

Cool Roof Colored Materials

A California PIER Program

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Cool 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)

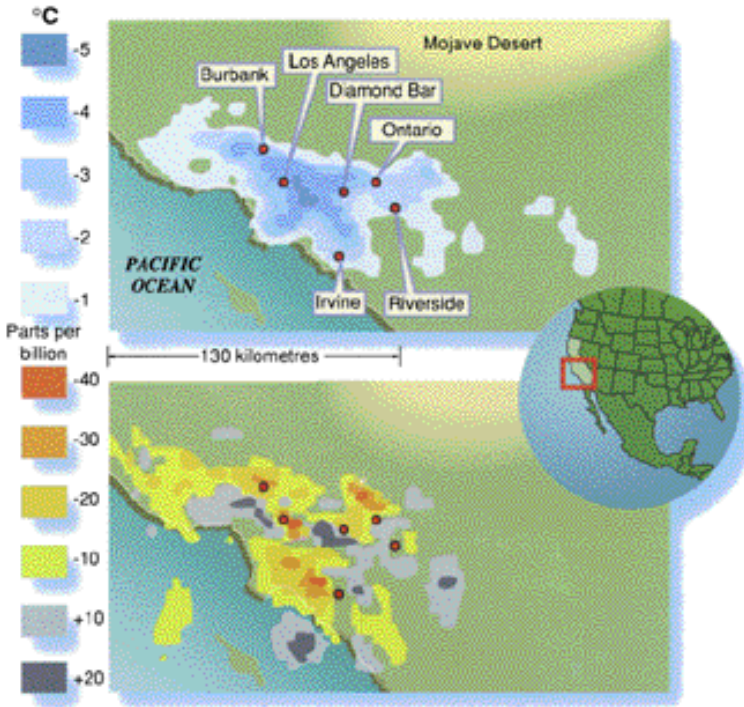
👉 Indirect Effect: reflective roofs and pavements

- transfer less heat to air
- lower ambient air temperature ~ 2-3 °F
- reduce smog ~ 5%

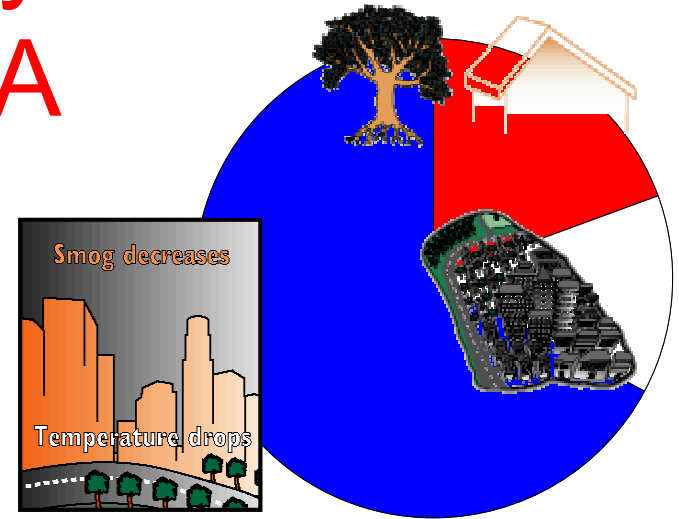


Simulated Meteorology and Air-quality Effects in LA

Temperature Change



Ozone Concentration Change



- 👉 **Savings for Los Angeles**
 - Direct, \$100M/year
 - Indirect, \$70M/year
 - Smog, \$360M/year
- 👉 **Estimate of national savings: \$5B/year**



Cool Roofing Materials Availability

- ☞ Low-sloped roofs: many materials available
 - coating (white)
 - single-ply membrane (white)
 - painted metal (white, cool colored)
- ☞ High-sloped roofs: limited material availability
 - tile
 - metal
 - shake
- ☞ **Over 70% of high-sloped roofs use asphalt shingles**



