Cool Roofing Technologies

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STEAB Visit to LBNL
August 14, 2007

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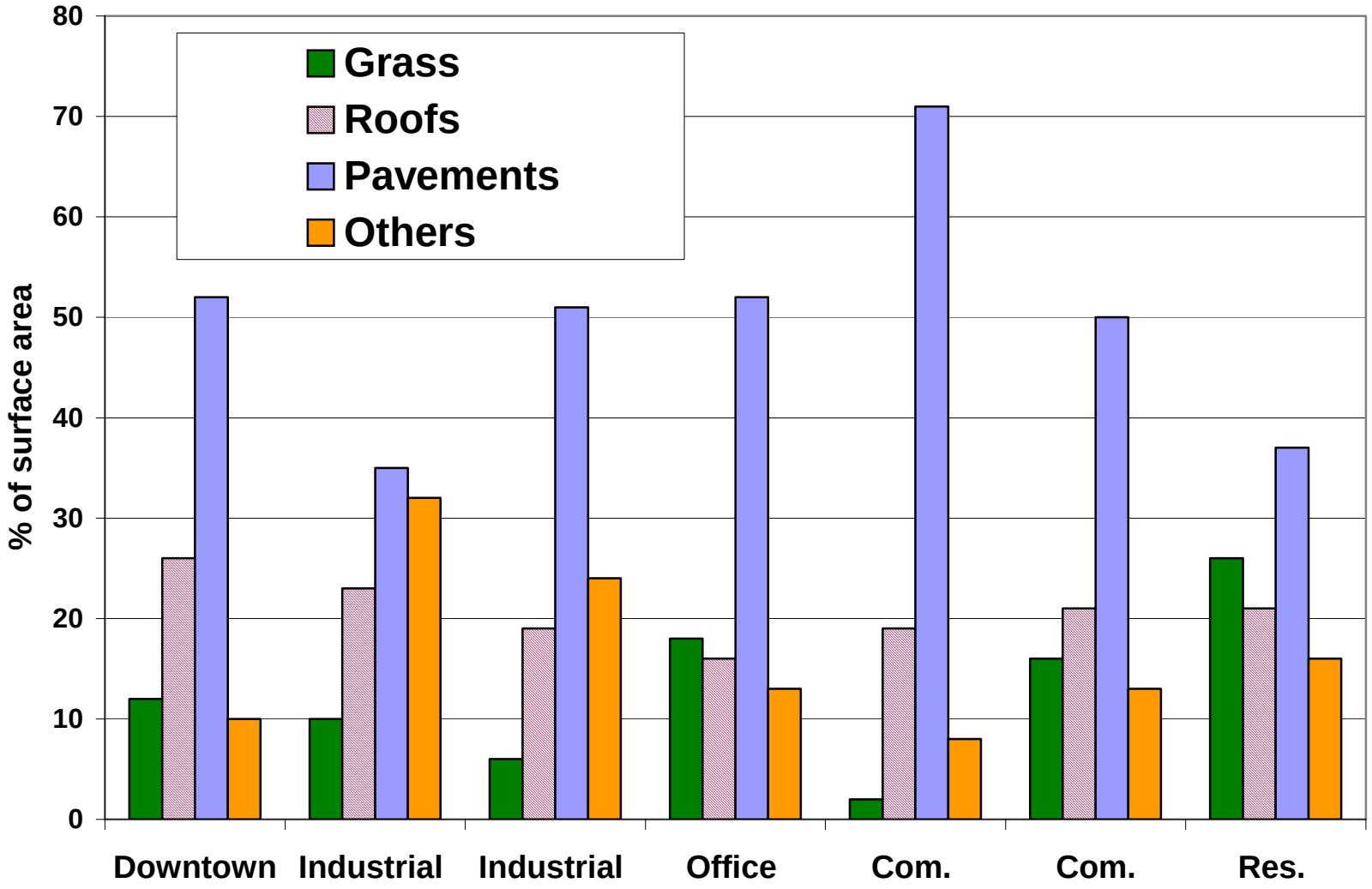
Orthophoto of Sacramento

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

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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

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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

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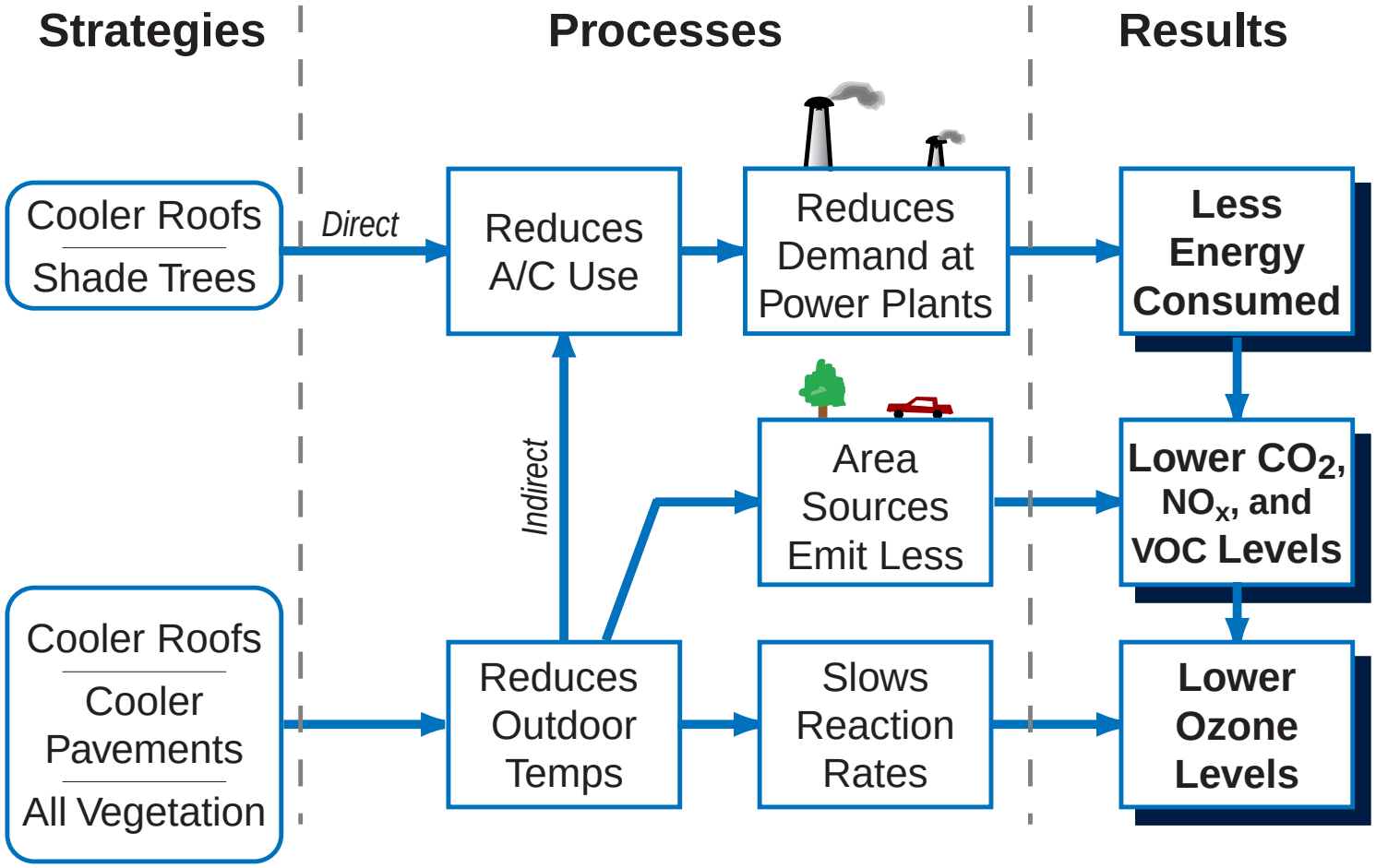
Methodology: Energy and Air-Quality Analysis



