

Cool Roofing Technologies

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STEAB Visit to LBNL

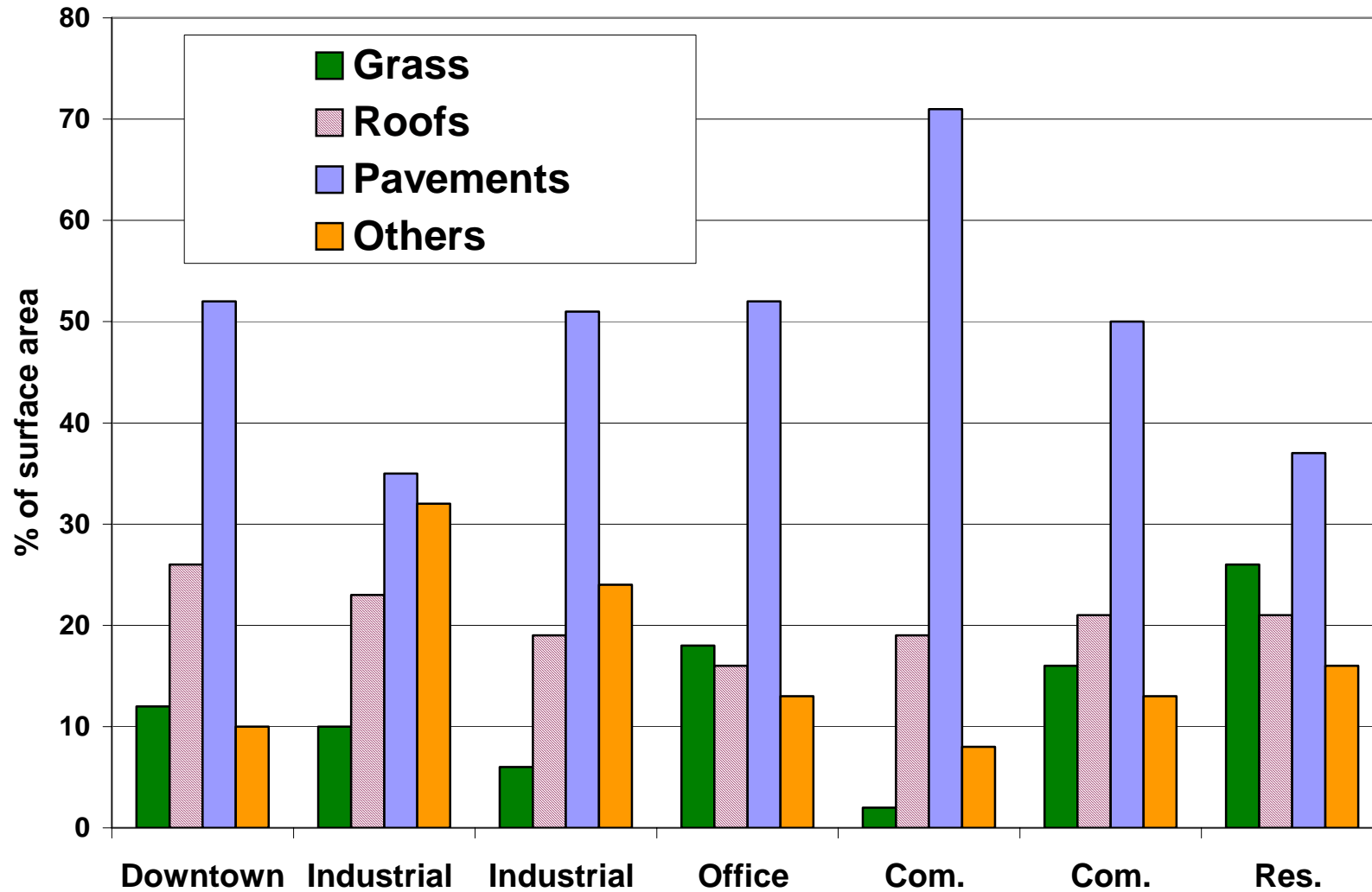
August 14, 2007



Orthophoto of Sacramento



Under the Canopy Fabric of Sacramento, CA



Cooling roofs by increasing solar reflectance

- A conventional dark roof **absorbs most sunlight**
- Increasing **solar reflectance**
 - reduces solar heat gain
 - lowers roof temperature
- High **thermal emittance**
 - facilitates radiative cooling
 - helps keep roof temperature low
- Lowering roof temperature can reduce
 - building cooling electricity use
 - peak power demand
 - ambient air temperature



Environmental impacts of cooling roofs

- Benefits

- increased human comfort
- slowed smog formation
- mitigation of urban heat islands in summer
- decreased waste from disposal of roofs

- Penalties

- slightly higher wintertime heating energy use
- degraded wintertime urban air quality



Direct and Indirect Effects of Light-Colored Surfaces

- **Direct Effect**

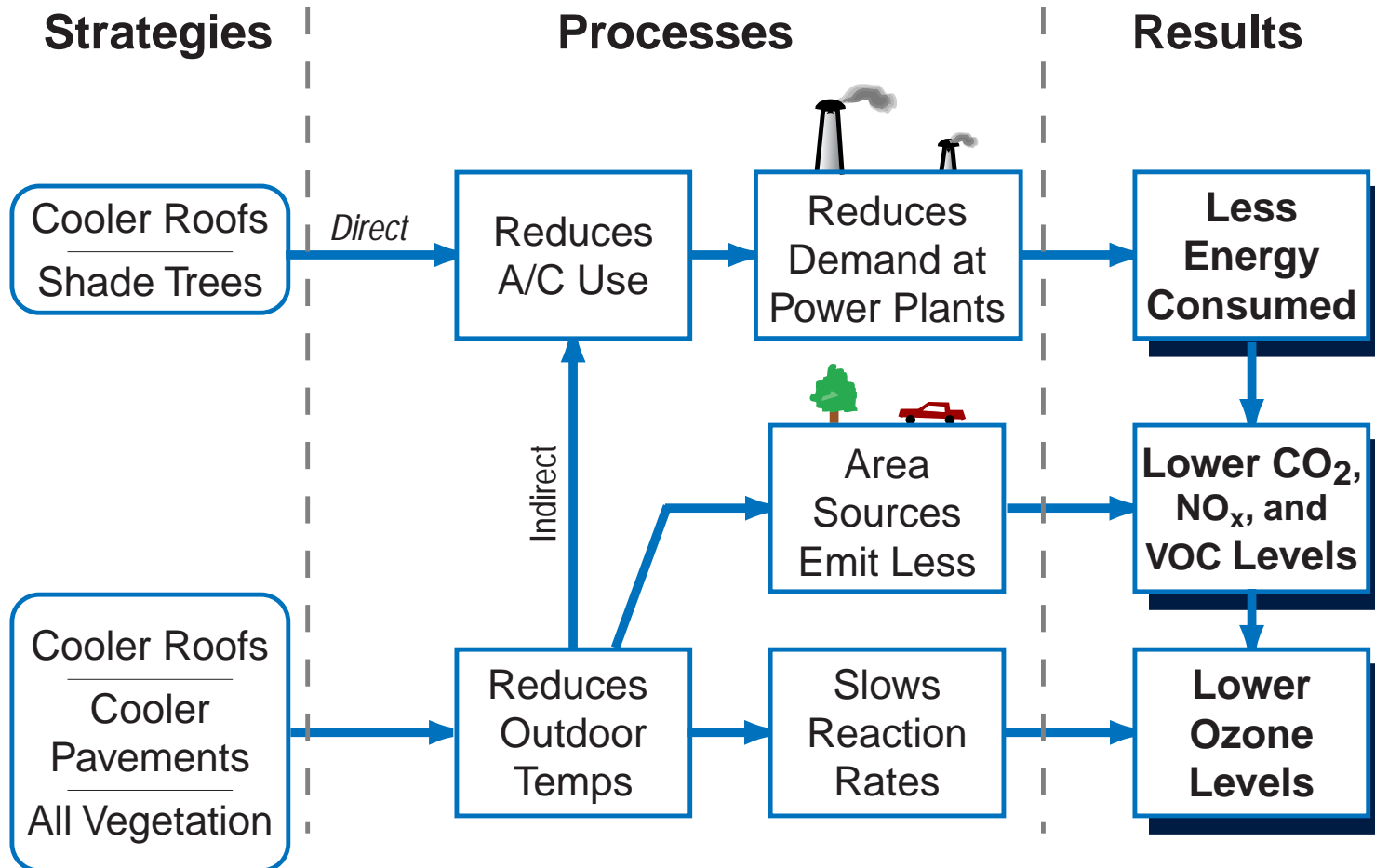
- **Light-colored roofs** reflect solar radiation, reduce air-conditioning use