ISP/LBNL Shingle With Whiter Roofing Granules

REFLECTING SOLAR HEAT

Black Shingle



R = 5 %, T = 180 °F

Conventional White Shingle



R = 29 %, T = 157 °F

Advanced White Shingle



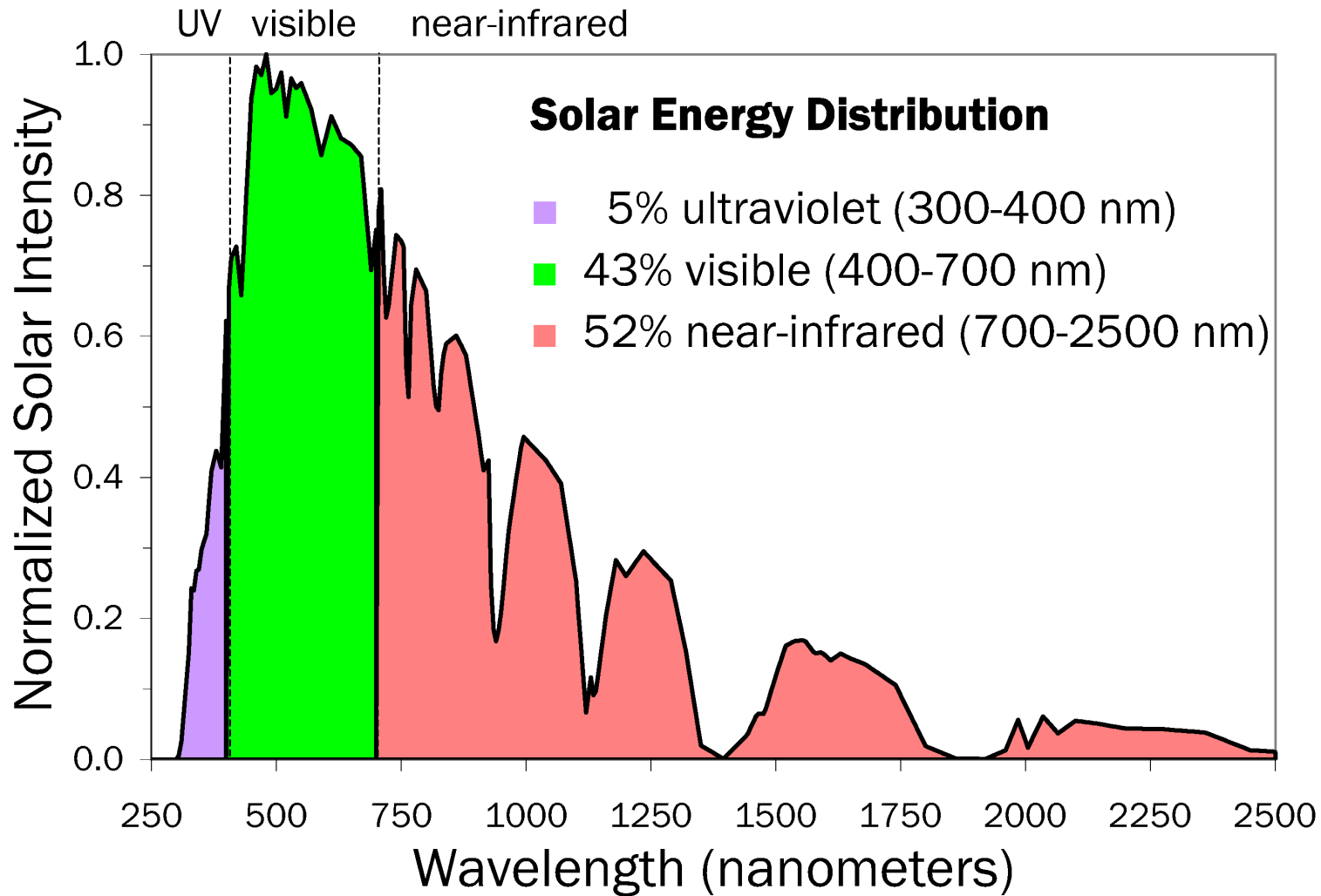
R = 60 %, T = 128 °F



White Roof is Nice, but Some Like it Colored

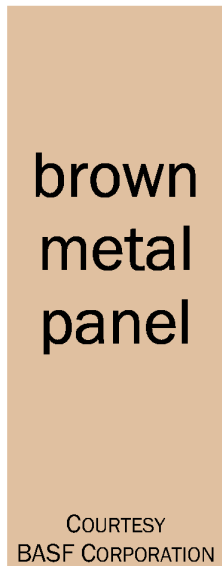


Solar Energy Distribution at Earth



Cool and Standard Browns

☞ Cool brown 16 °F cooler than standard brown



cool

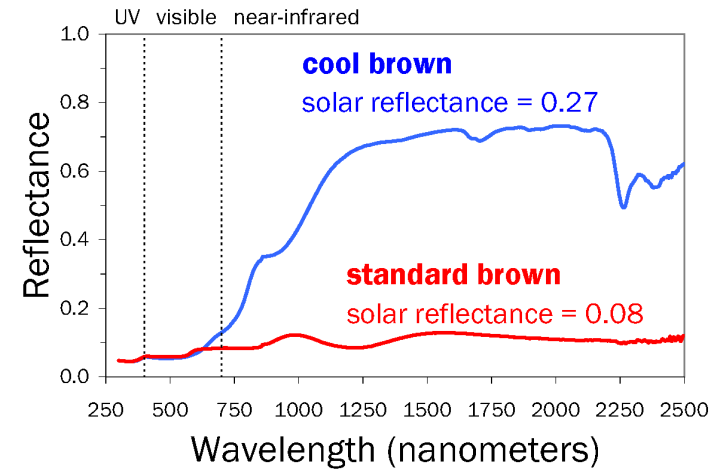


solar reflectance = 0.27
thermal emittance = 0.85
roof temp - air temp = 36°C (65°F)

standard



solar reflectance = 0.08
thermal emittance = 0.85
roof temp - air temp = 45°C (81°F)