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

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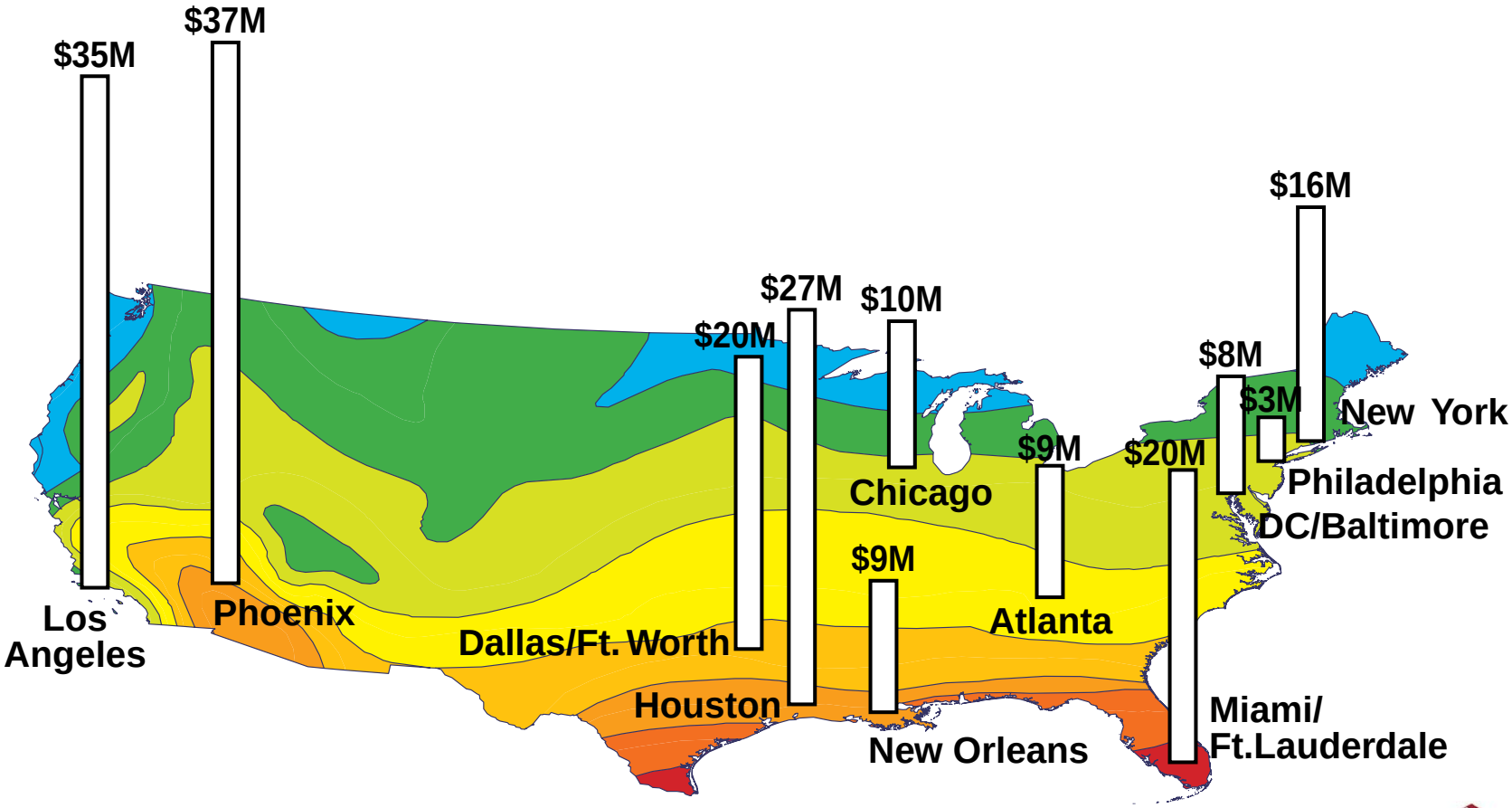
Potential National Savings from Changing Roof Reflectivity Peak Demand Savings in All U.S.



“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

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Cool Roofing Materials Availability High-Sloped Roofs

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

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ISP/LBNL Shingle With Whiter Roofing Granules