- **Indirect Effect**

- Light-colored surfaces in a neighborhood alter surface energy balance; result in lower ambient temperature



Methodology: Energy and Air-Quality Analysis



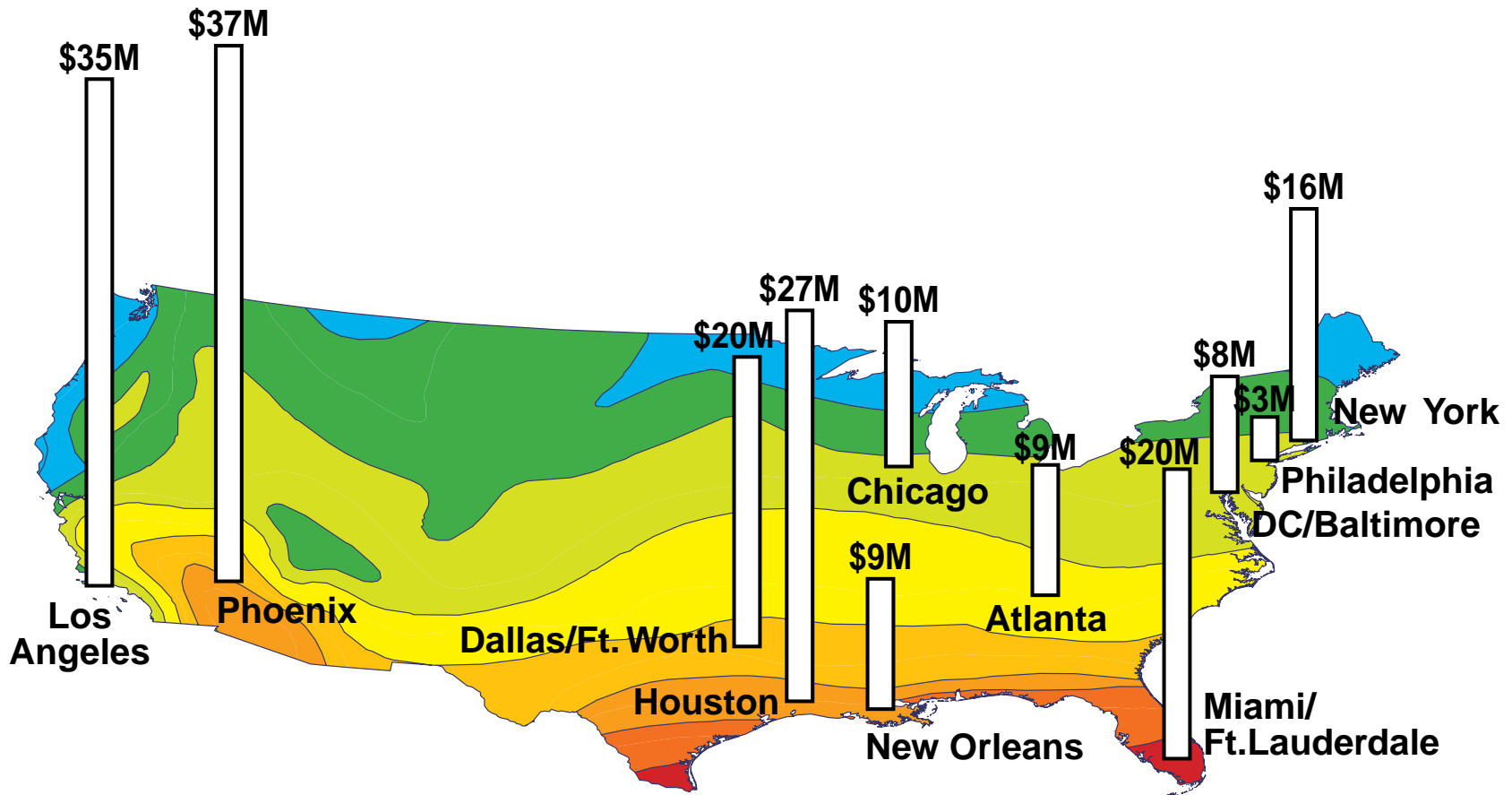
White Roofs: Measured Cooling Savings

- *Sacramento*: 80% in a house; 35% in two school bungalows
- *Florida*: 10%-43% in several houses, average 19%
- *California and Florida*: 5%–20% in several commercial buildings



Potential National Savings from Changing Roof Reflectivity

Peak Demand Savings in All U.S.



“Cool” products for low-sloped roofs

- Many materials available
 - coating (white)
 - single-ply membrane (white)
 - painted metal (white, cool colored)
- Products are rated by the Cool Roof Rating Council (CRRC)
 - labels solar reflectance, thermal emittance
 - website: www.coolroofs.org