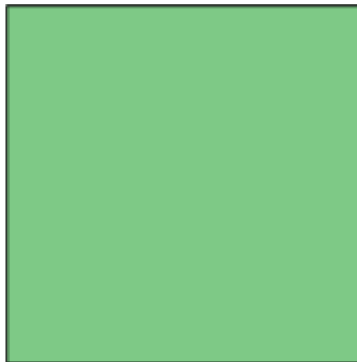
Cool and Standard Greens

- Cool green 12 °F cooler than standard green

green
metal
panel

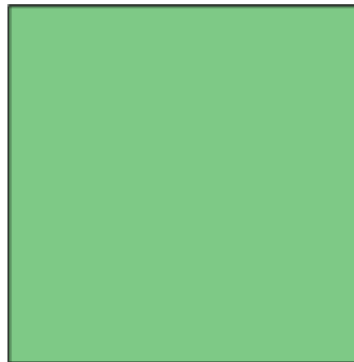
COURTESY
BASF CORPORATION

cool

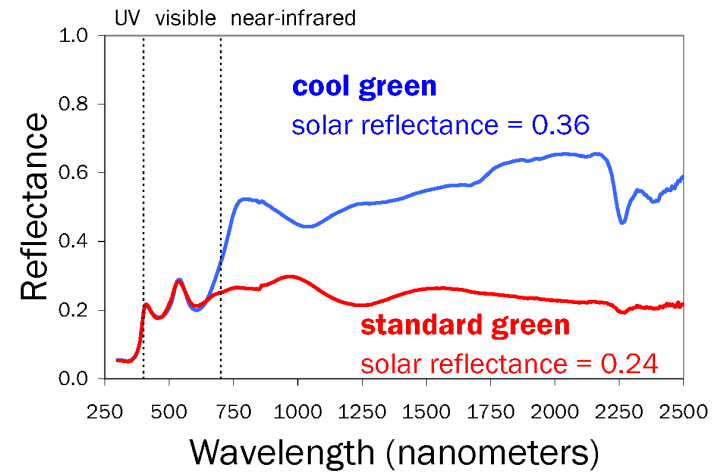


solar reflectance = 0.36
thermal emittance = 0.85
roof temp - air temp = 31°C (56°F)