White is ‘cool’ in Bermuda

and in Santorini, Greece

Cool Roof Technologies

Old

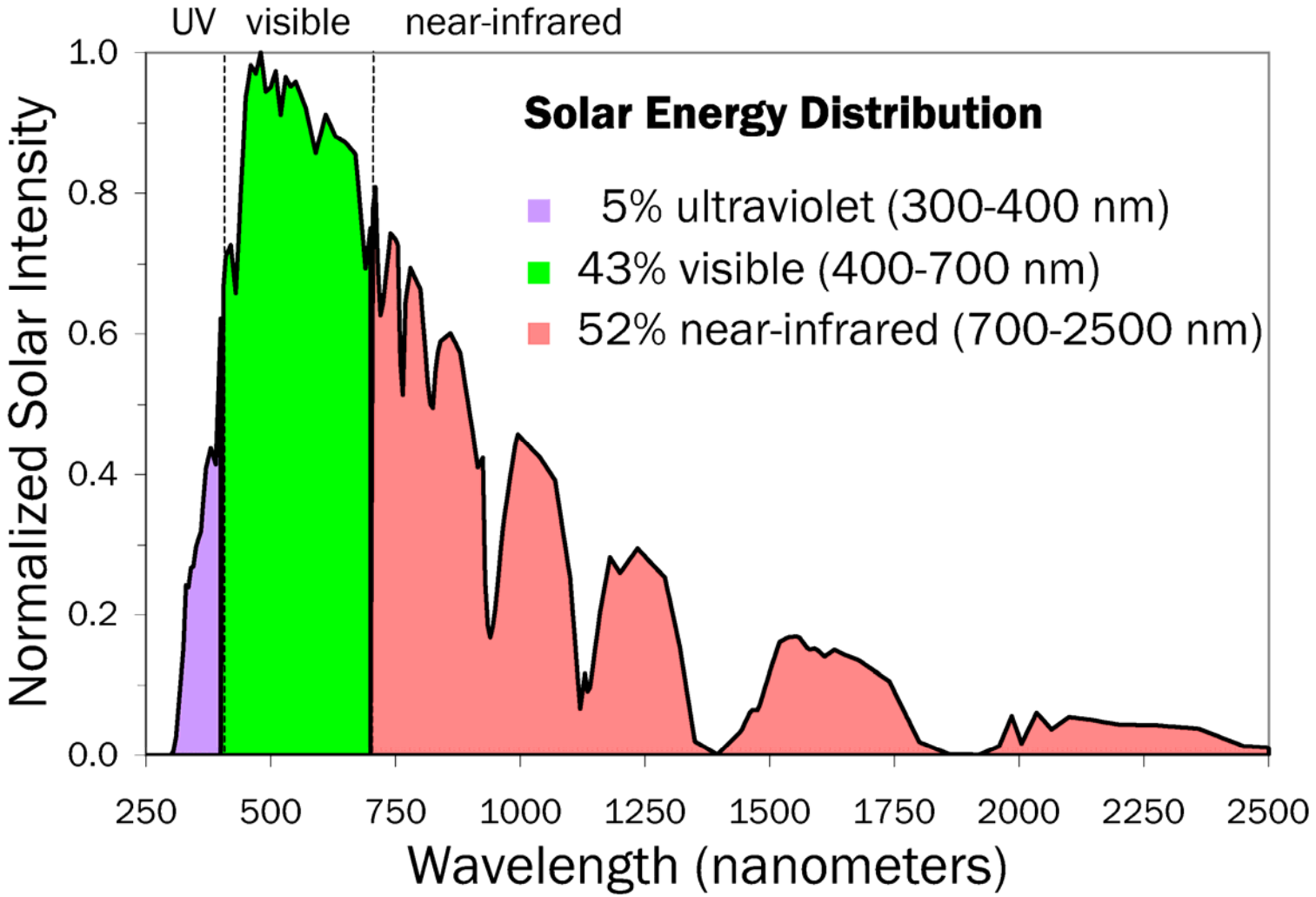
flat, white

pitched, white

New

pitched, cool & colored

Cool Colors Reflect Invisible Near-Infrared Sunlight



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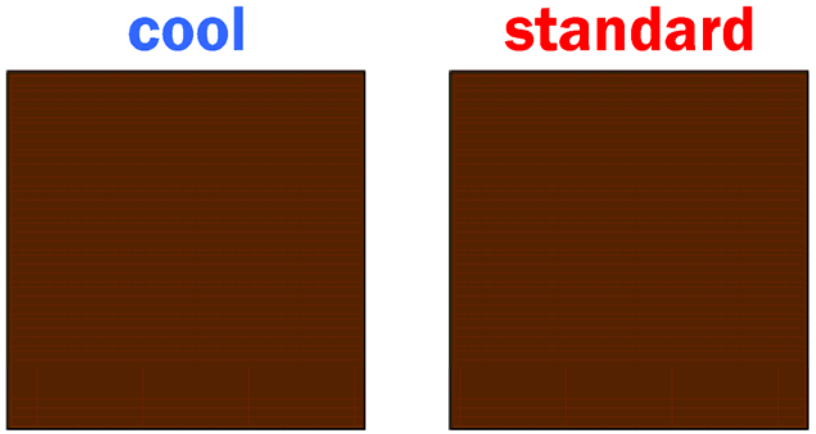
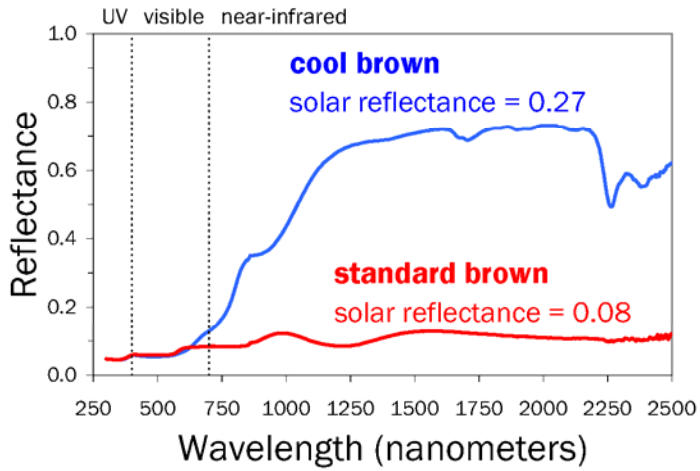
Cool and Standard Brown Metal Roofing Panels

- Solar reflectance ~ 0.2 higher
- Afternoon surface temperature ~ 10ºC lower

Courtesy BASF Coatings





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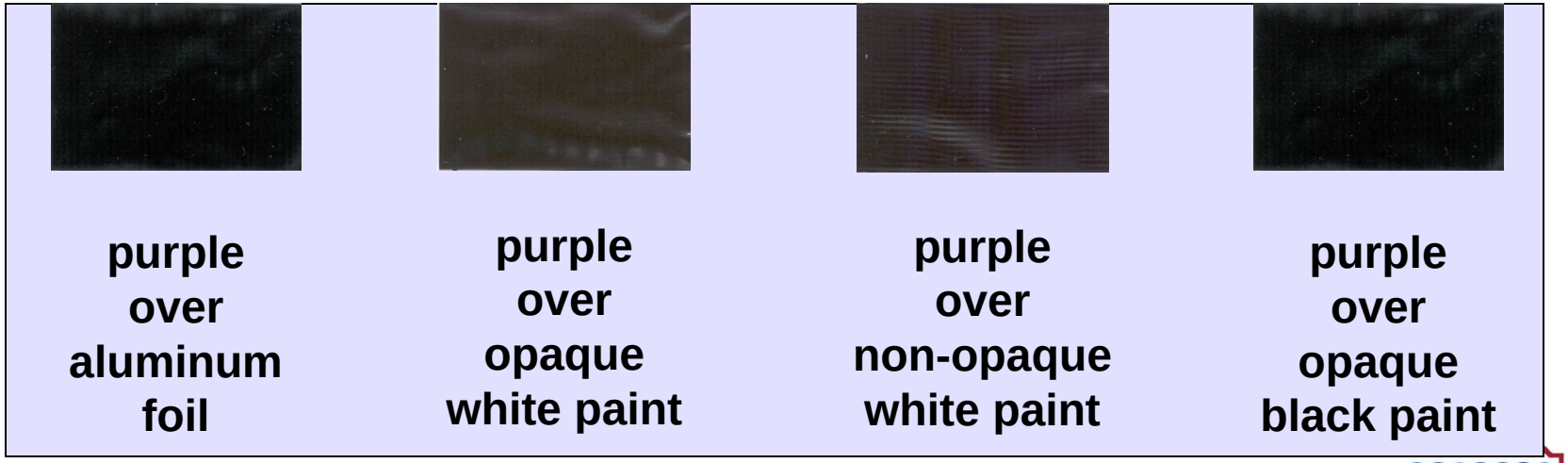
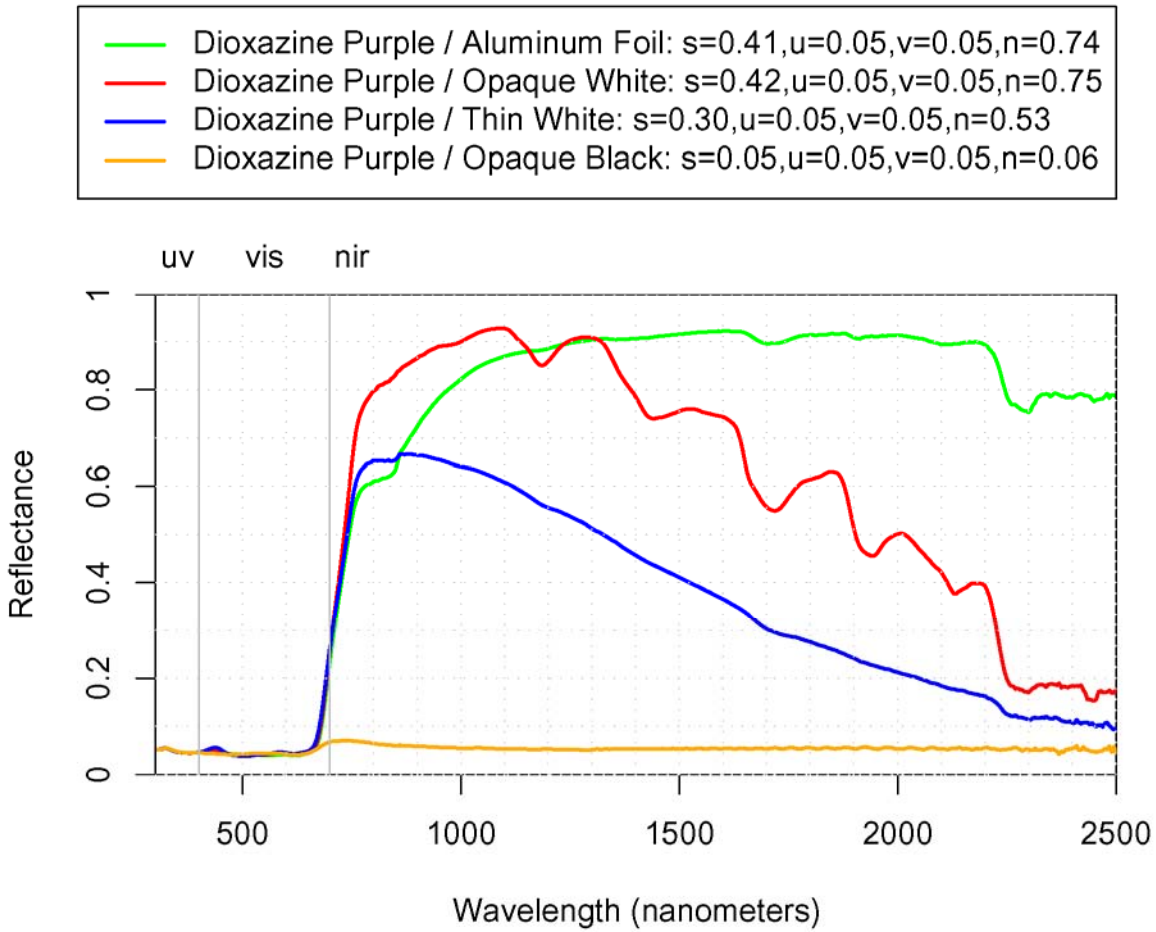
Example: Dioxazine Purple Over Various Undercoats