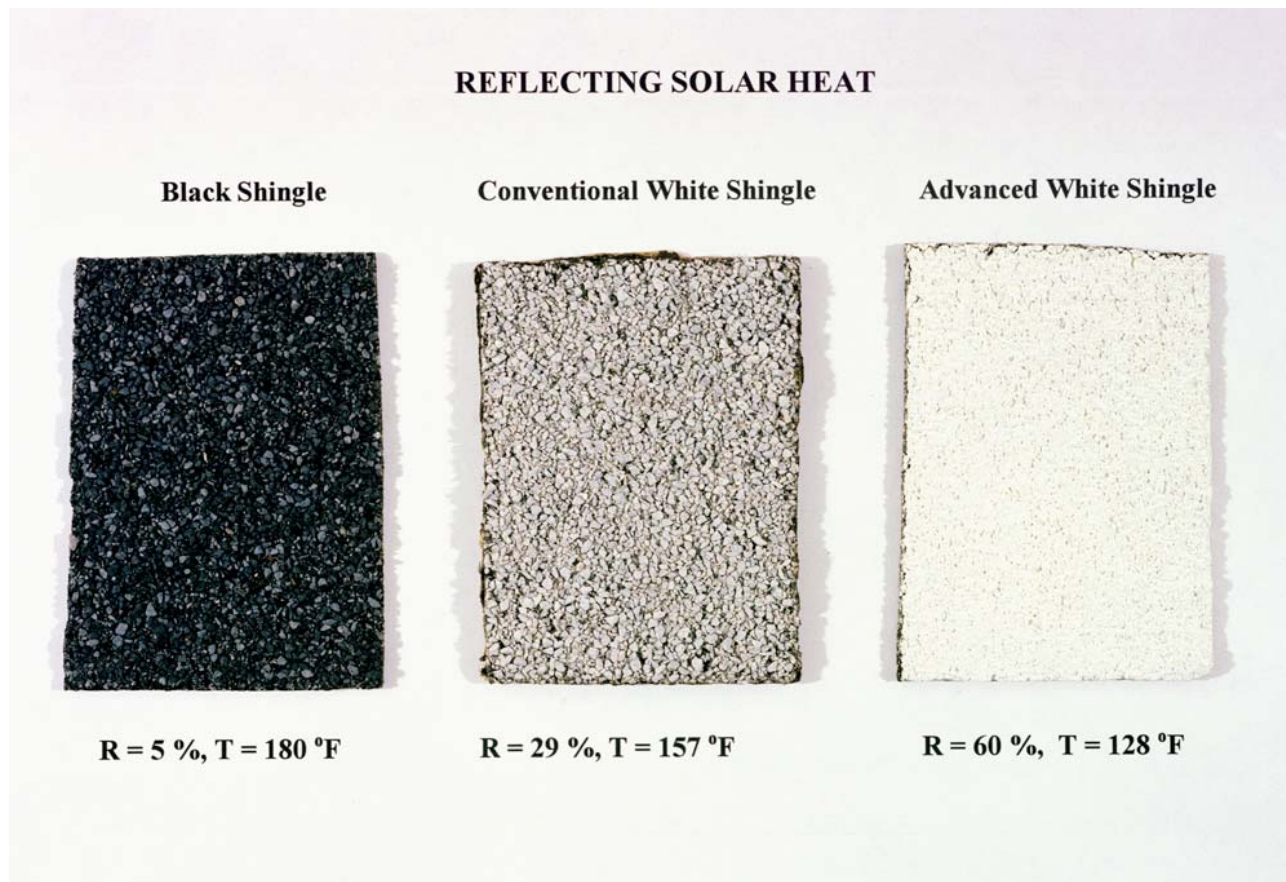
Cool Roofing Materials Availability

High-Sloped Roofs

- Limited but expanding material availability
 - Tile (several manufacturers)
 - Coatings (one manufacturer)
 - Metal (many manufacturers)
 - Shake (only for custom application)
 - Shingles (one manufacturer)
- **Over 70% of high-sloped roofs use hot asphalt shingles**