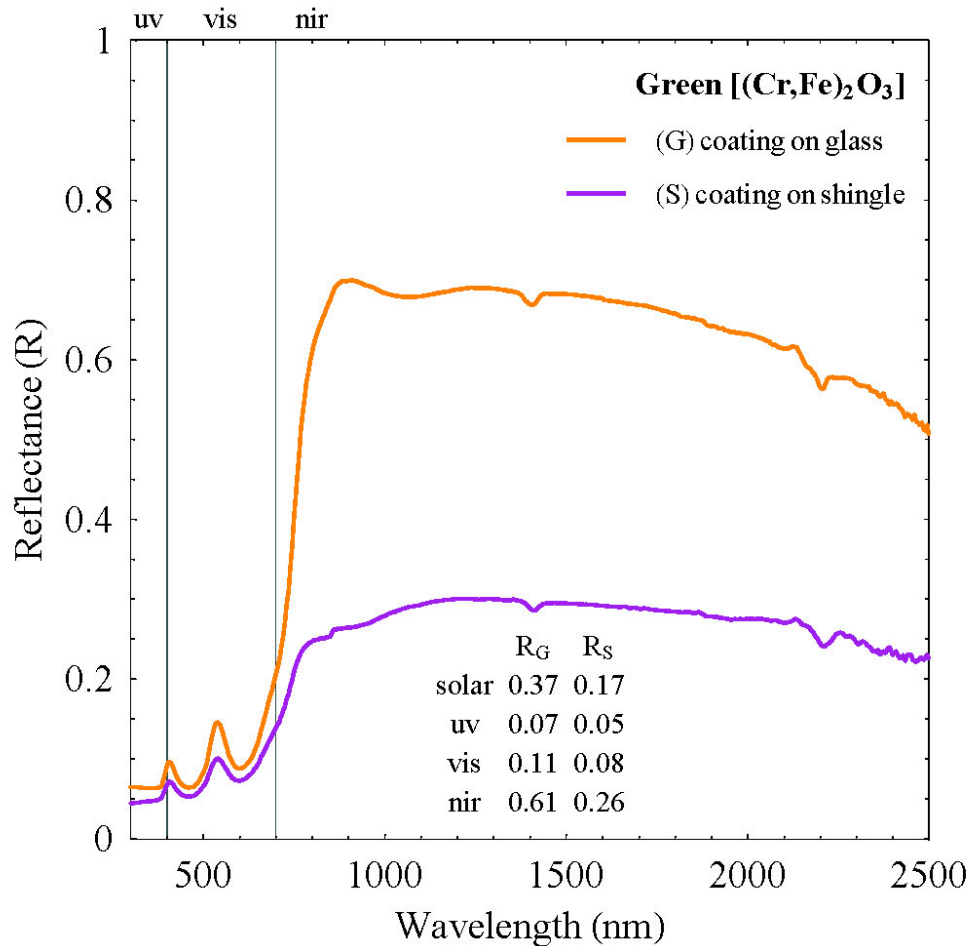
standard



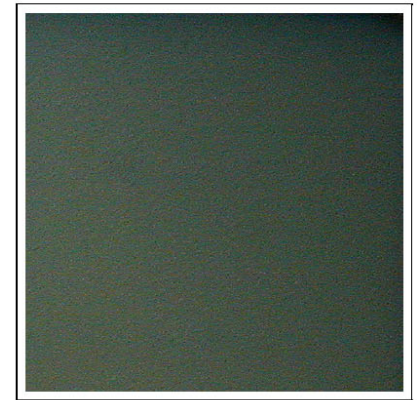
solar reflectance = 0.24
thermal emittance = 0.85
roof temp - air temp = 38°C (68°F)



From Cool Pigments to Cool Shingles: a Difficult Problem



R= 37%



(G) coating on glass

R= 17%



(S) coating on shingle



Technical Goals

- 👉 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



National Labs and Industrial Partnership

