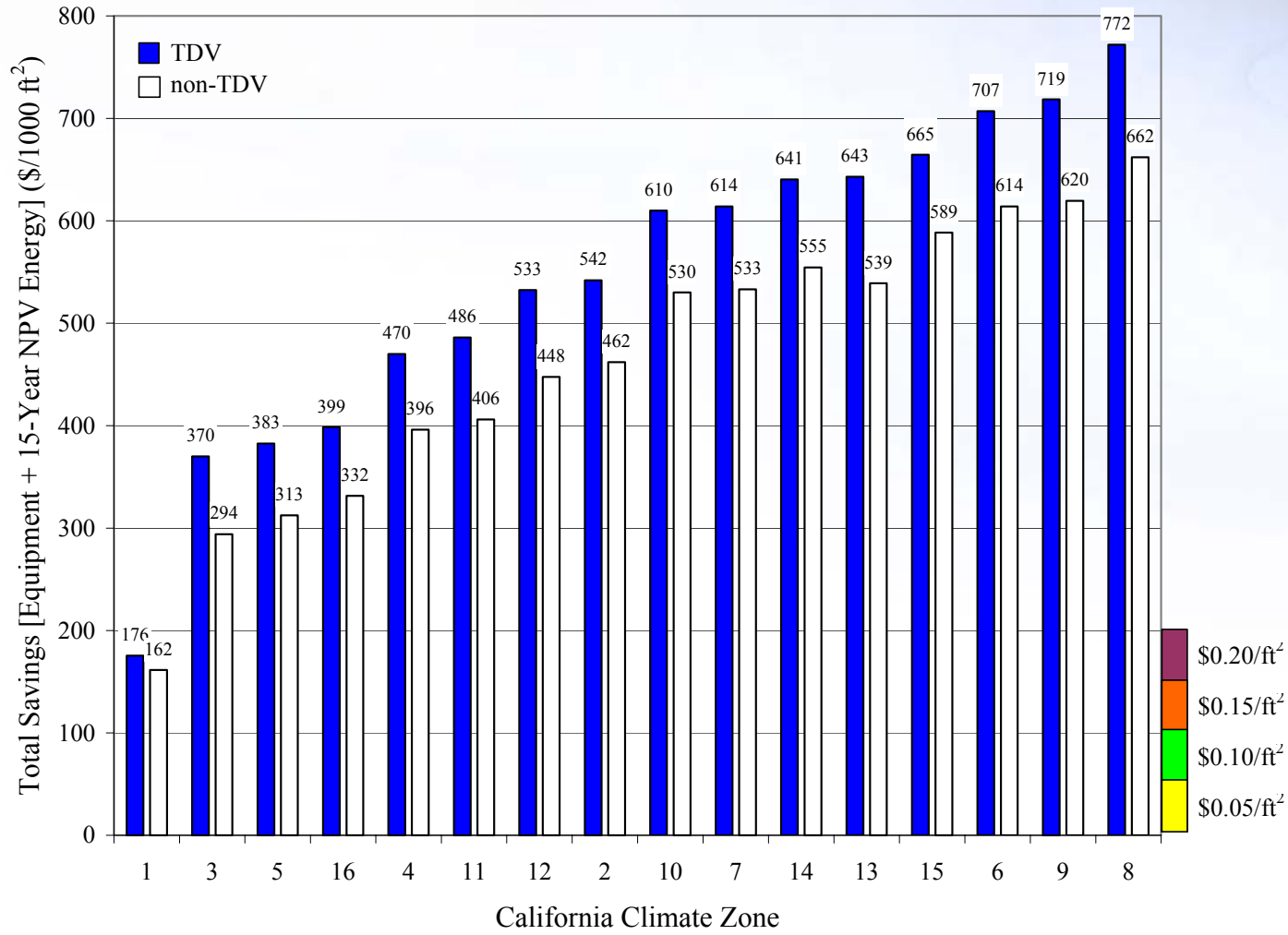
2.7.3 Title 24 Code Revisions

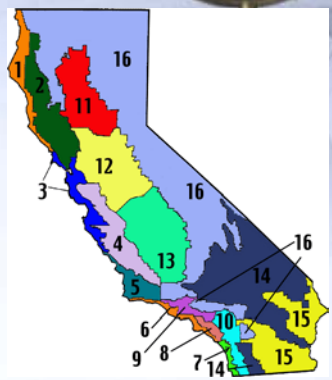
- Objective: Collaborate with Title 24 to revise the code to include cool colored roofs for sloped roof buildings
- Deliverables:
  - Document coordination with Cool Roofs Rating Council in monthly progress reports
  - Title 24 Database
- Schedule: 5/16/02 – 6/1/05

Code Change Proposal for Nonresidential Title 24 Prescriptive Requirements

- Prescriptive Requirements
  - adds requirement for non-residential buildings with low-sloped roofs (initial emittance $\varepsilon \geq 0.75$, reflectance ≥ 0.70)
- Overall-Envelope and Performance Approach
  - allows compliance credits or penalties
- Changes requirements for cool roofing products
  - qualifies low-emittance products with very high reflectance [initial emittance $\varepsilon < 0.75$, reflectance $\geq 0.70 + 0.34 \times (0.75 - \varepsilon)$]

Total Savings (15-Year NPV of Energy + Equipment Downsizing, $/1000 ft²)





Projected NR New Construction Annual Statewide Savings

- Increase in NR roof area..... **72 Mft^2**
- Increase in low-sloped NR roof area.....**46 Mft^2**
- Electricity savings.....**14.8 GWh**
- Natural gas deficit.....**199 ktherms**
- Source energy savings..... **132 GBTU**
- Peak power demand savings.....**9.2 MW**
- annual equipment savings..... **$4.6M**
- TDV NPV energy savings..... **$22.9M**
- TDV total savings (energy + equip)..... **$27.5M**
- non-TDV NPV savings..... **$18.9M**
- non-TDV total savings (energy + equip)... **$23.5M**

Plans

- Coordinate with the Title 24 staff
- Develop code change proposal(s)

Schedule of PAC meetings

	Meeting	Date
1.	Project Kick-off Meeting (completed)	May 16, 2002
2.	Project Advisory Committee Meeting 1 (PAC1)	September 12, 2002
3.	Project Advisory Committee Meeting 2 (PAC2)	March 6, 2003
4.	Project Advisory Committee Meeting 3 (PAC3)	September 4, 2003
5.	Critical Path Review Meeting 1 (CPR1)	October 3, 2003 (or September 5, 2003)
6.	Project Advisory Committee Meeting 4 (PAC4)	March 4, 2004
7.	Project Advisory Committee Meeting 5 (PAC5)	September 2, 2004
8.	Critical Path Review Meeting 2 (CPR2)	October 7, 2004 (or September 3, 2004)
9.	Project Advisory Committee Meeting 6 (PAC6)	March 3, 2005
10.	Project Final Meeting	October 6, 2005

Cool Colors Project Website

- Project information (including copies of this presentation) will be available online next week at

http://CoolColors.LBL.gov