ISP/LBNL Shingle With Whiter Roofing Granules



White is 'cool' in Bermuda



and in Santorini, Greece



Cool Roof Technologies

Old



flat, white



pitched, white

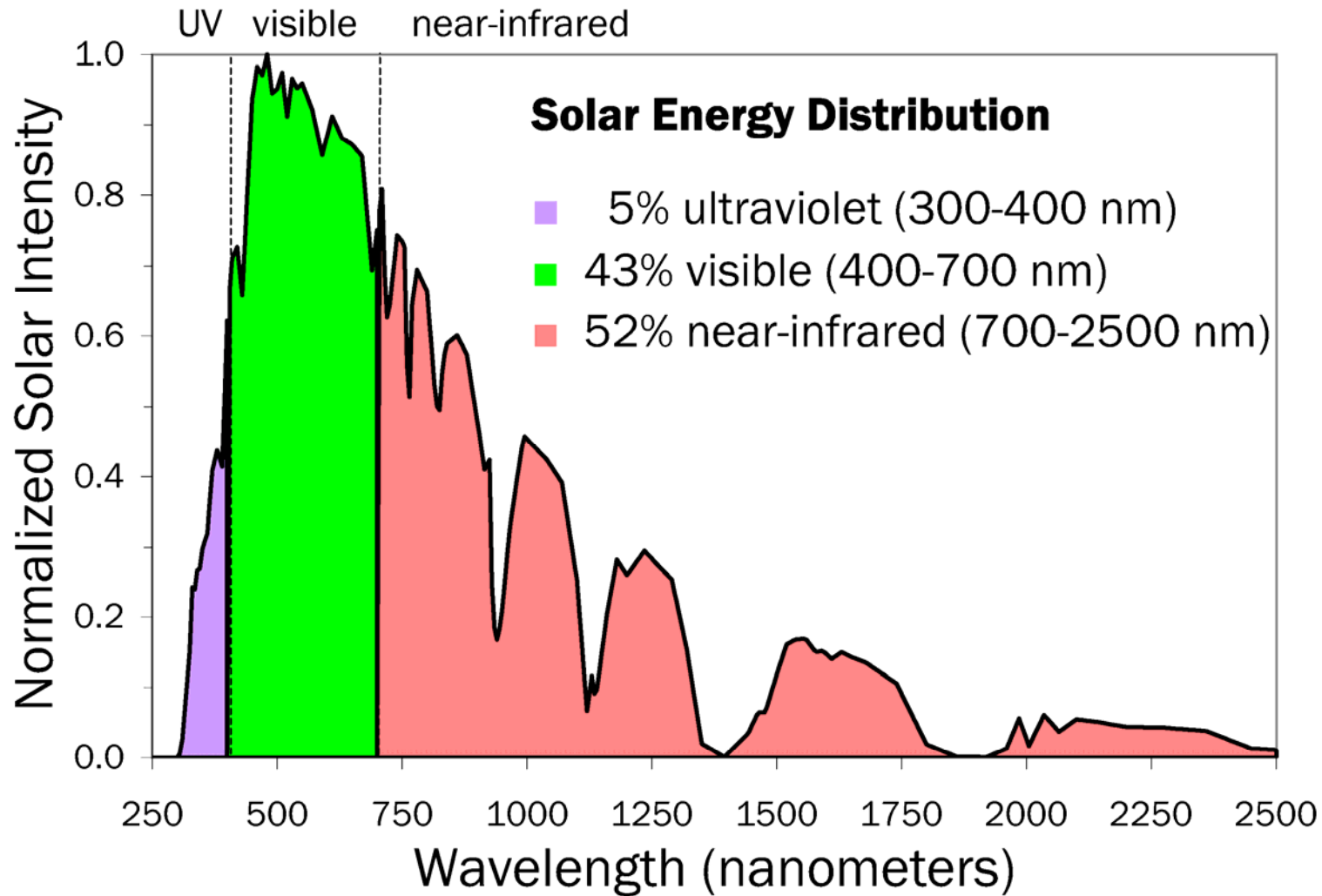
New



pitched, cool & colored

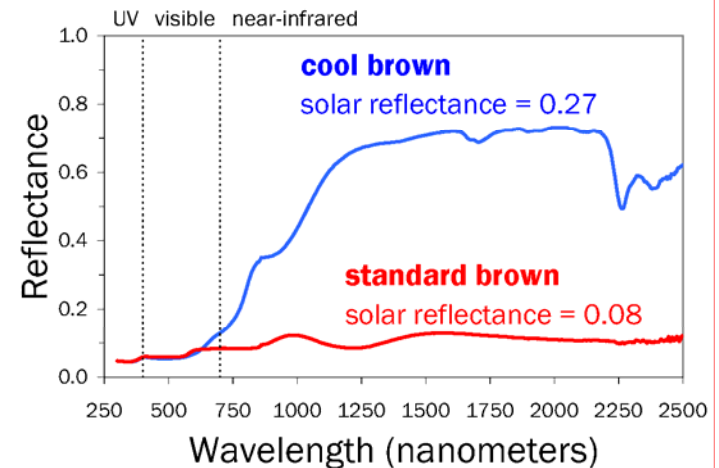
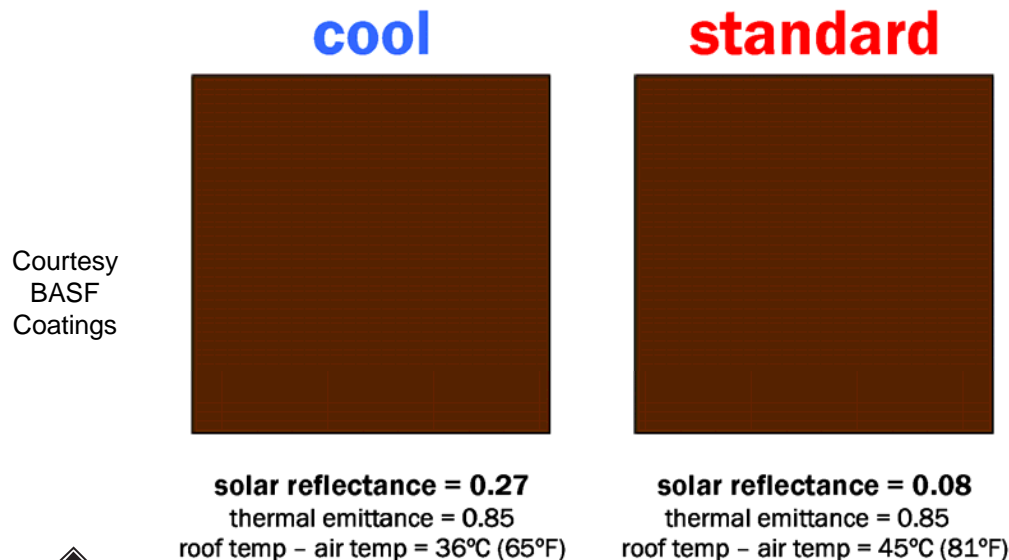


Cool Colors Reflect Invisible Near-Infrared Sunlight



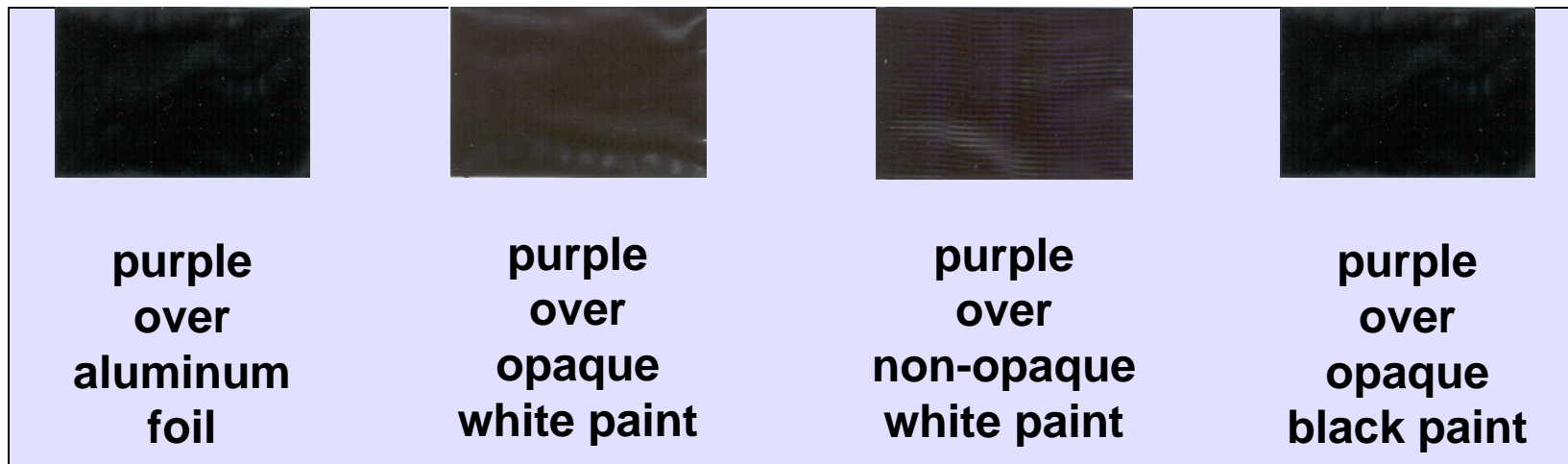
Cool and Standard Brown Metal Roofing Panels