- 👉 Program is sponsored by **CEC/PIER**
- 👉 **ORNL and LBNL are teaming with industry**
- 👉 **Broad industrial partnership**

👉 Industry partners

- 3M
- American Roof Tile Coating
- BASF
- Custom-Bilt Metals
- Elk Manufacturing
- Ferro
- GAF
- Hanson Roof Tile
- ISP Minerals
- MCA
- Monier Lifetile
- Shepherd Color Company



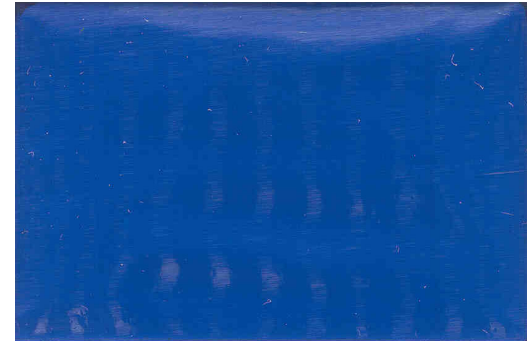
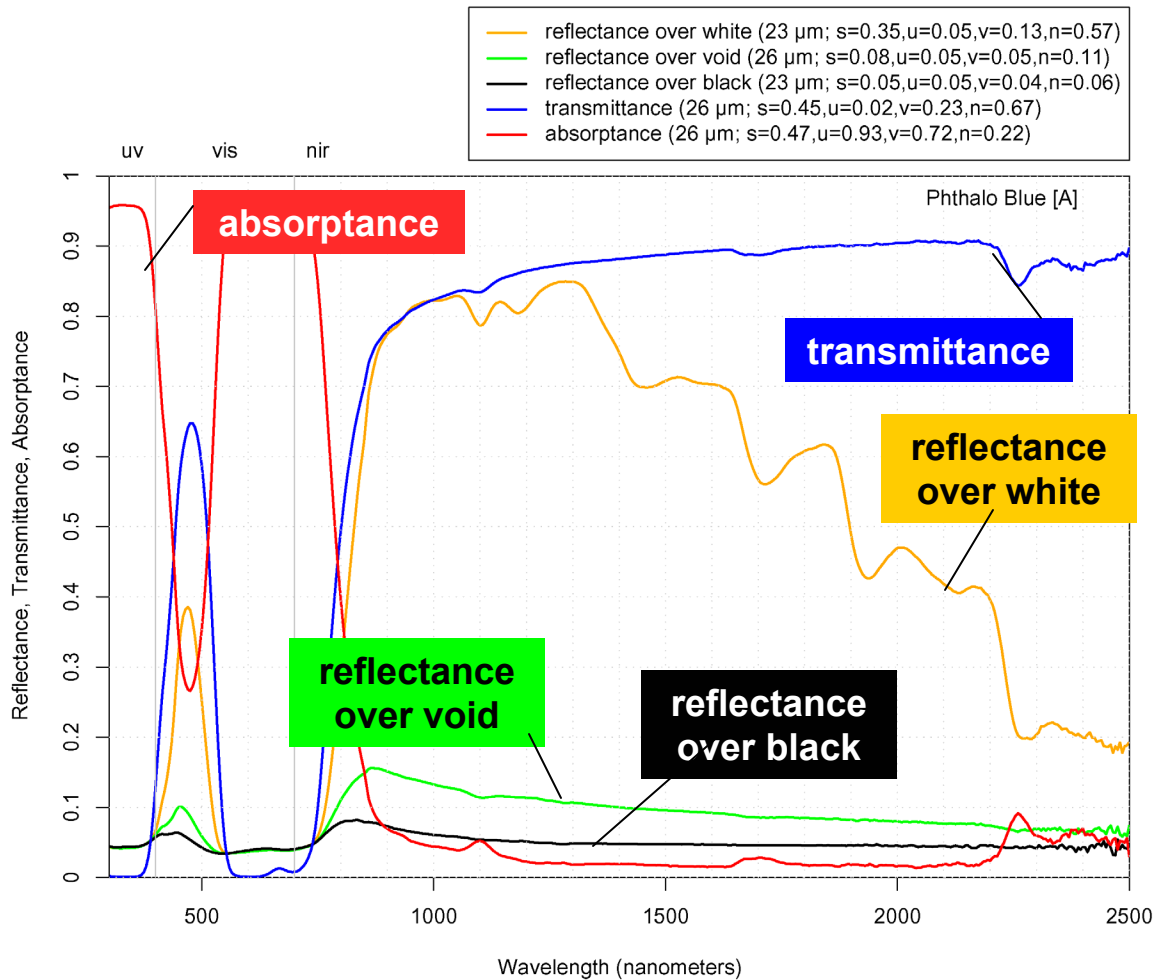
Technical Tasks

