



## White Roofs Cool the World, Directly Offset CO<sub>2</sub> and Delay Global Warming

As the threat of global warming becomes widely recognized, scientists have proposed using geo-engineering (manipulation of the Earth's environment) to quickly respond to this threat. Most proposed geo-engineering techniques are novel and unproven. Two simple technologies that have been around for thousands of years, cool roofs and cool pavements, should be the first geo-engineering techniques used to combat global warming.

Increasing the solar reflectance of urban surfaces reduces their solar heat gain, lowers their temperatures, and avoids transferring heat back into the atmosphere. This process of “negative radiative forcing” counters global warming. In a [recent study](#) to be published in journal *Climatic Change*, Akbari, Menon and Rosenfeld have calculated the CO<sub>2</sub> offset, or equivalent reduction in CO<sub>2</sub> emission, achieved by increasing the solar reflectance of urban surfaces<sup>1</sup>.

Most existing flat roofs are dark and reflect only 10 to 20% of sunlight. Resurfacing the roof with a white material that has a long-term solar reflectance of 0.60 or more increases its solar reflectance by at least 0.40. Akbari *et al.* estimate that so retrofitting 100 m<sup>2</sup> (1000 ft<sup>2</sup>) of roof offsets 10 tonnes of CO<sub>2</sub> emission. (For comparison purposes, we point out that a typical US house emits about 10 tonnes of CO<sub>2</sub> per year.) Emitted CO<sub>2</sub> is currently traded in Europe at about \$25/tonne, making this 10-tonne offset worth \$250.



100 m<sup>2</sup> (~1000 ft<sup>2</sup>) of a white roof, replacing a dark roof, offsets the emission of 10 tonnes of CO<sub>2</sub>

It is fairly easy to persuade (or to require) the owners of buildings to select white materials for flat roofs, and in California this has been required since 2005<sup>2</sup>. However, the demand for white *sloped* roofs is limited in North America, so California compromises by requiring only “cool colored” surfaces for sloped roofs. (This rule takes effect in July 2009.) Use of cool-colored surfaces increases solar reflectance by about 0.20 and yields a CO<sub>2</sub> offset of about five tonnes per 100 m<sup>2</sup>, or about half

<sup>1</sup> Akbari, H., S. Menon, and A. Rosenfeld. 2008. “Global cooling: increasing solar reflectance of urban areas to offset CO<sub>2</sub>,” In press, *Climatic Change*. Hashem Akbari is a senior scientist (email [H\\_Akbari@lbl.gov](mailto:H_Akbari@lbl.gov), phone +1-510-486-4287) and Surabi Menon (email [SMenon@lbl.gov](mailto:SMenon@lbl.gov), phone +1-510-486-6752) is a staff scientist with the Lawrence Berkeley National Laboratory. Arthur Rosenfeld is a commissioner with the California Energy Commission (email [Arosenfe@energy.state.ca.us](mailto:Arosenfe@energy.state.ca.us), phone +1-916-654-4930). This 2-page note is at: [www.energy.ca.gov/2008publications/CEC-999-2008-031/CEC-999-2008-031.PDF](http://www.energy.ca.gov/2008publications/CEC-999-2008-031/CEC-999-2008-031.PDF)

<sup>2</sup> California has justified cool roofs based on cooling energy saving alone. White roofs save building's cooling-energy use by about 20% (and hence directly reduce CO<sub>2</sub> emissions from power plants). The estimated U.S. potential savings for white roofs are in excess of \$1 billion per year in net annual energy bills (cooling-energy savings minus heating-energy penalties). Cool roofs also reduce the summertime urban temperatures leading to an improved urban air quality. The combined effect of the energy and air-quality savings from increasing the solar reflectance of urban surfaces in the U.S. alone can exceed \$2 billion per year. For urban dwellers worldwide savings would be many billion dollars/year.

that achieved with white surfaces. The solar reflectance of pavement can be raised on average by about 0.15, offsetting about four tonnes of CO<sub>2</sub> per 100 m<sup>2</sup>.

Over 50% of the world population now lives in urban areas, and by 2040 that fraction is expected to reach 70%. Pavements and roofs comprise over 60% of urban surfaces (roofs 20 to 25%, pavements about 40%). Akbari *et al.* estimate that permanently retrofitting urban roofs and pavements in the tropical and temperate regions of the world with solar-reflective materials would offset 44 billion tonnes of emitted CO<sub>2</sub>, worth \$1.1 trillion at \$25/tonne.

How can the reader visualize this *one time* offset of 44 billion tonnes of CO<sub>2</sub>? The average world car emits about 4 tonnes of CO<sub>2</sub> each year. Permanently increasing the solar reflectance of urban roofs and pavements worldwide would offset 11 billion car-years of emission. This is equivalent to taking the world's approximately 600 million<sup>3</sup> cars off the road for 18 years.

If only roofs are changed from their current dark colors to white for flat roofs and cool colors for sloped roofs, we can offset 24 billion tonnes of CO<sub>2</sub>. If we take 20 years to implement just the cool roofs portion, it's the equivalent of taking half of the cars in the world off the road for every year of the 20 year program (see table). The offset provided by cooling urban surfaces affords us a significant delay in climate change during which we can take further measures to improve energy efficiency and sustainability.

Equivalent Car Offsets from Cool Roofs		
Duration of Program	Annual CO <sub>2</sub> Offsets	Equivalent Cars Offset
10 Yr	2.4 Billion t/yr	600 million Cars for 10 years
20 Yr	1.2 Billion t/yr	300 Million Cars for 20 years

Akbari *et al.* propose an international campaign to use solar reflective materials when roofs and pavements are initially built or resurfaced in temperate and tropical regions. They point out that such an international "cool cities" program is a win, win, win proposition. Cool roofs reduce cooling-energy use in air conditioned buildings and increase

comfort in unconditioned buildings (win #1). Cool roofs and cool pavements mitigate summer urban heat islands, improving outdoor air quality and comfort (win #2). This latest research shows that cool roofs and cool pavements can cool the entire globe (win #3). Installing cool roofs and cool pavements in cities worldwide does not require delicate international negotiations about capping CO<sub>2</sub> emission rates.

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<sup>3</sup> Worldwide car ownership is currently estimated at 600million with projected totals of 1.3 billion by 2030.