- Solar reflectance ~ 0.2 higher
- Afternoon surface temperature ~ 10°C lower

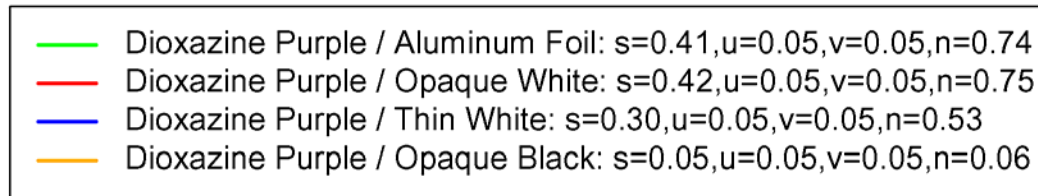


Example: Dioxazine Purple Over Various Undercoats

- 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

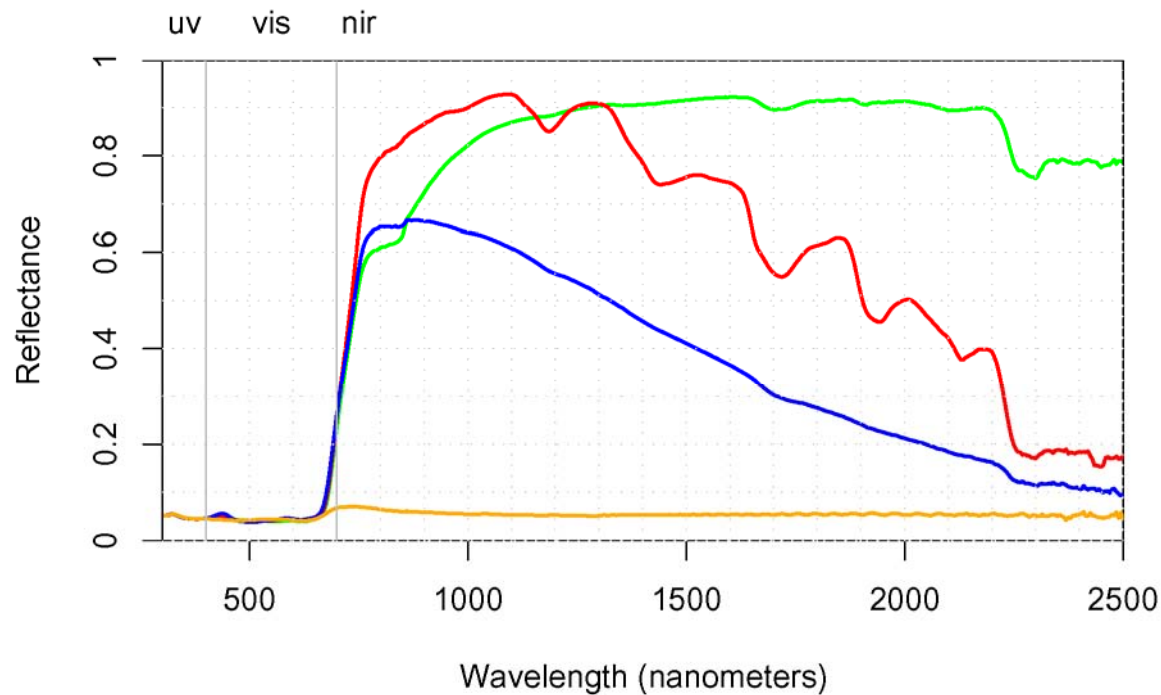


over aluminum
 $R_{\text{solar}} = 0.41$

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

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

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

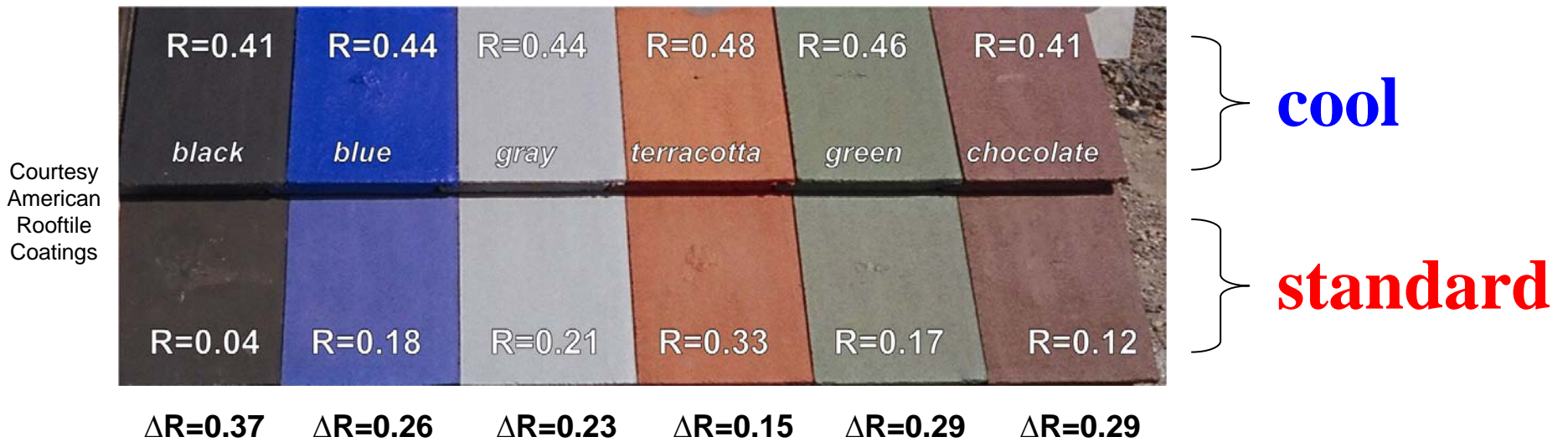


National Labs and Industrial Partnership

- Program is sponsored by CEC/PIER
- ORNL and LBNL are teaming with industry
- Broad industrial partnership
- Industry partners
 - 3M (granules)
 - American Roof Tile Coating
 - BASF (metal)
 - Custom-Bilt Metals
 - Elk Manufacturing (shingles)
 - Ferro
 - GAF (shingles)
 - Hanson Roof Tile
 - ISP Minerals (granules)
 - MCA (tiles)
 - Monier Lifestile (tile)
 - Shepherd Color Company