- Two-layer system
  - top coat: thin layer of dioxazine purple (14-27 µm)
  - undercoat or substrate:
    aluminum foil (~ 25 µm)
    opaque white paint (~1000 µm)
    non-opaque white paint (~ 25 µm)
    opaque black paint (~ 25 µm)



Dioxazine Purple Reflectances



over aluminum
R_{solar} = 0.41

over opaque white
R_{solar} = 0.42

over non-opaque white
R_{solar} = 0.30

over opaque black
R_{solar} = 0.05

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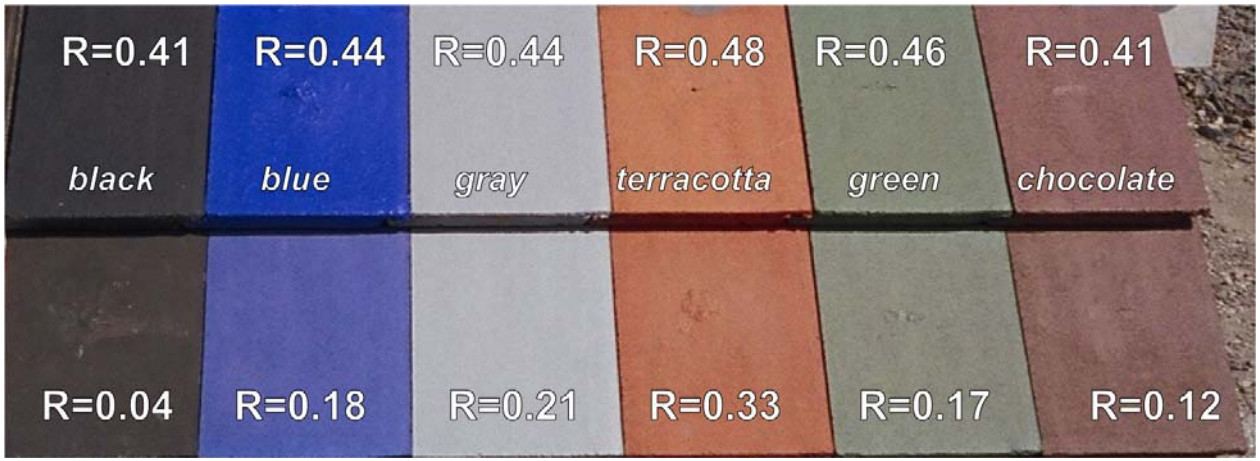
National Labs and Industrial Partnership

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

- **Industry partners**
  - **3M (ganules)**
  - **American Roof Tile Coating**
  - **BASF (metal)**
  - **Custom-Bilt Metals**
  - **Elk Manufacturing (shingles)**
  - **Ferro**
  - **GAF (shingles)**
  - **Hanson Roof Tile**
  - **ISP Minerals (ganules)**
  - **MCA (tiles)**
  - **Monier Lifetile (tile)**
  - **Shepherd Color Company**

Cool and Standard Color-Matched Concrete Tiles

Courtesy American Rooftile Coatings



cool

standard

ΔR=0.37 **ΔR=0.26** **ΔR=0.23** **ΔR=0.15** **ΔR=0.29** **ΔR=0.29**

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

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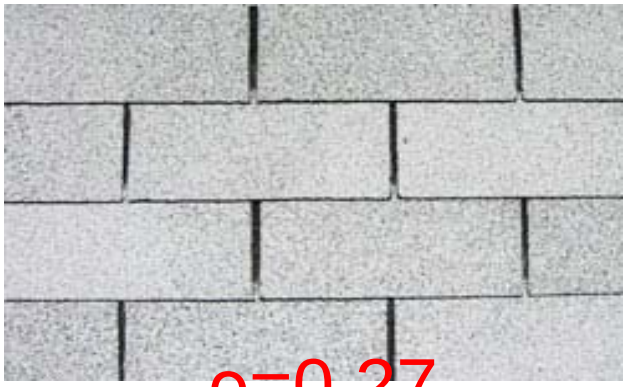
Increasing solar reflectance of fiberglass asphalt shingles: prototypes

