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

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Arthur H. Rosenfeld, Former Commissioner
California Energy Commission.

Distinguished Scientist Emeritus
Lawrence Berkeley National Lab.

AHRosenfeld@LBL.gov
510 495-2227

Presented by Kurt Shickman, Executive Director, Global Cool Cities Alliance

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

Decadal Land-Surface Average Temperature

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

Temperature Anomaly (°C)

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preprints and merged data now online at www.BerkeleyEarth.org
The Planet is Warming

Source: NASA
Greenland is about \( \frac{1}{4} \) the size of continental US
Permanent ice sheet has melted substantially

1% of world land area

(Comparable to global urban space)

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.
Reflective roofs stay cooler in sunlight and should age more slowly.

White roofs, cool-colored roofs save money and can even avoid the need to air condition.

OLD

flat, white

AC savings ≈ 15%

pitched, white

AC savings ≈ 10%

NEW

pitched, cool & colored

AC savings ≈ 5%
1995: Chicago Heat Wave, 739 reported* deaths
The highest risk group lived on the top floors of buildings with black roofs

* More than 250 additional deaths not autopsied
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
2010: Heat wave centered Southeast of Moscow
Temperature anomalies reached 12°C
10,000-15,000 deaths

New AC Load: India

Residential AC Units

Annual Growth: 14%

Source: World Bank
Electricity Load and Temperature

Smog Formation and Temperature

Maximum surface temperature at BWI versus peak 8-hr ozone concentrations in the Baltimore non-attainment area for the period May-September, 1994-2004 (Piety, 2007).

Source: Maryland Commission on Climate Change
A Real-World Example of Cooling

The whitewashed greenhouses of Almeria, Spain have cooled the region by 0.8 degrees Celsius each decade compared to surrounding regions, according to 20 years of weather station data.

Source: Google Earth
Cooling our planet
Solar-reflective surfaces cool the globe via “negative radiative forcing”

Source: Intergovernmental Panel on Climate Change (IPCC)
GLOBAL COOLING: whitening 100 m² (~1000 ft²) of gray roofing cancels out the emission of 10 t of CO₂
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.
Addressing Urban Heat Islands Help to Achieve Goal of Sustainable and Resilient Urban Areas

**Building Scale**
- Up to 20% reductions in cooling demand on top floor.
- Improved thermal comfort and productivity in unconditioned buildings (e.g., homes, warehouses etc.).
- Longer lasting roofs.

**Urban Scale**
- Improved air quality – a $10 billion energy and health cost reduction opportunity in the U.S. alone per year.
- Reduced peak electricity demand and avoided adoption of air conditioning.
- Greater resiliency to heat events and climate change.

**Global Scale**
- Offset the warming effect of 24 gigatons of CO₂ – equivalent to taking 500 coal power plants offline for 20 years.
- Every 10 square meters of white roof = 0.5 tons of CO₂ offset per year.
White roofs around the world
...in Santorini, Greece
...in Hyderabad, India

...and widely in the state of Gujarat, India.
Walmart store in northern California, ~2006
UC Davis switched to white membranes ~1980—Congrats, and some still in service 30 yrs later
San Jose, CA – 1993
San Jose, CA – 2011
Washington, DC (Federal) has problems with historical buildings
Pentagon
COOL CITIES, COOL PLANET

What to do now
Progress in energy efficiency standards

• In 2005, California’s “Title 24” energy efficiency standards prescribed white surfaces for low-sloped roofs on commercial and large residential buildings (apartments, hotels, etc.). Several hot states are following.

• In 2008, California prescribed “cool colored” surfaces for steep residential roofs in its 5 hottest climate zones, but not yet Los Angeles.