Cool and Standard Color-Matched Concrete Tiles



- Can increase solar reflectance by up to 0.5
- Gain greatest for dark colors



Increasing solar reflectance of fiberglass asphalt shingles: prototypes

cooler: $\rho=0.28$



$\rho=0.36$



$\rho=0.37$



warmer: $\rho=0.23$



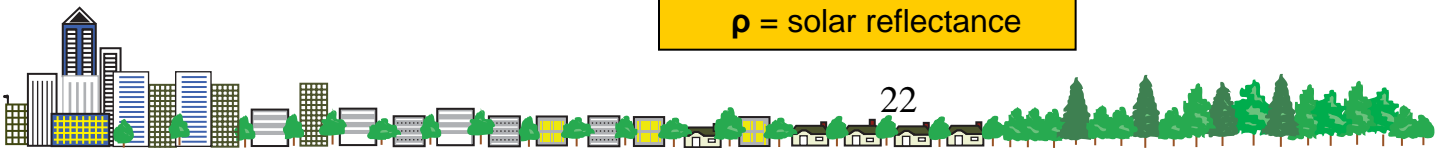
$\rho=0.27$



$\rho=0.28$



ρ = solar reflectance

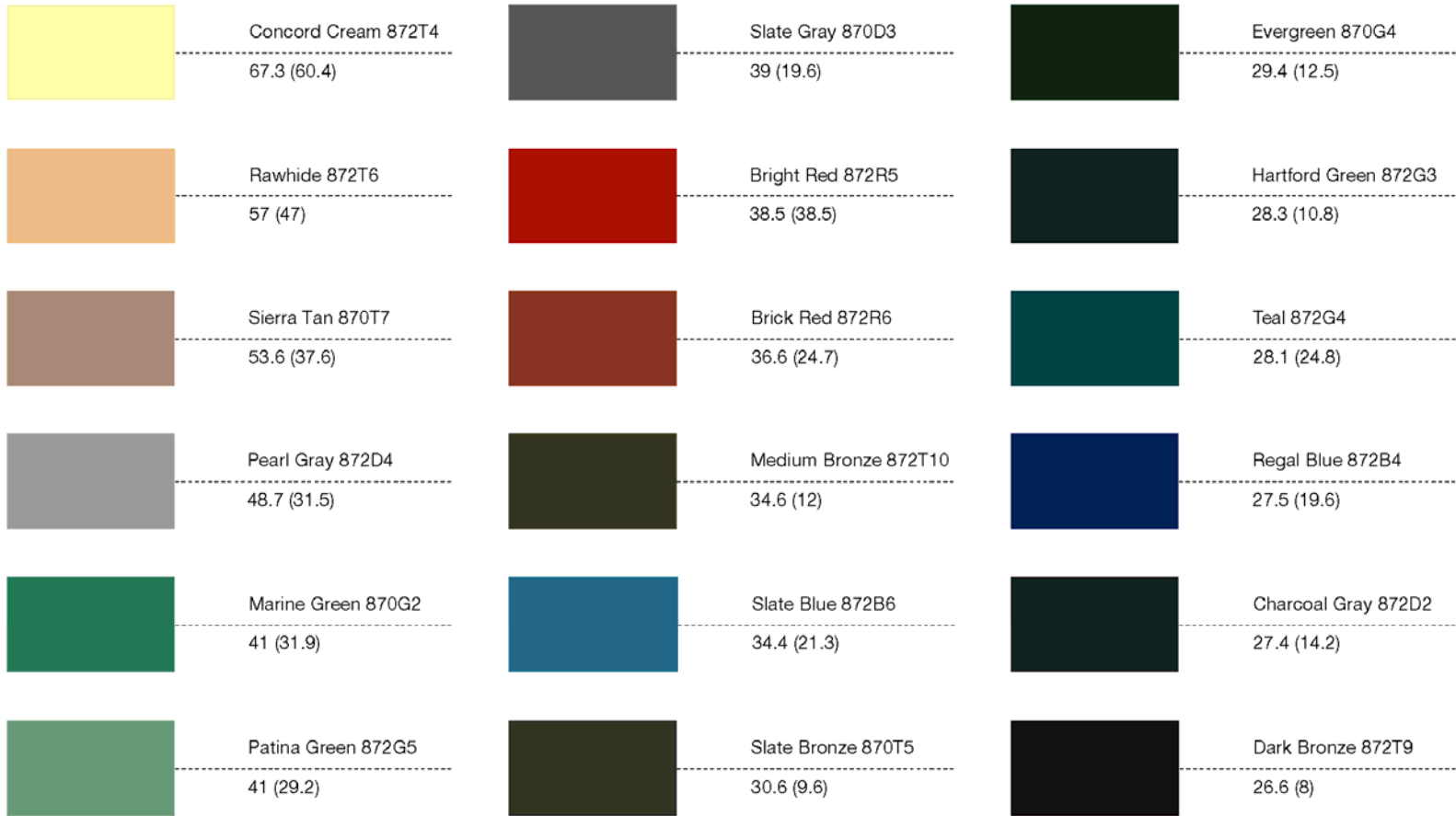


Increasing solar reflectance of fiberglass asphalt shingles: Elk Prestique® Cool Color Series



Increasing solar reflectance of metal roofing: BASF Ultra-Cool® metal roof coatings

Courtesy
BASF
Industrial
Coatings








numbers denote solar reflectances: cooler (warmer)