cooler: ρ=0.28

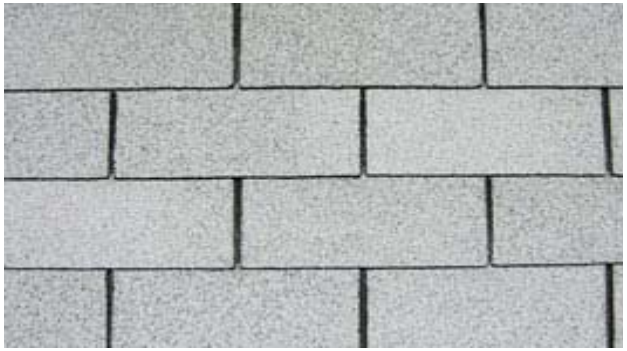
ρ=0.36



ρ=0.37

warmer: ρ=0.23

ρ=0.27



ρ=0.28

ρ = solar reflectance

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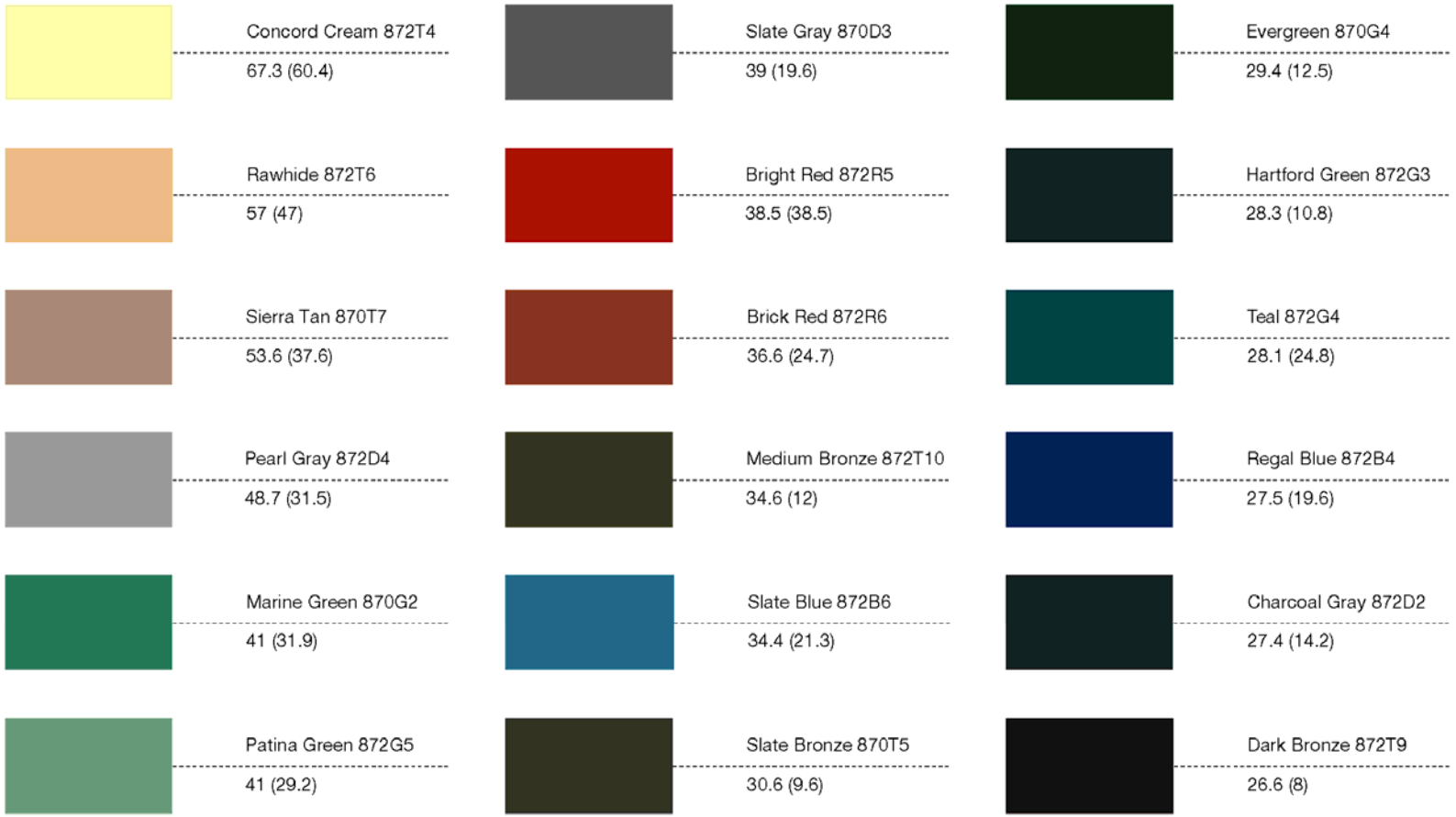
Increasing solar reflectance of fiberglass asphalt shingles: Elk Prestique® Cool Color Series

Color swatches:

Cool Antique Slate | Cool Barkwood | Cool Weatheredwood

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



Courtesy BASF Industrial Coatings

numbers denote solar reflectances: cooler (warmer)

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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