- 👉 Develop cool colored coatings
- 👉 Develop prototype cool-colored roofing materials
- 👉 Field-testing and product useful life testing
- 👉 Technology transfer and market plan



Optical Measurement

Example: Phthalo Blue



phthalo blue
over opaque white



phthalo blue
over opaque black

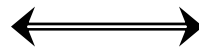


Adaptation of Kubelka-Munk Theory

- 👉 Kubelka-Munk (K-M) theory relates *paint film* properties to *pigment* properties

PAINT FILM PROPERTIES

- reflectance
- transmittance
- thickness



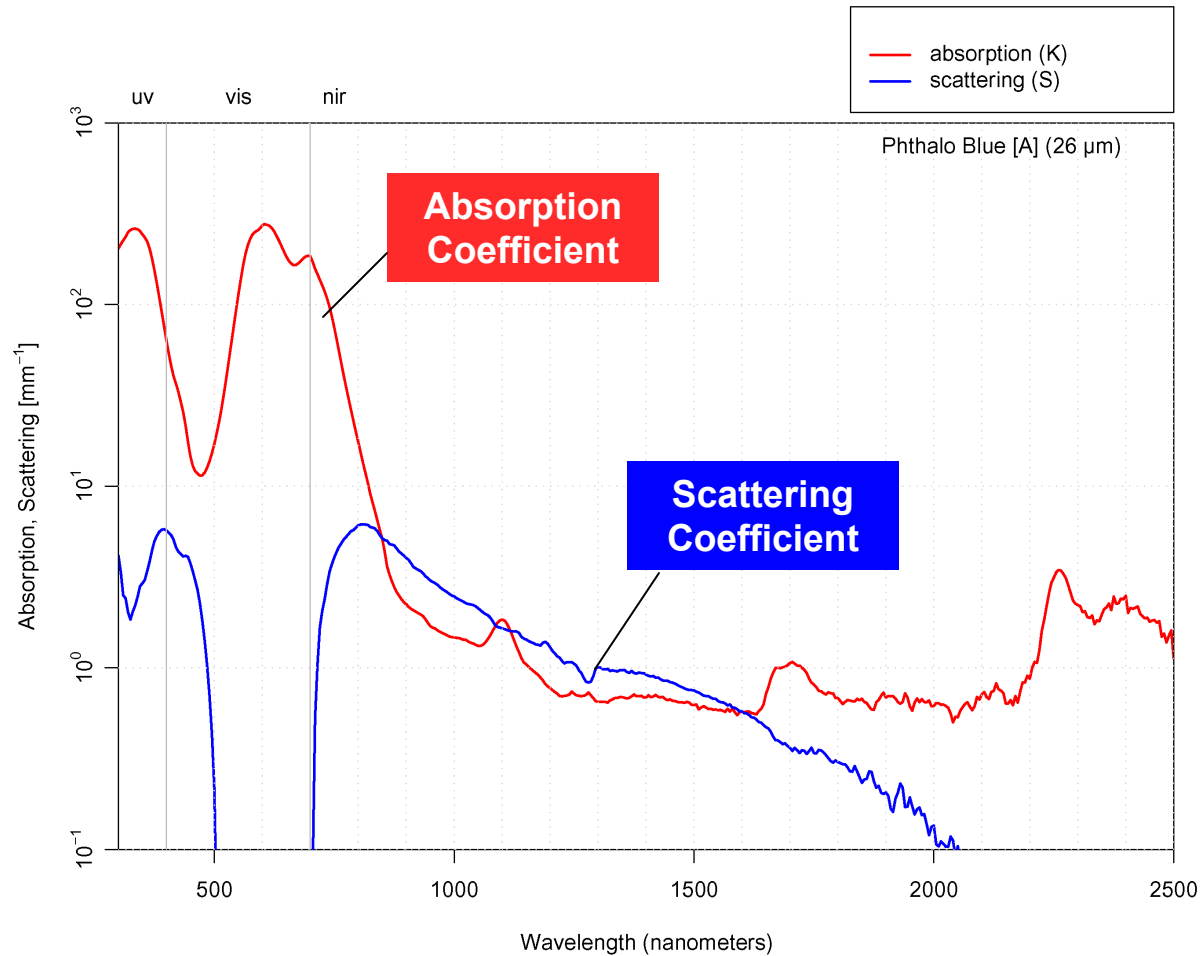
PIGMENT PROPERTIES

- scattering coefficient
- absorption coefficient

- 👉 K-M theory adapted by LBNL to better characterize pigments that weakly scatter light
- 👉 Weak scattering often found in the near-infrared (NIR) spectrum, about which we care greatly



Calculation Example: Phthalo Blue



Examples of Cool Pigments

☞ Opaque, scattering pigments

- TiO_2 white!
- Nickel and chrome titanates – yellows
- Infrared-reflective blacks – $(\text{Fe,Cr})_2\text{O}_3$ – and many related compounds
- Co_2TiO_4 – teal (bluish green)
- TiO_2 on mica flakes - various colors
- FeOOH yellow
- Fe_2TiO_4 – iron titanium oxide spinel – brown

☞ Transparent pigments

- Cobalt chromite and aluminate blues
- Various organic pigments (phthalo blue, quinacridone red,...)



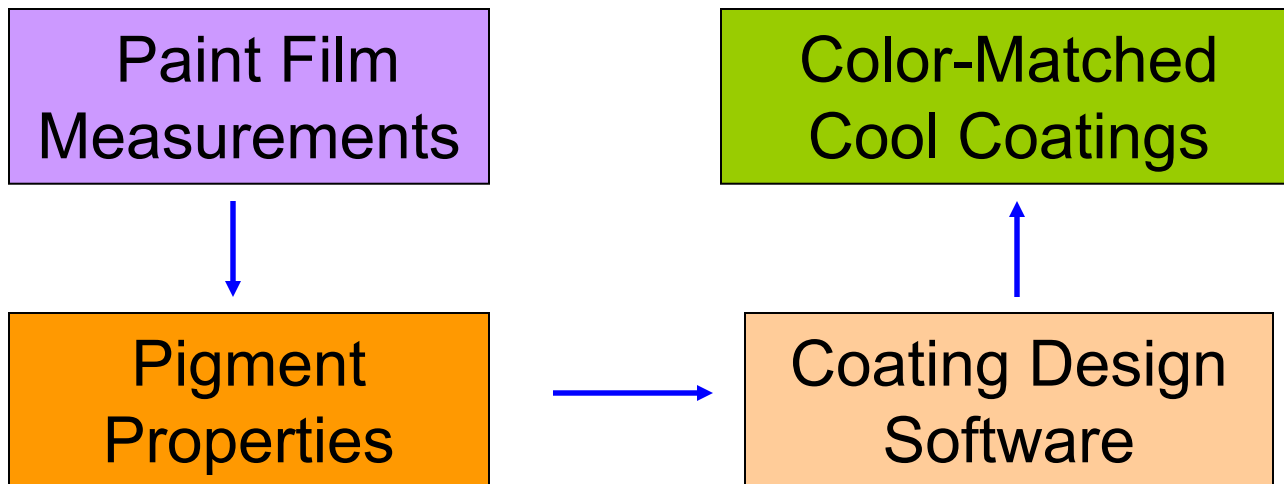
Examples of Hot Pigments

- ☞ Carbon black (also lamp black, ivory black)
- ☞ Fe_3O_4 black (magnetite)
- ☞ Copper chromite black
- ☞ Raw umber (brown)
- ☞ Burnt sienna (brown)
- ☞ Prussian blue ($\text{C}_6\text{FeN}_6 \cdot \text{H}_4\text{N}$)