Cool Metal Roofs

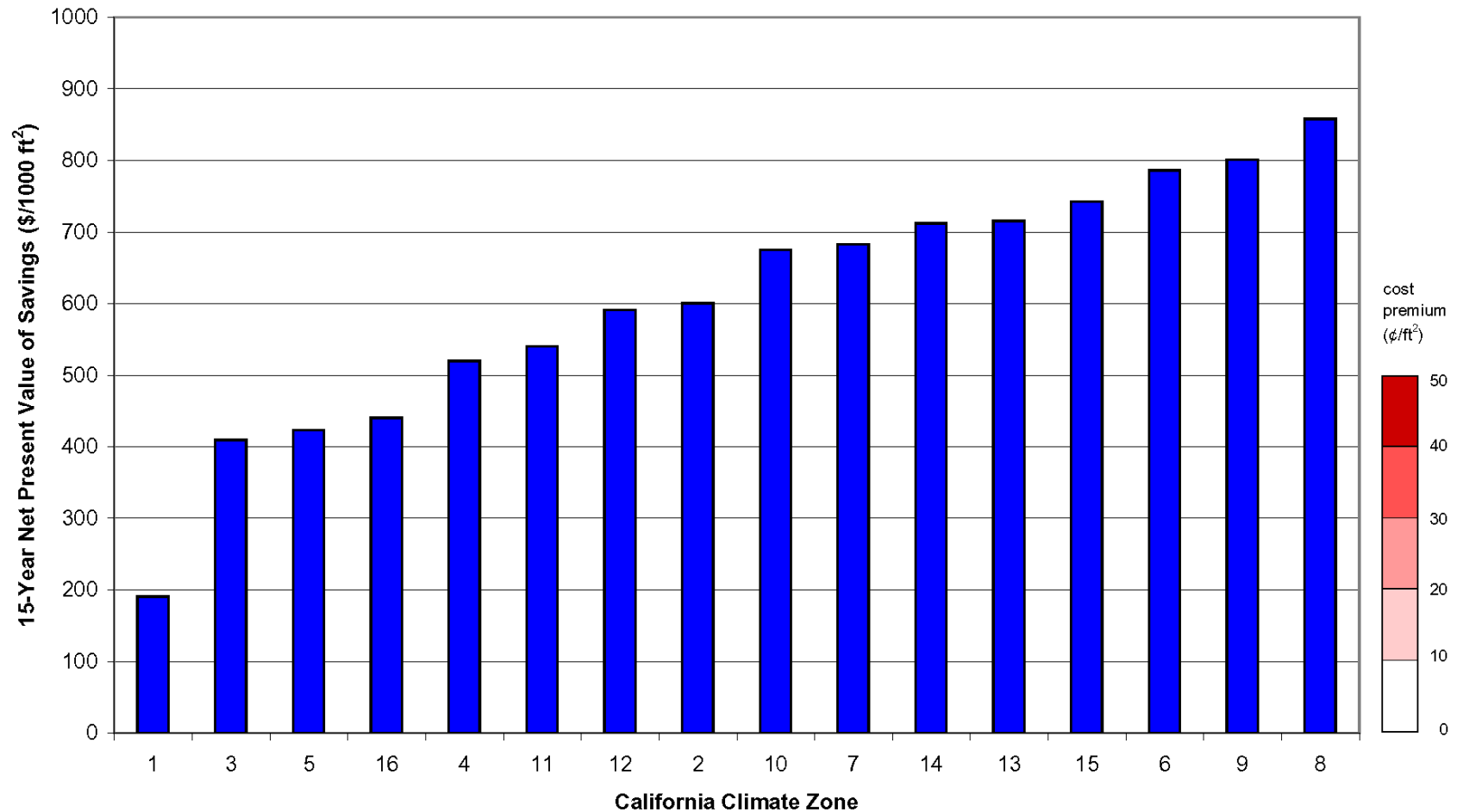


Increasing solar reflectance of clay tiles: MCA Clay Tile cool colored tiles

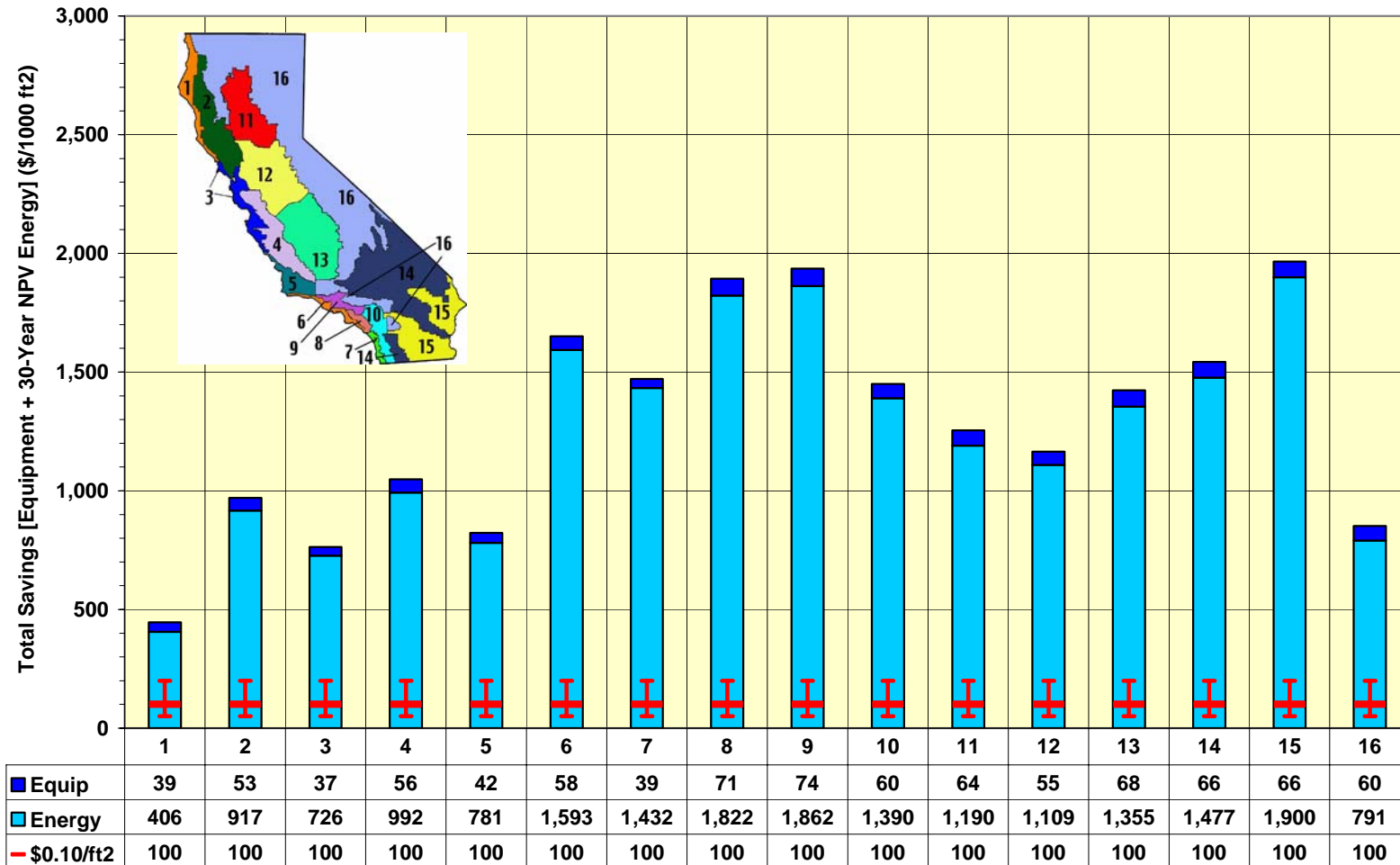
Model	Color	Initial solar reflectance	Solar reflectance after 3 years
Weathered Green Blend		0.43	0.49
Natural Red		0.43	0.38
Brick Red		0.42	0.40
White Buff		0.68	0.56
Tobacco		0.43	0.41



Non-residential building energy and equipment savings: 15-year net present value of savings (\$/1000 ft²)



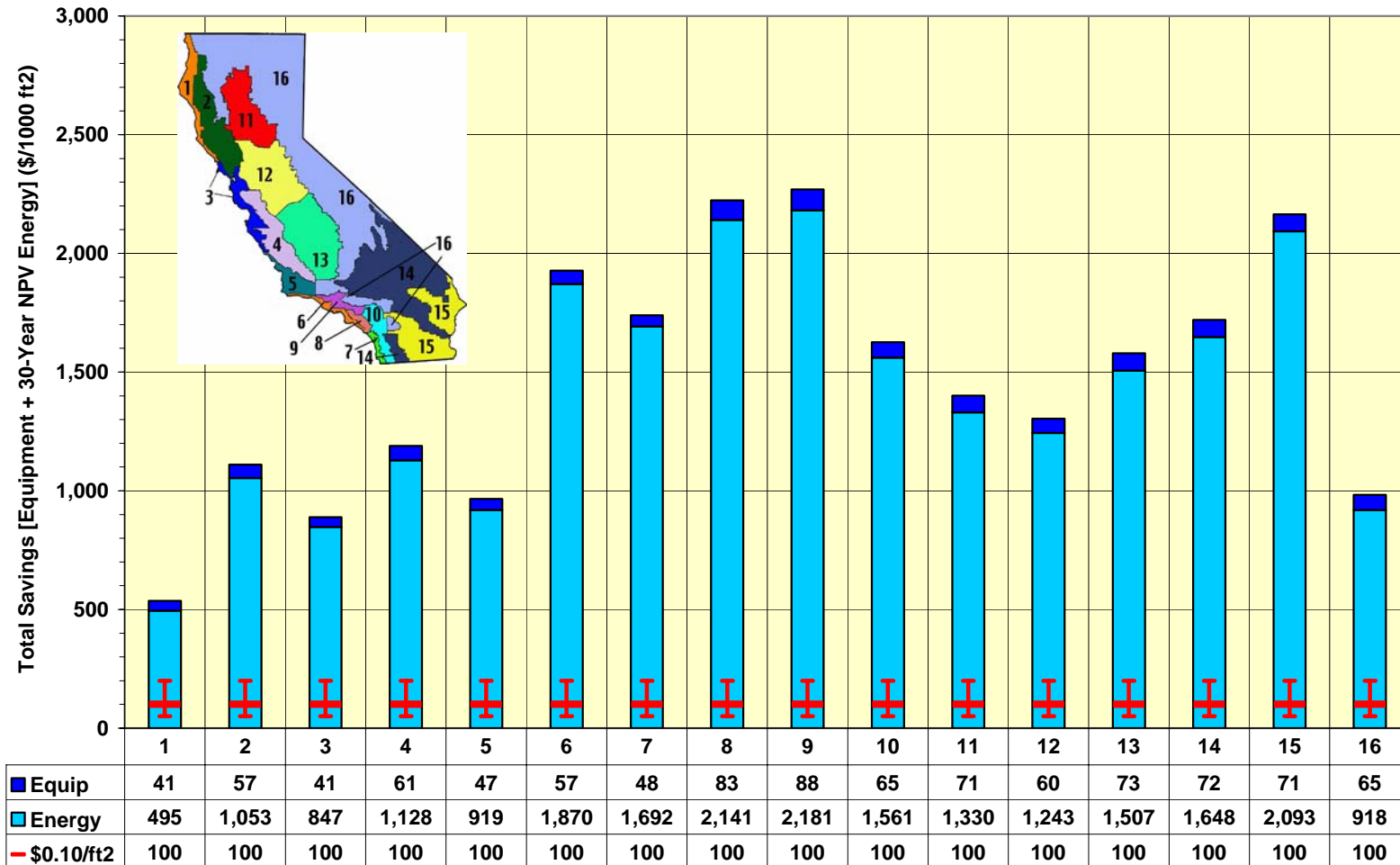
30-year net present value of savings (\$/1000 ft²): concrete tile roofs



California Climate Zone



30-year net present value of savings (\$/1000 ft²): metal roofs

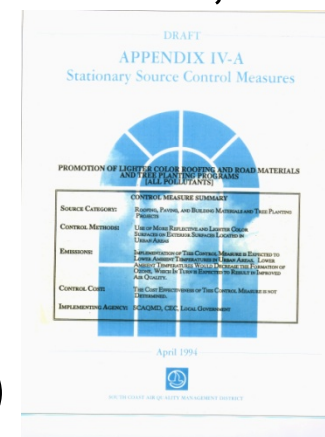


California Climate Zone



Cool Roofs Standards

- Building standards for reflective roofs
 - American Society of Heating and Air-conditioning Engineers (ASHRAE): New commercial and residential buildings
 - Many state: California, Georgia, Florida, Hawaii, ...
- Air quality standards
 - South Coast AQMD
 - S.F. Bay Area AQMD
 - EPA's SIP (State Implementation Plans)



