



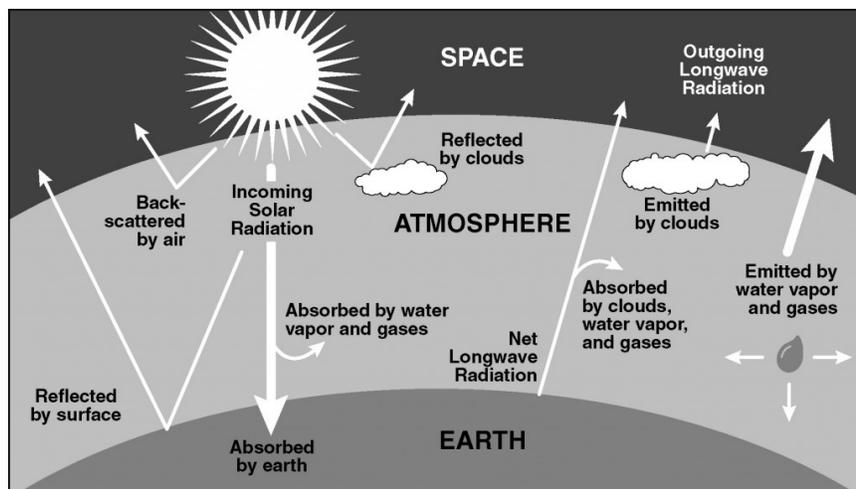
## Issue Brief #1: Do reflective roofs cool the world?

*Existing research indicates that solar reflective roofs are a good near-term strategy for climate change mitigation because they can cancel a portion of the warming effect of greenhouse gases. Most studies that have examined the global temperature effects of reflective roofs indicate a net global cooling effect, though one study finds a possible warming effect owing to reduced cloud cover and increased atmospheric heating from soot. However, these highly uncertain effects do not counteract the public health and energy saving benefits from mitigating urban heat islands, nor are they likely to offset the global effects of local cooling from reflective roofs.*

Solar reflective roofs are catching on across the country and around the world. Replacing traditional dark roofs with materials (such as white roofs) that absorb less sunlight keeps outside air temperatures lower, which dampens the severity of heat waves and slows smog formation. Reflective roofs also save building occupants money on air-conditioning bills.<sup>1</sup> These virtues are supported by decades of broadly accepted research and justify policies that require new or end-of-service-life replacement roofs for commercial buildings to be white.<sup>2</sup>

Proponents also point out that reflective roofs can cool the world. By reducing the electricity needed for air-conditioning, reflective roofs decrease greenhouse gas emissions from power plants and thereby indirectly cool the world. But the larger and more direct cooling benefit of reflective roofs that is discussed in the literature is a product of their most basic properties—they reflect, rather than absorb, most incoming sunlight. So instead of heating up and warming not only the surrounding air but also the atmosphere, reflective roofs

return sunlight back through the atmosphere and out into space, starting from the moment they are installed. A large-scale shift toward reflective roofs could therefore cool the world by reducing the amount of heat that is transmitted from the earth's surface and trapped in the atmosphere (see Figure 1)—this is known as the “albedo effect”.<sup>3</sup> And because this cooling effect is instantaneous, sooner is better from a climate change mitigation standpoint.



**Figure 1.** Earth's temperature is governed by a balance between incoming energy (direct from the sun or emitted from the atmosphere) and outgoing energy (reflected sunlight and heat radiated from the surface and atmosphere). Image source: Douglas DL (2010) Climate change and social adaptation: how the past can inform the future. Ename Center, Ghent, Belgium. Online at: <http://www.survivingearth.com/?p=197>

Earlier efforts to quantify this effect concluded that the use of more reflective surfaces in hot cities around the world would cancel the warming effect of 44–57 billion metric tons of emitted carbon dioxide<sup>4,5</sup>—up to 75% above current annual global emissions of carbon dioxide.<sup>6</sup> Subsequent long-term modeling of



more reflective urban surfaces found a sustained global cooling effect of 0.01–0.07°C (0.02–0.13°F),<sup>7</sup> which would cancel as much as 2% of global warming projected for the entire 21<sup>st</sup> century at the current emissions rate.<sup>8</sup> Another study estimated that increasing the reflectance of land surfaces (e.g., by converting to high-albedo roofs) could offset as much as 30% of greenhouse warming and slow climate change.<sup>9</sup>

A 2012 Stanford study determined that a worldwide conversion to reflective roofs may decrease global cloud cover and increase atmospheric heating from soot, suggesting a net global warming of 0.07°C (0.13°F). However, the study finds a population-weighted air temperature decrease of 0.02°C (0.04°F), meaning that reflective roofs generally cool the areas where people live while warming less populous areas.<sup>10</sup> The authors acknowledge that local cooling and urban heat island mitigation are accepted benefits of reflective roofs and that the larger-scale feedback effects that contribute to their findings, such as those related to clouds and soot, are subject to much greater uncertainty. Such feedbacks may reduce the global cooling benefit of reflective roofs and merit further study. However these feedbacks are unlikely to outweigh the global effects of local cooling from reflective roofs.