Coating Design Software

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



Application of Cool Colors to Roofing Products

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



Innovative Engineering Methods: NIR-Reflective Undercoating

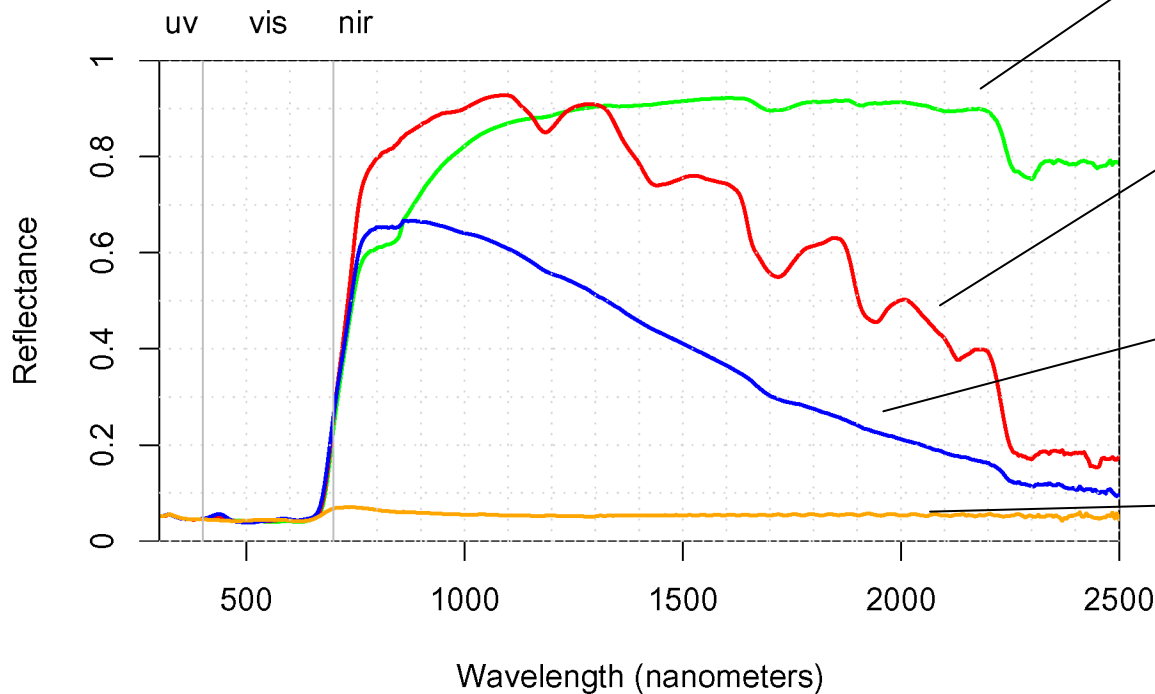
👉 Two-layer system

- top coat: thin layer of dioxazine purple (14-27 μm)
- undercoat or substrate:
 - aluminum foil ($\sim 25 \mu\text{m}$)
 - opaque white paint ($\sim 1000 \mu\text{m}$)
 - non-opaque white paint ($\sim 25 \mu\text{m}$)
 - opaque black paint ($\sim 25 \mu\text{m}$)



Dioxazine Purple Reflectances

- Dioxazine Purple / Aluminum Foil: $s=0.41, u=0.05, v=0.05, n=0.74$
- Dioxazine Purple / Opaque White: $s=0.42, u=0.05, v=0.05, n=0.75$
- Dioxazine Purple / Thin White: $s=0.30, u=0.05, v=0.05, n=0.53$
- Dioxazine Purple / Opaque Black: $s=0.05, u=0.05, v=0.05, n=0.06$



over aluminum
 $R_{\text{solar}} = 0.41$

over opaque white
 $R_{\text{solar}} = 0.42$

over non-opaque white
 $R_{\text{solar}} = 0.30$

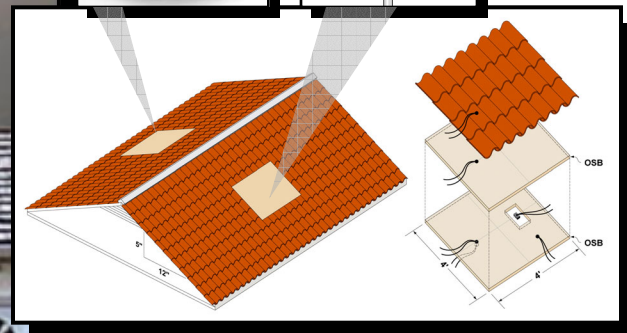
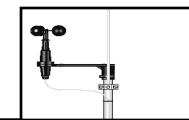
over opaque black
 $R_{\text{solar}} = 0.05$