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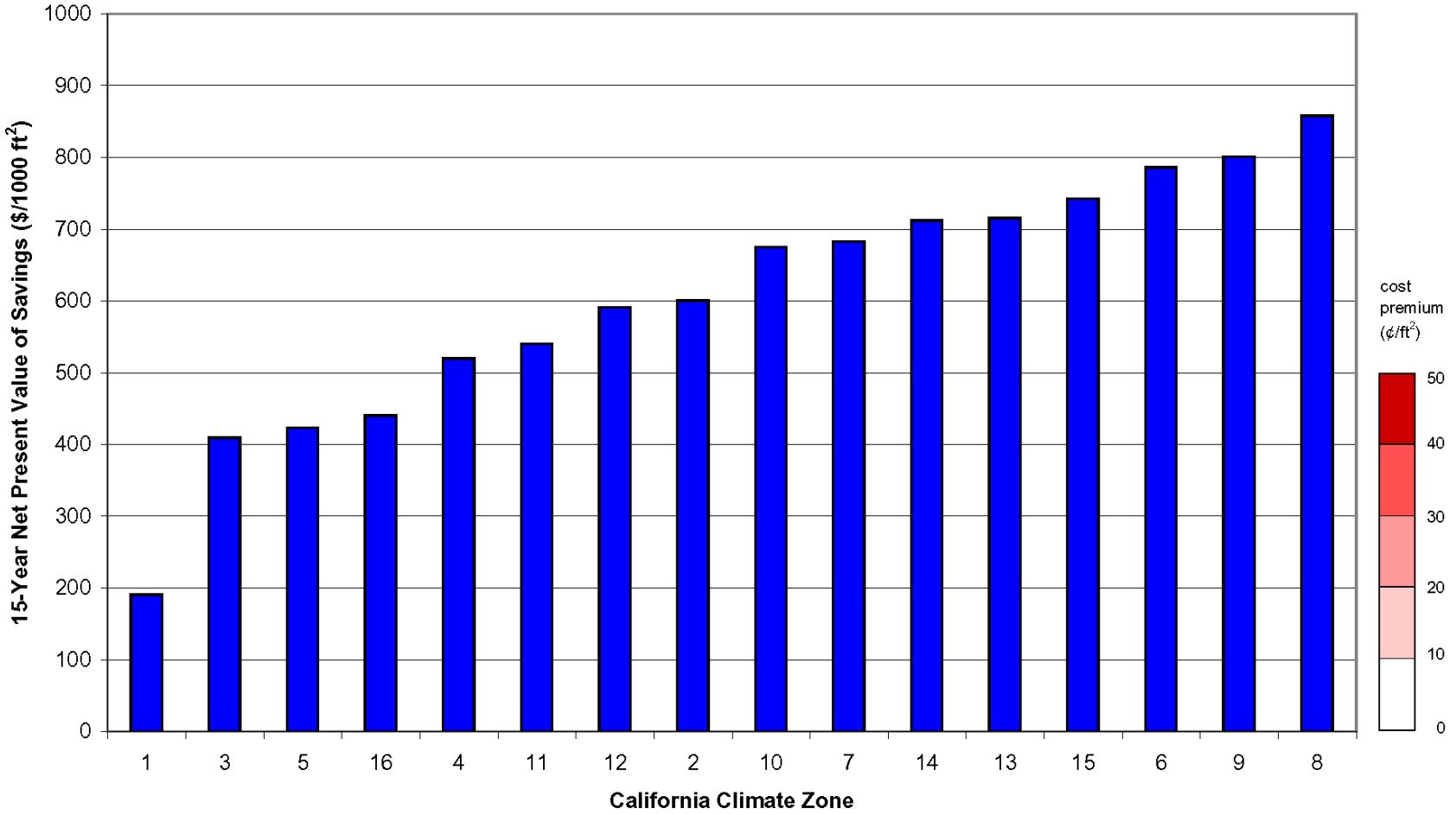
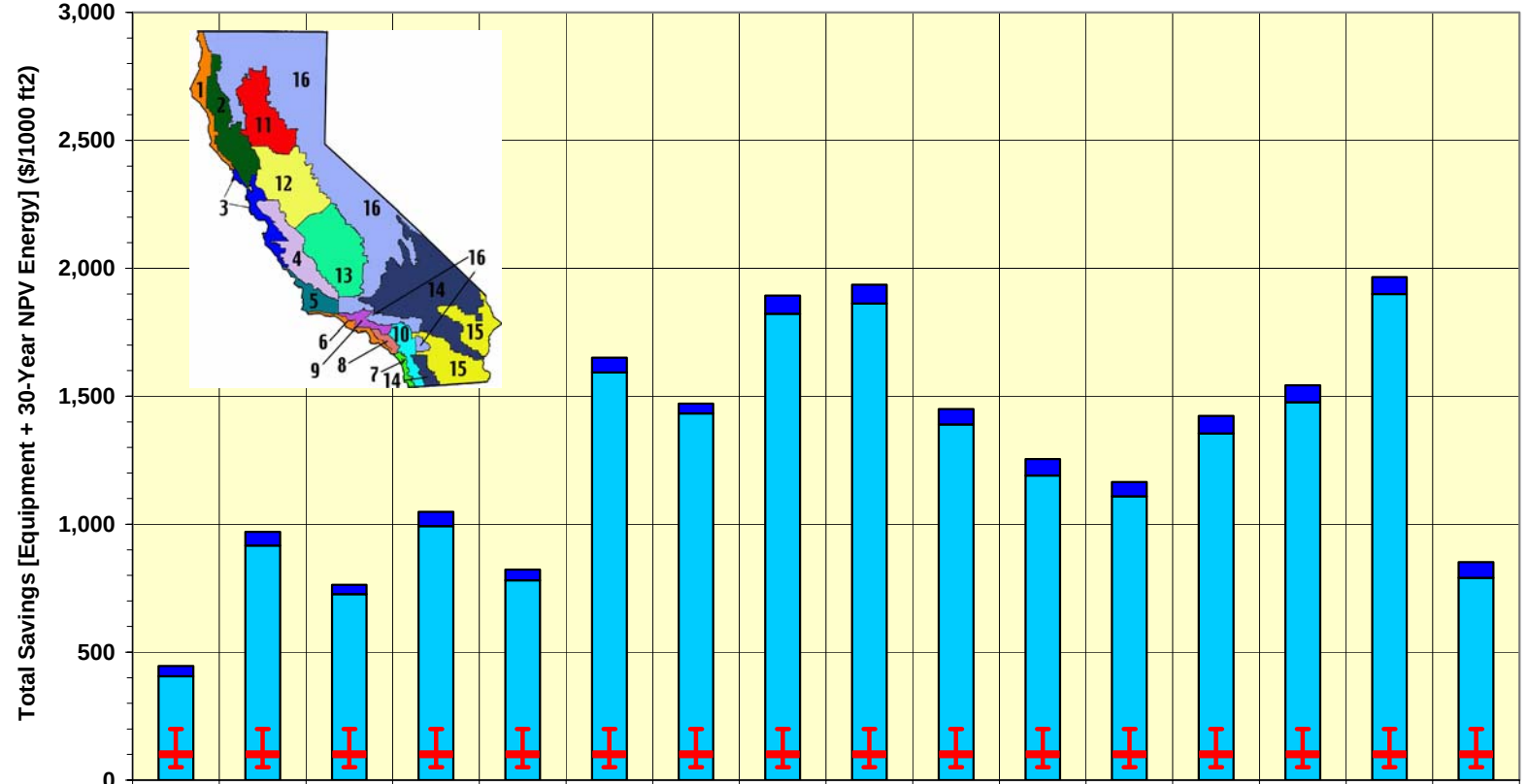
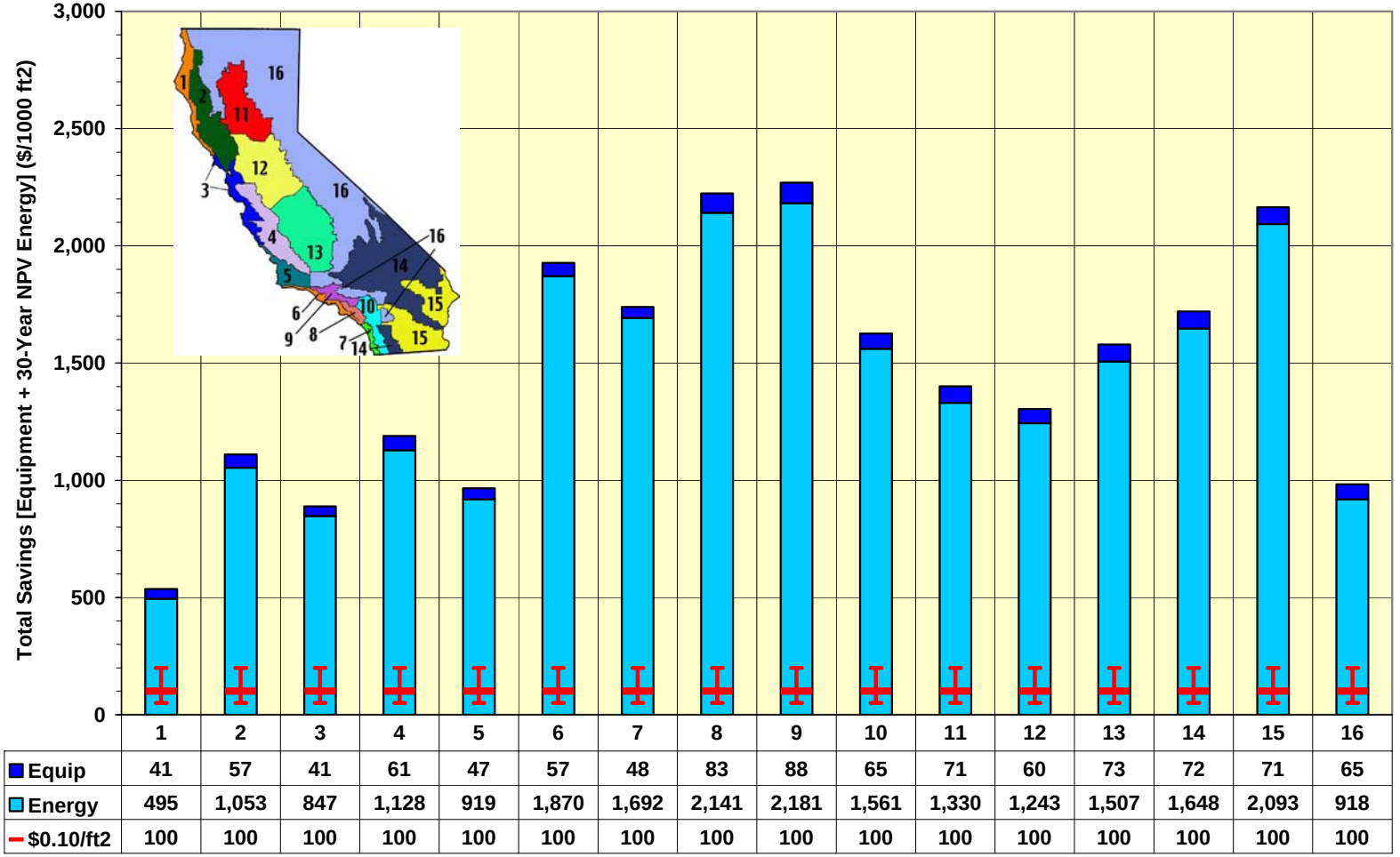
Non-residential building energy and equipment savings:15-year net present value of savings ($/1000 ft^2)



30-year net present value of savings ($/1000 ft^2): **concrete tile roofs**

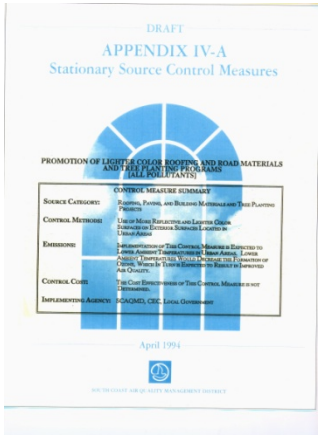


30-year net present value of savings ($/1000 ft^2): **metal roofs**



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)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APPENDIX IV-A

Stationary Source Control Measures

PROMOTION OF LIGHTER COLOR ROOFING AND ROAD MATERIALS AND TREE PLANTING PROGRAMS [ALL POLLUTANTS]

CONTROL MEASURE SUMMARY

Source Category:

Control Methods:

Emissions:

Control Costs:

Implementing Agency:

April 1994

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White Roofs Programs in California

- One Time CEC Incentive -- $20 Million
  - at $0.15 to $0.20 per square foot
- California utilities incentives
- 2001 to 2005-- **credits** white and cool colored roofs
- 2005 **requires** cool flat roofs
- 2008 may **require** cool roofs for all buildings

