



## Cool Roofs and Global Cooling

Surabi Menon, Ronnen Levinson, Marc Fischer, Dev Millstein,  
Nancy Brown, Francisco Salamanca, Igor Sednev and Art Rosenfeld

Heat Island Group, Lawrence Berkeley National Laboratory

4 November 2011

The recent *Journal of Climate* paper by Stanford researchers Mark Jacobson and John Ten Hoeve (2011) is a useful contribution to the literature on urban heat islands and mitigation potential of reflective (or white or cool) surfaces such as roofs and pavements. However, the article's results regarding white roofs are preliminary and uncertain. Moreover there are other published papers that address the broader benefits of white roofs. In our view, these studies taken together raise important issues that need to be considered from the policy viewpoint to fully understand the mitigation potential from more reflective (or white or cool) surfaces.

Lawrence Berkeley National Laboratory's [Heat Island Group](#) has conducted extensive research on cool materials and their effects on regional and global climate. Due to media coverage highlighting the paper's conclusions that speculatively suggest an overall global warming influence of converting worldwide roofs to white, the Heat Island Group would like to draw attention to a few points of the paper. We believe its conclusions need to be analyzed more carefully.

### Concerns about study by Jacobson and Ten Hoeve (2011)

- (1) Uncertainty is identified as significant by the authors themselves

**The authors themselves contend that white roofs may reduce temperatures locally but may or may not reduce overall global warming.** They also state that the **uncertainty range associated with their results**—that the urban heat island effect contributes 2-4% of gross global warming—**may likely be larger than the model range presented.**

- (2) Numerical results may be statistically insignificant

In the paper they report an overall warming of the Earth by about 0.07 K, for the case where worldwide roofs are converted to white, but the **variability in model predictions is not reported** for such a change. Moreover, the **percent changes in various climate parameters for differences between white and nonwhite roofs are smaller than 1%.** This makes it difficult to isolate noise from signal unless the simulations are run far longer than the 20 years considered, especially for the equilibrium climate simulations presented. Even if they contend that their results are significant, the variability in the model predictions needs to be reported to provide a quantitative basis for comparison with the magnitude of the warming effect.

- (3) Results are based on specific assumptions

Surfaces were characterized at the 1 square km scale in the model, but the climate responses were averaged over a 200,000 square km scale. The results from the study would also strongly depend on the modeling assumptions made since various feedbacks from changes to a small fraction of the total Earth area (about 0.128% of the Earth's area

is considered urban) are accounted for at a scale that is exceptionally large, 200,000 square km. In fact, **the authors themselves rightly conclude that the results regarding white roofs in their paper apply only to assumptions made.** This is an important and critical point in the paper: the interpretation of the point is that the results could be different depending on the model used and how clouds and the climate respond to small changes imposed on extremely small surface areas.

- (4) Finer resolution is essential to capture cloud and climate feedbacks

With respect to the net effect of increased reflectance on global climate, moisture and cloud feedbacks make it conceivable that increasing surface reflectance in one place could warm the climate in another. This is still uncertain, and a subject for additional research. It is critical for this question to be resolved at the urban scale (1 square km) and not at the 200,000 square km scale used in the simulations. **As the authors state: "Feedbacks of local changes to the global scale were magnified over high-latitude snow and sea ice, causing a net but highly-uncertain warming effect on global climate."**

### Other related studies from the Heat Island Group

- (1) Jacobson and Ten Hoeve (2011) do not discuss any changes in their reflected radiation at the top of the atmosphere. For comparison, a recent study by [Millstein and Menon \(2011\)](#) quantified the response of surface heating and air temperatures to the installation of white roofs and photovoltaic panels within the continental U.S. Millstein and Menon simulated a 12-year period using a regional (resolving at the 625 square km scale) climate model that allowed the atmosphere to respond to changes caused by more reflective (or whiter) urban surfaces. Quantitative estimates of the changes due to white roofs and the variability through time of radiative fluxes and temperature were documented for both major urban cities and over the U.S. as a whole. While local surface air temperature response to white roofs was significant over all urban cities, the temperature response averaged over the continental U.S. was not as significant, possibly due to natural variability. However, **the change in total outgoing radiation at the top of the atmosphere showed a significant increase, demonstrating that increasing the surface reflectance did reduce net radiation absorbed by the Earth.**
- (2) Other studies that have examined the impacts from worldwide conversion of urban surfaces to white by [Oleson et al. \(2010\)](#)—which did include climate feedbacks—and [Akbari et al. \(2009\)](#)—which did not include climate feedbacks—indicate similar and significant reductions in net absorbed radiation from the global application of white surfaces in urban environments. Recent work by Akbari and Matthews (2010) using an intermediately complex global climate model with an interactive global carbon cycle, found the short term CO<sub>2</sub> offset equivalent to be ~ 80 gigatonnes, increasing to about 180 gigatonnes in 200 years, for an increase in albedo of urban areas by 0.1.
- (3) There are documented local benefits for energy consumption and carbon emissions. [Levinson and Akbari \(2010\)](#) produced a detailed analysis considering both the cooling energy savings and the heating energy penalties that could be obtained by using white roofs on U.S. commercial buildings. The results show that annual primary (fuel) energy savings, carbon savings, and energy cost savings are positive for building stocks in all individual states. The U.S.-average cooling energy saving is eight times larger than the