Building Energy-Use Measurements at California Demonstration Sites

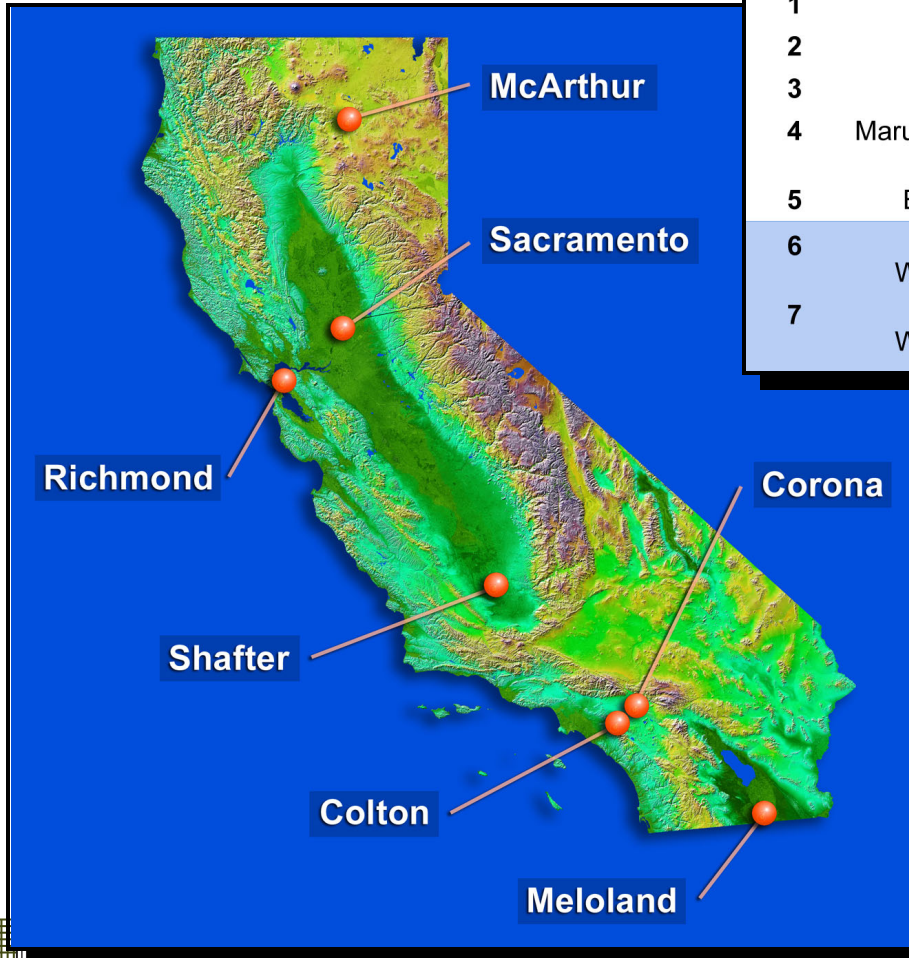


Monitoring six buildings in Sacramento



Materials Testing at Weathering Farms in California

CA Topographic Map



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

Field Exposure Sites



Steep-slope Assembly Testing

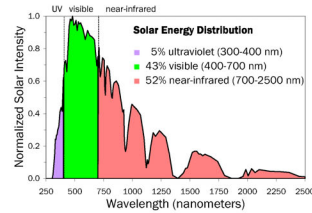
- **Some Sixty Roofs Under Evaluation**
- **Residential & Commercial Markets**
- **AISI, MCA, NamZAC, NCCA, MBMA, SPRI and RCMA**





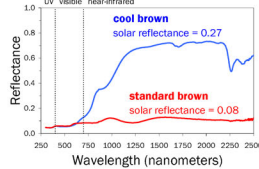


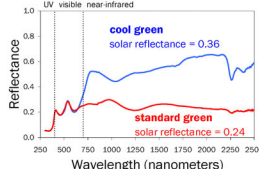
Brochure

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			
<small>COURTESY BASF CORPORATION</small>	<small>solar reflectance = 0.27 thermal emittance = 0.85 roof temp - air temp = 36°C (85°F)</small>	<small>solar reflectance = 0.08 thermal emittance = 0.85 roof temp - air temp = 45°C (81°F)</small>	
green metal panel			
<small>COURTESY BASF CORPORATION</small>	<small>solar reflectance = 0.36 thermal emittance = 0.85 roof temp - air temp = 31°C (86°F)</small>	<small>solar reflectance = 0.24 thermal emittance = 0.85 roof temp - air temp = 38°C (68°F)</small>	

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."

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Cool Colors Project Website

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

<http://CoolColors.LBL.gov>