Earlier research has also suggested that brightening land surfaces could alter cloud cover. A 2007 study suggested that increasing land albedo reduces surface temperatures, which slows evaporation and therefore may diminish cloud formation.<sup>11</sup> Since clouds block out the sun, decreased cloud cover allows more sunlight to reach the land surface and potentially counteract the global cooling effect from lighter-colored surfaces. Another study found that urbanization with highly reflective roofs in Phoenix, AZ would reduce precipitation by 4%.<sup>12</sup> Yet because the study mostly compared precipitation with urbanization and reflective roofs to precipitation without any urbanization, it is unclear whether this result can be fairly attributed to reflective roofs. In addition, a 2011 paper modeled high-albedo cities and found that urban cooling reduced cloud cover in some nearby rural areas and increased summer afternoon temperatures in those locations. Nevertheless, this study found that reflective roofs increased the net amount of energy leaving the atmosphere, which indicates a global cooling effect.<sup>13</sup> Increasing the reflectance of roofs seems to affect cloud formation, but the net effect of this interaction on a global scale seems far from certain and is dependent on a wide variety of factors at a local level.

Whereas clouds effectively reflect sunlight and prevent it from reaching the surface, atmospheric soot particles effectively absorb sunlight—whether it comes from above or below. The authors of the Stanford study note that by reflecting most sunlight, high-albedo roofs nearly double the energy absorbed by soot particles that then heat the atmosphere. Since the layer of atmospheric soot lets some sunlight through, a portion of the sunlight reflected by a reflective roof will leave the atmosphere through that layer. By contrast, dark roofs absorb nearly all of the sunlight they receive and allow hardly any to exit the atmosphere. Reflective roofs therefore decrease the absorption of sunlight at the earth’s surface by more than they increase absorption by soot higher in the atmosphere. Soot may reduce the global cooling from reflective roofs, but it hardly negates it.

The possibility that reflective roofs may produce unforeseen atmospheric consequences deserves further investigation. However, these feedback effects do not negate the public health and energy saving benefits from mitigating urban heat islands, nor do they necessarily indicate a net global warming from using reflective roofs in cities. Complex atmospheric dynamics may prevent high-albedo roofs from realizing



the full global cooling potential attributed to them in earlier studies, but the fundamentals remain unchanged—reflective roofs absorb less of the sun’s energy, decreasing the amount of heat that gets trapped in the atmosphere and making it more likely than not that they can cool the world.

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<sup>1</sup> Akbari H, Pomerantz M, Taha H (2001) Cool surfaces and shade trees to reduce energy use and improve air quality in urban areas. *Solar Energy* 70:295–310.

<sup>2</sup> Akbari H, Levinson R (2008) Evolution of cool roof standards in the United States. *Advances in Building Energy Research* 2:1–32.

<sup>3</sup> “Albedo” is a Greek word meaning “whiteness.”

<sup>4</sup> Akbari H, Menon S, Rosenfeld A (2009) Global cooling: increasing world-wide urban albedos to offset CO<sub>2</sub>. *Climatic Change* 94:275–286.

<sup>5</sup> Menon S, Akbari H, Mahanama S, Sednev I, Levinson R (2010) Radiative forcing and temperature response to changes in urban albedos and associated CO<sub>2</sub> offsets. *Environmental Research Letters* 5: 11pp.

<sup>6</sup> 2011 estimate of 9.5 billion metric tons of carbon emitted (35 billion metric tons of carbon dioxide) from: Le Quere C et al. (2013) The global carbon budget 1959–2011. *Earth System Science Data* 5:165–185. Online at: [http://www.globalcarbonproject.org/global/pdf/pep/Post2006/LeQuere\\_2013\\_TheGlobalCarbonBudget1959%20%AD2011\\_ESSD.pdf](http://www.globalcarbonproject.org/global/pdf/pep/Post2006/LeQuere_2013_TheGlobalCarbonBudget1959%20%AD2011_ESSD.pdf).

<sup>7</sup> Akbari H, Matthews HD, Seto D (2012) The long-term effect of increasing the albedo of urban areas. *Environmental Research Letters* 7: 10 pp.

<sup>8</sup> Intergovernmental Panel on Climate Change (IPCC) (2007) Climate Change 2007: The Physical Science Basis: Summary for Policymakers. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M and Miller HL (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA: 18 pp. Online at: [http://www.ipcc.ch/publications\\_and\\_data/ar4/wg1/en/spm.html](http://www.ipcc.ch/publications_and_data/ar4/wg1/en/spm.html)

<sup>9</sup> Hamwey RM (2007) Active amplification of the terrestrial albedo to mitigate climate change: an exploratory study. *Mitigation and Adaptation Strategies for Global Change* 12:419–439.

<sup>10</sup> Jacobson MZ, Ten Hoeve JE (2012) Effects of urban surfaces and white roofs on global and regional climate. *Journal of Climate* 25:1028–1044.

<sup>11</sup> Supra at 9.

<sup>12</sup> Georgescu M, Mahalov A, Moustou M (2012) Seasonal hydroclimatic impacts of Sun Corridor expansion. *Environmental Research Letters* 7: 9 pp.

<sup>13</sup> Millstein D, Menon S (2011) Regional climate consequences of large-scale cool roof and photovoltaic array deployment. *Environmental Research Letters* 6: 9 pp.