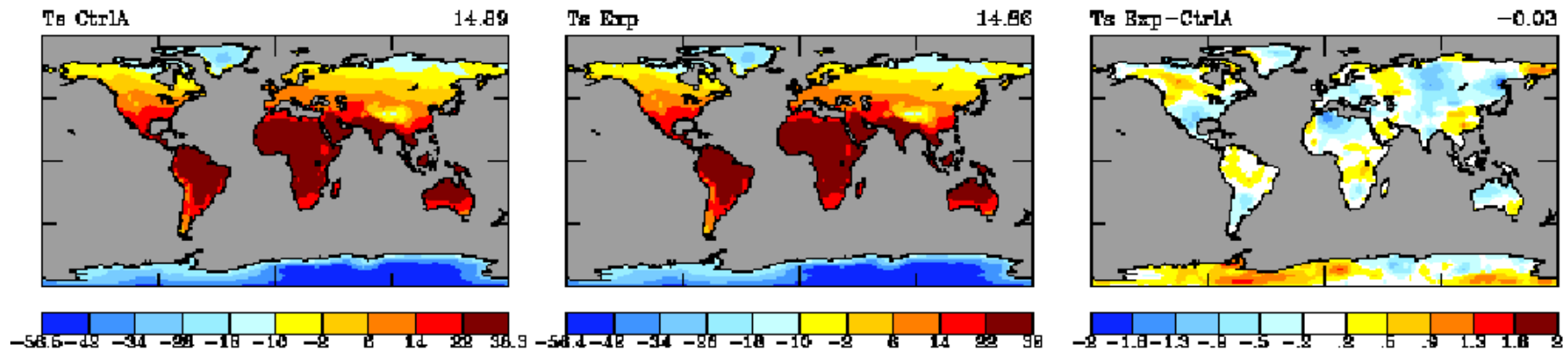
Potentials to Increase Urban Albedo is 0.1

- Typical urban area is 25% roof and 35% paved surfaces
- Roof albedo can increase by 0.25 for a net change of $0.25 \times 0.25 = 0.063$
- Paved surfaces albedo can increase by 0.15 for a net change of $0.35 \times 0.15 = 0.052$
- Net urban area albedo change at least 0.10



Effect of Increasing Urban Albedo by 0.1

- Net Change in Global albedo
= [City/Land]x[Land/Globe]x Δa = [2]x[1]x Δa
= 0.01 x 0.29 x 0.1 = 0.0003 [3]
- The effect on global temperature
 - Using three different calculations is about 0.01K



Carbon Equivalency

- Modelers estimate a warming of 2K in 60 years, so 0.03K/year
- Change of 0.1 in urban albedo will result in 0.01K, a delay of ~0.3 years in global warming
- World's current rate of CO₂ emissions = 25 G tons/year (4.1 tons/year per person)
- World's rate of CO₂ emissions averaged over next 60 years = 40 G tons/year
- Hence 0.3 years delay is worth 12 Gt CO₂; ~ 200 Mt CO₂/year



Equivalent Value of Avoided CO₂

- CO₂ currently trade at ~\$10/ton
- 12Gt worth \$120 billion, for changing albedo of roofs and paved surface
- Cooler roofs alone worth \$60B
- Cooler roofs also save air conditioning (and provide comfort) worth over \$6,00B - \$900B over 60 years; 100 Mt CO₂/year
- We would like to start an international organization where the developed countries offer \$1 million per large city in a developing country, to trigger a cool roof/pavement program in that city



Market Deployment of Cool Color Cars



- Toyota experiment (surface temperature 10 °C cooler with cool coatings.)
- Ford is also working on a similar technology.



Effect of A/C on fuel consumption

	US	Cal.
No. of Vehicles (10^6)	213	26
Miles/year/car (10^3)	12	12
Fuel Eff [mpg]	20	20
Annual fuel use [10^9 gal]	130	15
Annual fuel expense at 2.5 \$/gal [\$B]	230	38
Reduced efficiency due to A/C	15%	15%
% time AC runs	50%	50%
A/C contribution to fuel use [10^9gal]	9.6	1.2
A/C contribution to fuel expense [\$B]	24	3

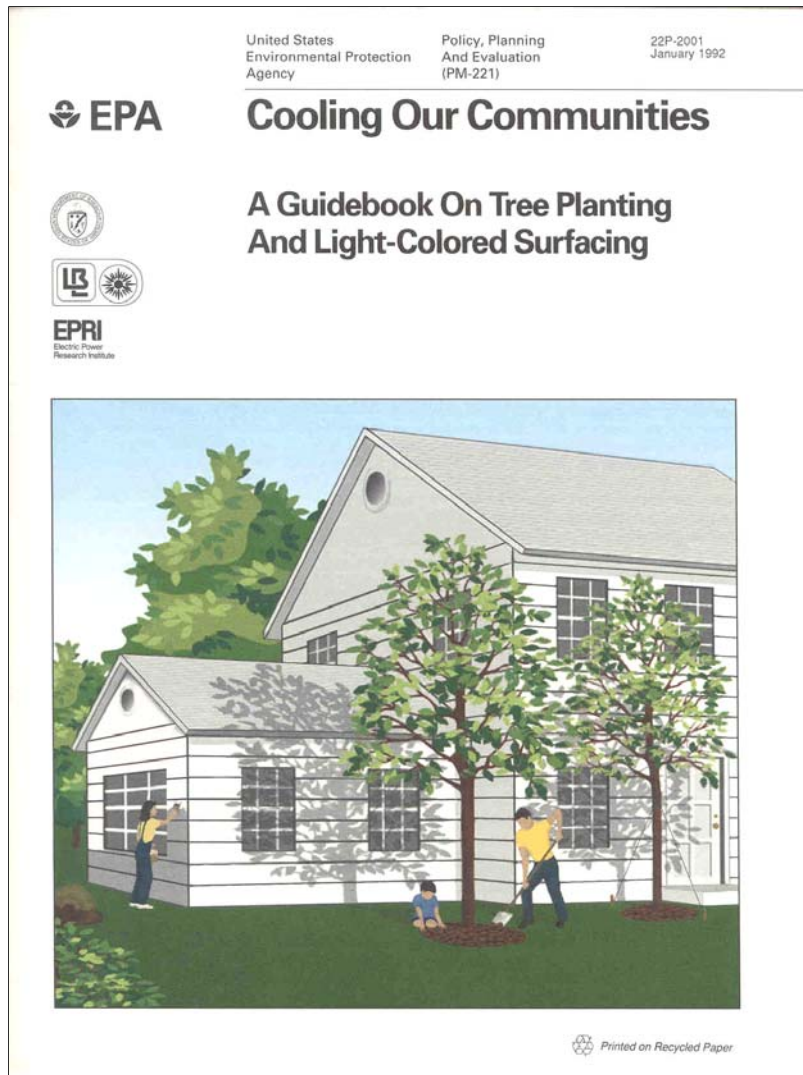


Benefits of 2.8K (5°F) reduction in soak temperature

	US	Cal.
Reduction in AC capacity	11%	11%
Improvement in mpg	1.8%	1.8%
Reduced NOx emission	4.5%	4.5%
Reduced fuel expense (\$M)	2876	346
Reduced CO emission (tonne/day)	978	117.8
Reduced NOx emission (tonne/day)	103	12.4
Reduced NMHC emission (tonne/day)	18	2.2



Practical Guidelines



- EPA Guidebook (1992)
 - Good practical information
 - Greatest focus on trees
- EPA is working on a new edition