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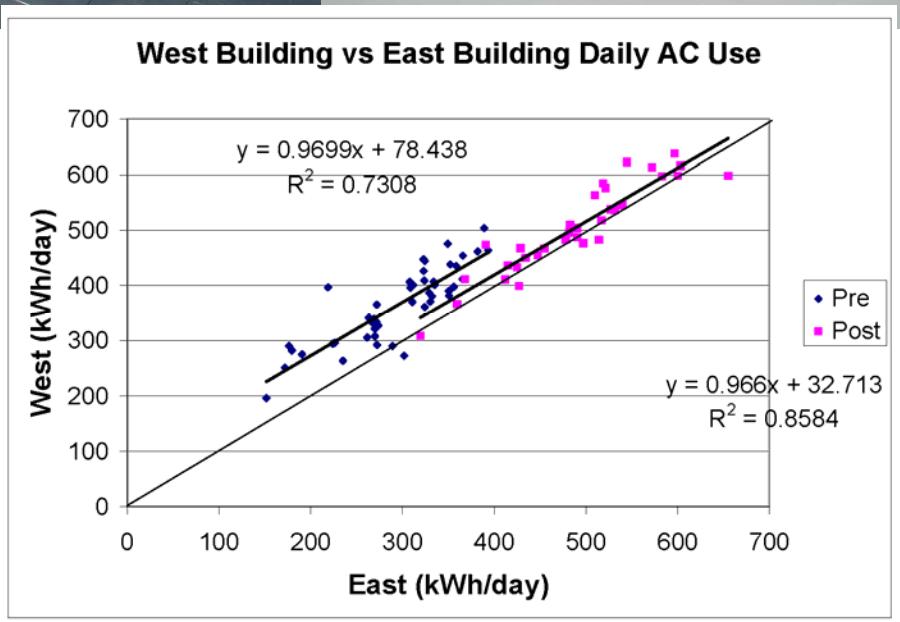
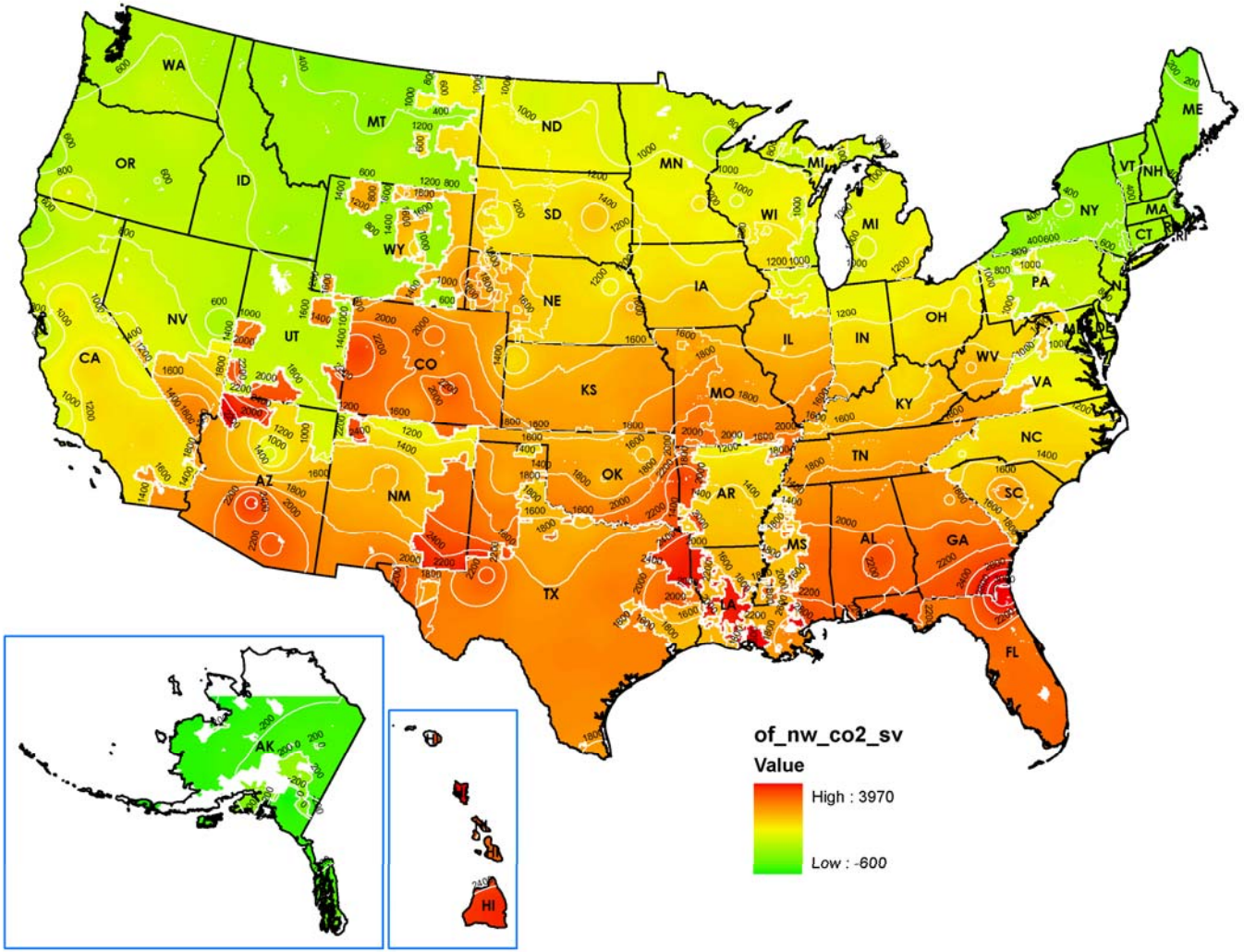
Cool Roof Programs around the World

- U.S.
- Europe
- Asia
- Middle East
- China
- India (Hyderabad demos; see graphs; funded by U.S.AID)



Cool Roofs to Save CO2



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Cool Surfaces also Cool the Globe

- Cool roof standards are designed to reduce a/c demand, save money, and save emissions. In Los Angeles they will eventually save ~$100,000 per *hour*
- Annual savings in the U.S. = $1-2B; ~ 7 M tons CO_2
- Annual savings in the world = $10-15B; ~ 100 M tons CO_2
- But higher albedo surfaces (roofs and pavements) directly cool the world (0.01 K) quite independent of avoided CO_2. So we discuss the effect of cool surfaces for tropical, temperate cities

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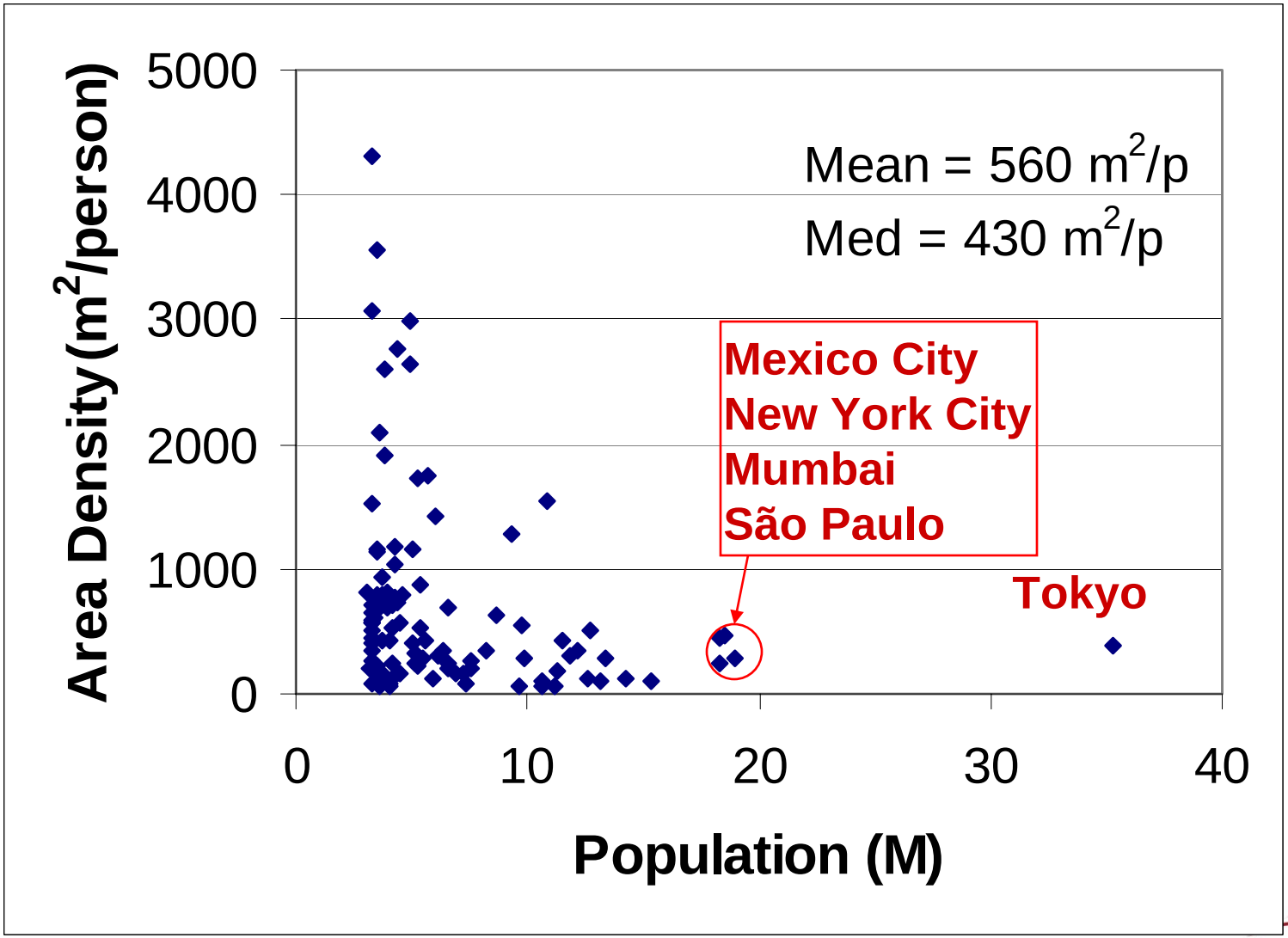
100 Largest Cities have 670 M People



