White Roofs to Cool your Building, your City and (this is new!) Cool the World

Greenbuild Acceptance Talk
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Presentation available at www.ArtRosenfeld.org
Berkeley Earth Surface Temperature Project

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10-year moving average of surface temperatures over land
Anomalies relative to the Jan 1950 - Dec 1979 mean
Gray band indicates 95% statistical / spatial uncertainty interval

preprints and merged data now online at www.BerkeleyEarth.org
Especially in cities, thanks to the urban heat island effect

- Human activity, combined with dark roofs and pavements, make cities hotter than surrounding rural areas.
- Higher temperatures lead to greater energy use, lower air quality, and a reduced quality of life in urban areas.
Black vs. White Roofs

• Comparison on an August afternoon in Sacramento, CA, when air temperature was about 100°F:

When sunlight hits a black roof:
- 38% heats the atmosphere
- 52% heats the city air
- 5% is reflected
- 4.5% heats the building

Black Roof
80°C (177°F)

When sunlight hits a white roof:
- 10% heats the atmosphere
- 8% heats the city air
- 80% is reflected
- 1.5% heats the building

White Roof
44°C (111°F)

A new white roof (right) absorbs about 80 percent less sunlight than a black roof (left).
1995: Chicago Heat Wave
739 reported deaths
The highest risk group lived on the top floors of buildings with black roofs
Aug. 2003: European heat wave
Temperature anomalies reached 10°C
52,000 Europeans died—18,000 Italians (2006 assessment)

Country | Fatalities
--- | ---
Italy | 18,257
France | 14,802
Germany | 7,000
Spain | 4,130
England & Wales | 2,139
Portugal | 2,099
Smaller countries | 4,025
Total of above | 52,452

http://earthobservatory.nasa.gov/IOTD/view.php?id=3714
Art’s Epiphany
2003 European Heat Wave

• CEC Energy Efficiency Committee was responsible for Title 24, and I chaired the Committee; a real opportunity to convince T-24 team that “flat roofs shall be white”
• CA Title 24—Building Energy Efficiency Standards
  – Covers new buildings and major retrofits
• CEC adopted white roof requirement for flat roofs in 2005, effective 2007
• Compliance seems ok, and installations of white roofs are running millions of square feet PER MONTH
What about green roofs?
(i.e. vegetated roofs)

• Green roofs automatically comply with T-24 as “cool roofs”
• NYC and Chicago have adopted exactly CA’s regulations for white roofs and of course are actively promoting green roofs
• Green roofs reduce building heat load and mitigate urban heat island effect just as well as white roofs
  – Caveats:
    • Per square foot, they are only 1/3 as effective at offsetting global warming as white roofs
    • I don’t promote green roofs for CA or any climate with no rain in the summer
San Jose, CA – 1993
Progress: San Jose, CA – 2011
Cooling our planet
New AC Load: India

Residential AC Units

Annual Growth: 14%

Source: World Bank
GLOBAL COOLING: whitening 100 m$^2$ (~1000 ft$^2$) of dark roofing cancels out the emission of 10 t of CO$_2$
How much CO$_2$ equivalent is offset if we whiten all eligible urban flat roofs world-wide? (i/ii)

• Answer: 24 Gigatonnes (Gt)
  – 2/3 of a year’s worldwide emission
  – Gigatonne = billion metric tons

• If implemented over 20 years (the life of a roof or a program) this is $\approx$ 1.2 Gt/year.
How much CO$_2$ equivalent is offset if we whiten all eligible urban flat roofs world-wide? (ii/ii)

- Offset is equivalent to **taking half the cars in the world off the road for 20 years.**
  - There are about 600 million passenger cars world wide, and they each emit $\approx 4$ t CO$_2$/year.
In terms of avoided power plants

• Full white roof potential avoids 500 medium-sized coal fired power plants or 1,000 medium-sized gas fired power plants
• For comparison, global power plants emit annually ~15 Gt CO2, equivalent to the output of 6,000 typical midsized power plants (2/3 coal, 1/3 gas)
• Further comparison – the real avoided emissions from global CFL deployment is equivalent to 400 power plants.
How to promote white as the color for flat roofs? Enter Global Cool Cities Alliance—GCCA

- Public-private partnership launched in 2009 thanks to the contagious enthusiasm of DoE Secretary Steve Chu
- Two targets—domestic & international
- Strategy: work with building code officials to require and enforce “Flat roofs shall be white”
- Int’l diplomacy: GCCA is “implementing agent” of Cool Roof and Pavement working group of the G-20 Energy Ministers
  - India, Japan, Mexico, and U.S. have signed up
- “100 Cool Cities” program open to all large cities
  - U.S.: Chicago, NYC, Philadelphia, San Jose
  - Abroad: Athens, Mexico City, New Delhi, Sao Paolo, Taipei
- Visit www.GlobalCoolCities.org so your city, company, or public interest group can join
Contact Information
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Resources on the web

- LBNL – Heat Island Group
  - HeatIsland.LBL.gov
- Art Rosenfeld’s website
  - www.ArtRosenfeld.org
- Global Cool Cities Alliance
  - www.GlobalCoolCities.org
- Cool Roofs and Cool Pavements Toolkit
  - www.CoolRoofToolkit.org
SUPPLEMENTARY SLIDES
Sunlight — more than meets the eye

Solar Irradiance Distribution

- 6.6% ultraviolet (300 - 400 nm)
- 44.7% visible (400 - 700 nm)
- 48.7% near-infrared (700 - 2500 nm)

Air Mass 1 Global Horizontal (AM1GH) Solar Irradiance
White, cool color, warm color

Reflectance vs. Wavelength (nm)

- **standard white** ($R_{sol} = 0.82$)
- **cool red** ($R_{sol} = 0.39$)
- **dark gray** ($R_{sol} = 0.23$)

Irradiance (W m$^{-2}$ nm$^{-1}$)

- **solar irradiance**

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**Images:**
- White roof
- Cool red roof
- Gray roof
Cool colored roofs available today

- **Cool concrete tile**: SR ≥0.40
  - Standard concrete tile (same color)
  - Solar reflectance gain = +0.37 +0.26 +0.23 +0.15 +0.29 +0.29

- **Cool clay tile**: SR ≥0.40
  - Courtesy MCA Clay Tile

- **Cool metal**: SR ≥0.30
  - Courtesy BASF Industrial Coatings

- **Cool fiberglass asphalt shingle**: SR ≥0.25
  - Courtesy Elk Corporation

Sample colors and textures for each type are shown in the diagram.