• Other U.S. states & all countries with hot summers ought to follow.
Recent cool roof progress (2005 – 2012)

• **2005**
  – California Title 24 – “Flat roofs shall be white” (15 out of 16 climate zones). Walmart adopts white roofs for ALL stores.
  – EPA ENERGY STAR lists Cool Roof Materials

• **2010**
  – June 1\textsuperscript{st}, 2010 – Memo from U.S. Energy Secretary Steven Chu calls for all DOE Buildings to have white roofs, if cost-effective
  – June 16\textsuperscript{th}, 2010 – Marine Corp follows suit, Pentagon GSA following.
  – June 19\textsuperscript{th}, 2010 – RetroFIT Philly announces winner of “coolest block” contest to white-coat black roofs of row houses.

• **2011-12**
  – 2012--US launched, at G20 Energy Ministers meeting, a voluntary Cool Roofs Working Group, and offers technical assistance to “charter” developing countries: India, Japan, Mexico, & US joined (further discussions with Brazil, China, South Africa).
  – New York City and Chicago adopt “If it’s flat it shall be white or green”
To come in 2013…

- Model codes will be modified to prescribe “flat roofs shall be white”
  - ASHRAE for commercial buildings
  - IECC for residential buildings
- But states and cities must still adopt model codes
OPPORTUNITIES

• The dramatic and simple advantages of white roofs are easily understood worldwide – people just “get it”
• Those of cool-colored roofs are harder to describe, but can eventually be significant
  – At least for wealthier nations
• Paved surfaces are a harder sell but a large source of untapped potential – a typical “tragedy of the commons”
Global Cool Cities Alliance (GCCA)

The Global Cool Cities Alliance is dedicated to advancing policies and actions that increase the solar reflectance of our buildings and pavements as a cost-effective way to promote cool buildings, cool cities, and to mitigate the effects of climate change through global cooling.

- Descriptions of the science, the benefits, and the costs of cool surfaces.

- Simple actions to design programs and policies drawn from global best practices.

- Links to sample materials and relevant organizations.

- Coming soon: a comprehensive “knowledge base” of research, best practices, code/ordinance language, sample program materials and an expert forum.
The Cool Roofs and Pavements Working Group

• Formed under Clean Energy Ministerial’s Global Superior Energy Performance Partnership

• Four official members – India, Japan, Mexico, and the U.S.
  • Participation from Brazil and South Africa
  • Countries include 8 of the 20 largest cities.

• Robust participation from industry, NGOs, and technical experts

• Initiatives: affordable housing, building codes with active projects in India and Mexico

• Next meeting: New Delhi October 3\textsuperscript{rd} – 5\textsuperscript{th}
Working Together

• Participate in the Cool Roofs and Pavements Working Group

• Join GCCA Technical Advisory Council

• Participate in Expert Forum (coming soon)

• Participate in the codes collaborative
Resources on the web

- **LBNL – Heat Island Group**
  - [HeatIsland.LBL.gov](HeatIsland.LBL.gov)

- **Art Rosenfeld’s website**
  - [www.ArtRosenfeld.org](www.ArtRosenfeld.org)

- **Global Cool Cities Alliance**

- **Cool Roofs and Cool Pavements Toolkit**
  - [www.CoolRoofToolkit.org](www.CoolRoofToolkit.org)
Thank You!

Kurt Shickman
Executive Director
Global Cool Cities Alliance
kurt@globalcoolcities.org
GlobalCoolCities.org / CoolRoofToolKit.org
001-202-550-5852
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
Duro-Last membrane (dark gray [LBNL]/matte)  
\[ G:\text{sol}=0.23, \text{uv}=0.09, \text{vis}=0.26, \text{nir}=0.22 \]

white membrane  
\[ G:\text{sol}=0.82, \text{uv}=0.12, \text{vis}=0.90, \text{nir}=0.83 \]

red tile  
\[ G:\text{sol}=0.39, \text{uv}=0.07, \text{vis}=0.20, \text{nir}=0.60 \]

White, cool color, warm color
Cool colored roofs available today

- **Cool concrete tile**
  - SR ≥ 0.40
  - Solar reflectance gain = +0.37 +0.26 +0.23 +0.15 +0.29 +0.29
  - Courtesy American Rooftile Coatings

- **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

- **Standard concrete tile**
  - (same color)
  - R=0.04 R=0.18 R=0.21 R=0.33 R=0.17 R=0.12