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Global cooling: increasing world-wide urban albedos to offset CO_2

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Abstract Increasing urban albedo can reduce summertime temperatures, resulting in better air quality and savings from reduced air-conditioning costs. In addition, increasing urban albedo can result in less absorption of incoming solar radiation by the surface-troposphere system, countering to some extent the global scale effects of increasing greenhouse gas concentrations. Pavements and roofs typically constitute over 60% of urban surfaces (roof 20–25%, pavements about 40%). Using reflective materials, both roof and pavement albedos can be increased by about 0.25 and 0.15, respectively, resulting in a net albedo increase for urban areas of about 0.1. On a global basis, we estimate that increasing the world-wide albedos of urban roofs and paved surfaces will induce a negative radiative forcing on the earth equivalent to offsetting about 44 Gt of CO_2 emissions. At ~$25/tonne of CO_2, a 44 Gt CO_2 emission offset from changing the albedo of roofs and paved surfaces is worth about $1,100 billion. Furthermore, many studies have demonstrated reductions of more than 20% in cooling costs for buildings whose rooftop albedo has been increased from 10–20% to about 60% (in the US, potential savings exceed $1 billion per year). Our estimated CO_2 offsets from albedo modifications are dependent on assumptions used in this study, but nevertheless demonstrate remarkable global cooling potentials that may be obtained from cooler roofs and pavements.

1 Introduction

In many urban areas, pavements and roofs constitute over 60% of urban surfaces (see Table 1; roof 20–25%, pavements about 40%) (Akbari et al. 2003; Rose et al.

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Table 1 Urban fabric

Metropolitan Areas	Vegetation	Roofs	Pavements	Other
Salt Lake City	33.3	21.9	36.4	8.5
Sacramento	20.3	19.7	44.5	15.4
Chicago	26.7	24.8	37.1	11.4
Houston	37.1	21.3	29.2	12.4

Source: Rose et al. (2003)

2003; Akbari and Rose 2001a, b). Many studies have demonstrated buildings cooling-energy savings in excess of 20% upon raising roof reflectivity from an existing 10–20% to about 60%. We estimate a U.S. potential savings in excess of \$1 billion per year in net annual energy bills (cooling-energy savings minus heating-energy penalties). Increasing the albedo of urban surfaces (roofs and pavements) can reduce the summertime urban temperature and improve the urban air quality (Taha 2001, 2002; Taha et al. 2000; Rosenfeld et al. 1998; Akbari et al. 2001; Pomerantz et al. 1999). The energy and air-quality savings resulting from increasing urban surface abedos in the U.S. alone can exceed \$2 billion per year.

Increasing the urban albedo results in reflecting more of the incoming global solar radiation and countering to some extent the effects of global warming. Here we quantify the effect of increasing the albedo of urban areas on in terms of CO_2 emission offset.

2 Estimating global urban areas

Figure 1 lists the area densities for the 100 largest metropolitan areas of the world (Demographia 2007). The median area density is about 430 m^2 per urban dweller. The 100 largest metropolitan areas (with a total population of 670 million) comprise about 0.26% of the Earth land area. Assuming that about 3 billion people live in urban areas, the total urban area of the globe is estimated at about 1.2% of the land area.

As an independent verification for the estimate of urban areas, we used the data from Global Rural–Urban Mapping Project (GRUMP) Urban Extent Mask (CIESIN 2007). The Urban Extent Mask combines National Oceanic and Atmospheric Administration measurements of nighttime lights with the US Defence Mapping Agency Digital Chart of the World's Populated Places to assess the geographic extents of rural and urban areas (Balk et al. 2004). Equal-area sinusoidal projection of the 30-arc-sec urban extent mask indicates that of the Earth's 149 million km^2 of land area, 128 million km^2 is rural and 3.5 million km^2 is urban. The 3.5 million km^2 of urban land represents 2.4% of global land area and 0.7% of global surface area. Most of the 17.5 million $km^2$of unclassified land lies in Antarctica (14 million km^2) or Greenland (2.2 million km^2). The GRUMP estimate of 2.4% is twice the estimate of 1.2%.[1] Furthermore, the analysis from McGranahan et al. (2005) shows that the urban areas account for 2.8% of the land area. We expect that the GRUMP estimate is closer to reality, since the population densities in the world's

[1]We note that a United States Geological Survey analysis of 1992 data shows a value of 0.17% for the fraction of the urban areas to the total land surface area (USGS 1999). This number is seven to 16 times smaller than the other three estimates shown above.