Dense Urban Areas are 1% of Land

- Area of the Earth = 511×10^{12} m^2
- Land Area (29%) = 148×10^{12} m^2 [1]
- Area of the 100 largest cities = 0.38×10^{12} m^2 = 0.26% of Land Area for 670 M people
- Assuming 3B live in urban area, urban areas = [3000/670] x 0.26% = 1.2% of land
- But smaller cities have lower population density, hence, urban areas = 2% of land
- Dense, developed urban areas only 1% of land [2]

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Potentials to Increase Urban Albdeo 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 0.25x0.25=0.063
- Paved surfaces albedo can increase by 0.15 for a net change of 0.35x0.15=0.052
- Net urban area albedo change at least 0.10

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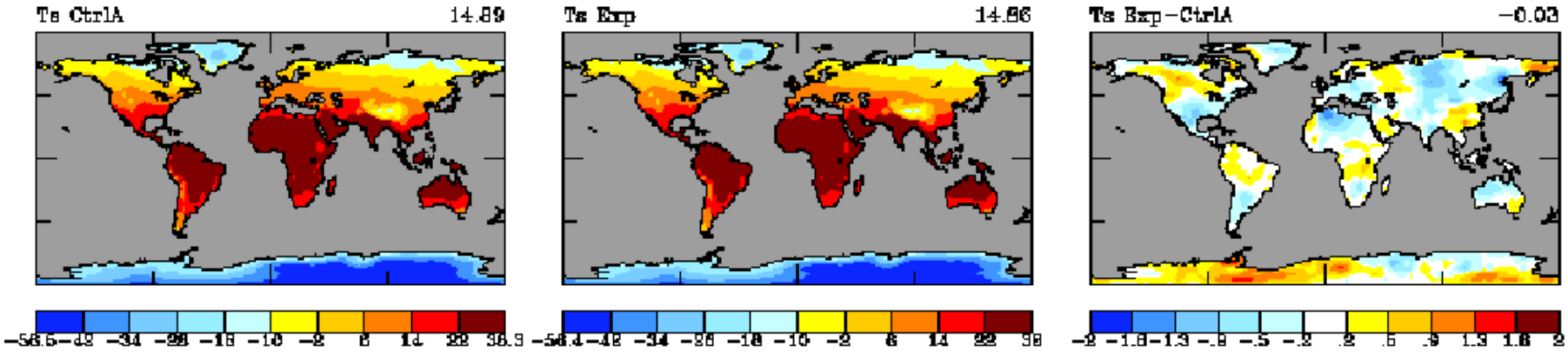
Effect of Increasing Urban Albedo by 0.1

- Net Change in Global albedo
  = [City/Land]x[Land/Globe]xΔa = [2]x[1]xΔa
  = 0.01 x 0.29 x0.1 = 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 CO_2 emissions = 25 G tons/year (4.1 tons/year per person)
- World's rate of CO_2 emissions averaged over next 60 years = 40 G tons/year
- Hence 0.3 years delay is worth 12 Gt CO_2; ~ 200 Mt CO_2/year

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Equivalent Value of Avoided CO_2

- CO_2 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 CO_2/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

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Market Deployment of Cool Color Cars

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

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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 [10^9gal]	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

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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

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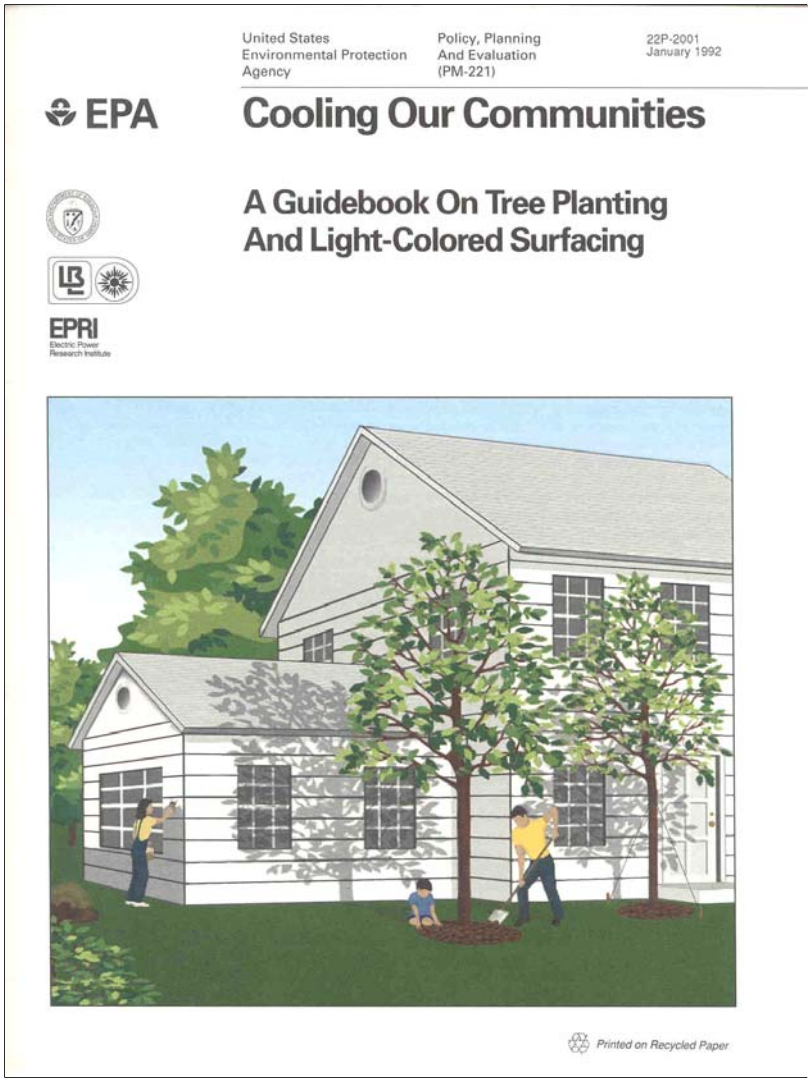
Practical Guidelines



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