U.S.-average heating energy penalty. Upgrading 80% of the roofs on U.S. commercial buildings would yield an energy cost saving of \$0.7B/year, and a carbon emission reduction of 6 million tonnes CO<sub>2</sub>/year. Upgrading 95% of U.S. homes with cool colored roofs—dark materials that reflect the invisible part of sunlight—could save an additional \$1B in energy and another 9 million tonnes CO<sub>2</sub> each year. Most of the U.S. roofing stock could be upgraded at little to no cost over the next 20 years by choosing cool replacement products when existing roofs reach the end of their service lives. These types of savings were not considered in Jacobson and Ten Hoeve (2011).

To conclude, white roofs provide a sensible, low-cost solution that significantly reduces energy need and costs in a wide variety of climates, and a growing body of work suggests that selective use of white roofs may also reduce heating of the Earth's surface. A [new observational and modeling study](#) currently underway by the Heat Island Group will in fact compare the radiative fluxes, temperature and building heat fluxes attained with white roofs to those attained with dark roofs. This study will use both surface-based and satellite-retrieved data of radiative fluxes and temperature to support results from the model regarding the cooling/heating benefits of cool roofs.

Selective use of white roofs makes sense as part of an integrated strategy for a more sustainable human existence on Earth. However, the potential benefits offered by cool roofs do not diminish the need for sustained reductions in anthropogenic greenhouse gas emissions to control global climate, or the need for increased use of renewable energy sources.

## References

- Akbari, H., S. Menon and A. Rosenfeld, 2009: Global cooling: Increasing world-wide urban albedos to offset CO<sub>2</sub>. *Climatic Change*, 94, 3-4, 275-286. <http://dx.doi.org/10.1007/s10584-008-9515-9>
- Akbari, H. and D. Matthews: 2010. "Global Cooling Updates: Reflective Roofs and Pavements." Proceedings of the 3<sup>rd</sup> International Passive and Low Energy Cooling for the Built Environment, Palenc 2010, Sep 29-Oct 1, Rhodes, Greece.
- Jacobson, M. and J.E. Ten Hoeve, 2011: Effects of urban surfaces and white roofs on global and regional climate. *J. Clim.*, In press. <http://dx.doi.org/10.1175/JCLI-D-11-00032.1>
- Levinson, R. and H. Akbari, 2010: Potential benefits of cool roofs on commercial buildings: conserving energy, saving money, and reducing emission of greenhouse gases and air pollutants. *Energy Efficiency*, 3(1): 53-109. <http://dx.doi.org/10.1007/s12053-008-9038-2>
- Millstein, D. and S. Menon, 2011: Regional climate consequences of large-scale cool roof and photovoltaic array deployment. *Environ. Res. Lett.* 6:034001. <http://dx.doi.org/10.1088/1748-9326/6/3/034001>
- Oleson, K.W., G.B. Bonan and J. Feddema, 2010: Effects of white roofs on urban temperature in a global climate model. *Geophysical Res. Lett.*, 37, <http://dx.doi.org/10.1029/2009GL042194>

## News Releases

[Berkeley Lab Project in India To Measure Impact of Pollution on Cool Roofs](#), October 13, 2011

[Efficacy of Cool Roofs Varies from City to City](#), July 26, 2011

[Global Model Confirms: Cool Roofs Can Offset Carbon Dioxide Emissions and Mitigate Global Warming](#), July 19, 2010

[Cool World: A Modest Proposal to Cool the Planet by Cooling the Neighborhood](#), December 11, 2008