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

Int’l. Conf. on Accelerated Aging of Cool Roofs
Berkeley, CA  July 28, 2011

Arthur H. Rosenfeld, Former Commissioner
California Energy Commission.

Distinguished Scientist Emeritus
Lawrence Berkeley National Lab.

AHRosenfeld@LBL.gov
510 495-2227

Presentation available at www.ArtRosenfeld.org
Bird’s eye view of urban land use

The surface of Sacramento, CA is about

- 20% roofs
- 30% vegetation
- 40% pavement

~ 1 km²
Chicago Heat Wave 1995, 739 Deaths
The highest risk group lived on the top floors of buildings with black roofs
European Heat Wave 2003, 30,000 Deaths
Moscow-Centered Heat Wave 2010, ~10,000 Deaths
White roofs around the world
...in Santorini, Greece
...in Hyderabad, India

...and widely in the state of Gujarat, India.
Walmart store in northern California, ~2005
Congratulations to UC Davis
White roofs are popular in Tucson, AZ
Washington, DC (Federal) has problems
Pentagon
Cooling our planet
Consider a Spherical Cow
(A Course in Environmental Problem Solving)
By John Harte, UC Berkeley
University Science Books, Mill Valley, CA 1988

Urban Heat Islands Ch3.B.9
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
Atmospheric greenhouse effect (i/ii)
Solar-reflective surfaces cool the globe via “negative radiative forcing”
GLOBAL COOLING: making 100 m² (1000 ft²) of gray roofing white offsets 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 300 million cars 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 can **offset** the emissions from 500 medium-sized coal fired power plants or 1,000 medium-sized gas fired power plants.

That is just the albedo effect – if the building is air conditioned, it will also avoid comparable *real* CO2 back at the power plant.
3 papers and 1 memo estimate tonnes of CO₂ offset by 100 m² (1000 ft²) of white roof. May 2010

<table>
<thead>
<tr>
<th>Study (available at CoolWhitePlanet.org)</th>
<th>Method</th>
<th>Cloud cover estimation</th>
<th>CO₂ offset (atmospheric) per 100 m²</th>
<th>CO₂ offset (emitted) per 100 m²</th>
<th>World-wide potential CO₂ offset (emitted) from cool roofs</th>
<th>CO₂ offset compared to Akbari et al. 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Akbari et al. 2009 (LBNL)</td>
<td>calculation</td>
<td>~ 50%</td>
<td>5.5 t</td>
<td>10 t</td>
<td>24 Gt</td>
<td>100%</td>
</tr>
<tr>
<td>Menon et al. 2010 (LBNL)</td>
<td>GCM + land use model (summer only)</td>
<td>GCM</td>
<td>7 t</td>
<td>13 t</td>
<td>30 Gt</td>
<td>130%</td>
</tr>
<tr>
<td>Oleson et al. 2010 (NCAR)</td>
<td>GCM + urban canyon model</td>
<td>GCM</td>
<td>7 t</td>
<td>13 t</td>
<td>30 Gt</td>
<td>130%</td>
</tr>
<tr>
<td>VanCuren et al. 2010 (CARB)</td>
<td>measured solar radiation</td>
<td>not needed</td>
<td>3 t</td>
<td>5 t</td>
<td>Addresses CA only; coastal CA is foggy.</td>
<td>50%</td>
</tr>
</tbody>
</table>

It is assumed that of 1 tonne of CO₂ emitted only 0.55 tonnes remain in the atmosphere after one year, so the atmospheric and emitted columns are just in the ratio of 0.55/1.
Corroboration Since 2010

Vancuren, et al. is now refereed and published.

Franco Cotana, et al., University of Perugia, will present their 2008 paper at Lawrence Berkeley National Laboratory (LBNL) on July 28th, 2011. They estimate 7 tonnes of CO2 offset per 100 m2 vs. 10 by Akbari, et al. 

_Hear Anna Pisello & Frederico Rossi at lunch Friday._

All estimates so far agree within a factor of 2.

Now we need calculations for _individual regions._
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 buildings. Several hot states are following. Also New York City, effective January 2012. Vegetated (“green”) roofs are deemed “white.

• In 2008, California prescribed “cool colored” surfaces for steep residential roofs in its 5 hottest out of 16 climate zones.

• Other U.S. states & all countries with hot summers should follow.
Recent cool roof progress (2005 – 2011)

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

- **2011**
  - 100 Cool Cities launched – see [www.GlobalCoolCitiesAlliance.org](http://www.GlobalCoolCitiesAlliance.org)
  - Spring 2011 – US launched, at annual G20 Energy Ministers meeting, a voluntary Cool Roofs Working Group, and offered technical assistance to developing countries who join early. India, Mexico, have joined so far, with Japan expected.
To come 2012, 2013

• Model codes will be modified to prescribe “flat roofs shall be white”
  – ASHRAE 90.1(2013) for commercial buildings
  – EECC(2-12) for residential and commercial buildings
• But states and cities still must adopt model codes
Global Cool Cities Alliance could unite many initiatives and trade associations
What about “Green” (Vegetated) Roofs?

ADVANTAGES

• In a rainy summer they cool buildings and cities comparably with white roofs.
• They hold up ~half of storm water.

DISADVANTAGES

• Their albedo is only ~20%, so they absorb sunshine, get warm, and then cool by evapo-transpiration. The absorbed heat is trapped by the greenhouse effect and the cooling by evaporation is cancelled within hours or days by the condensation of the water vapor into rain.
• For global cooling they are only one-third as effective as white roofs.
• Their first cost is ~$15/sq. ft. (depending on roof type) and may need an irrigation system.
• I support them, but, as a 5% niche, they can be a distraction.
Resources on the web

• Art Rosenfeld’s website
  – ArtRosenfeld.org

• Cool Colors Project
  – CoolColors.LBL.gov

• Heat Island Group
  – HeatIsland.LBL.gov

• Cool Communities Project
  – CoolCommunities.LBL.gov

• Roof Savings Calculator
  – RoofCalc.com

• Global Cool Cities Alliance
  – GlobalCoolCities.org

• Cool Roof Rating Council
  – CoolRoofs.org

• Cool California
  – CoolCalifornia.org

• EPA Heat Islands
  – epa.gov/heatisland

• Energy Star Cool Roofs
  – EnergyStar.gov