Implementation of Light-Colored Surfaces: Profits for Utilities and Labels for Paints

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Problem: Urban Heat Islands

Summer urban heat islands with temperatures 5-8°F higher than surrounding areas are found throughout the U.S. These urban heat islands are primarily caused by removal of urban vegetation, use of building and paving materials that absorb the sun's heat, and an increase in amount of transportation and industrial exhaust and waste heat. Summer maximum temperatures in major mid-latitude North American cities are increasing at a rate of 0.3 to 1°F per decade. One of the worst cases is Atlanta, where temperatures at the airport have risen 4°F in the last decade.

In several U.S. utility systems that we examined, peak power demand increases (depending on the humidity) 1.5 to 3.0% per °F and the probability of smog episodes increases by 2 to 4% per °F (see Figure 1) (Akbari et al. 1991). As a result of the 4°F warming, the U.S. air-conditioning load is up by about 10 gigawatts (GW) on a hot afternoon, worth about $1 million/hour and costing rate-payers $1 billion/year. Providing this power requires significant additional generating capacity and results in increased pollutant emissions and higher energy bills that affect all urban dwellers.

Solutions: Shade Trees and Light-Colored Surfaces

Through computer simulation of urban climates and energy use combined with several field-monitoring projects, two heat island mitigation measures were identified: shade trees and light-colored surfaces. Trees improve the urban climate and, by shading and evapotranspiration, reduce summer cooling-energy use in buildings at less than 10% of the capital cost of the avoided power plants and air-conditioning equipment (Akbari et al. 1990). Using light-colored roof paints and surfacing the asphalt of streets and parking lots with light-colored sand are even more effective.

High-albedo materials used on major urban surfaces such as rooftops, streets, sidewalks, school yards, and the exposed surfaces of parking lots will save cooling energy use by directly reducing the heat gain through a building's envelope (direct effect) and also by lowering the urban air temperature in the neighborhood of the building (indirect effect). Analyses of the direct and indirect effects through computer simulation suggest that major urban-scale changes in albedo can reduce peak cooling loads in many U.S. cities by 30-50% (Taha et al. 1991 and Taha et al. 1992).

The remarkable dependence of surface temperature on color is shown in Figure 2. Urban areas can be lightened through use of high-albedo materials for both building and urban surfaces. For example, the following options are available for building surfaces: using light-colored roofing materials rather than dark ones at the time of re-roofing, adding light-colored aggregate to the roofing material, placing light-colored rocks on flat or gently-sloped roofs, coating roofs with elastomeric coatings and single plies, and using light-colored concrete tiles on sloping roofs. For urban surfaces, options include using light-colored aggregates in the upper layer of the asphalt in new pavements, using a light-colored slurry or chip seal when resurfacing, using concrete rather than asphalt, whitetopping, using artificial lighteners in preparing the mixtures of asphalic concrete and slurry seals, and using paints of lighter colors that are specifically designed to resist weathering, wear and tear, and other environmental effects.

Costs

For paved surfaces, the a cost-effective option is the use of light aggregates in resurfacing the top layer. Assuming these aggregates are locally available, there should be no significant additional cost over that of dark materials. For steep roofs, regular dark asphalt shingles and asphalt shingles with light aggregates have the same average installed cost, and white concrete tile is about $5/m^2 more that typical concrete tile. For flat and gently sloping roofs, dark built-up asphalt, light built-up asphalt, built-up asphalt with white-coated gravel, built-up asphalt with reflective paint, and single-ply white polymer roofing all have the same average installed costs.

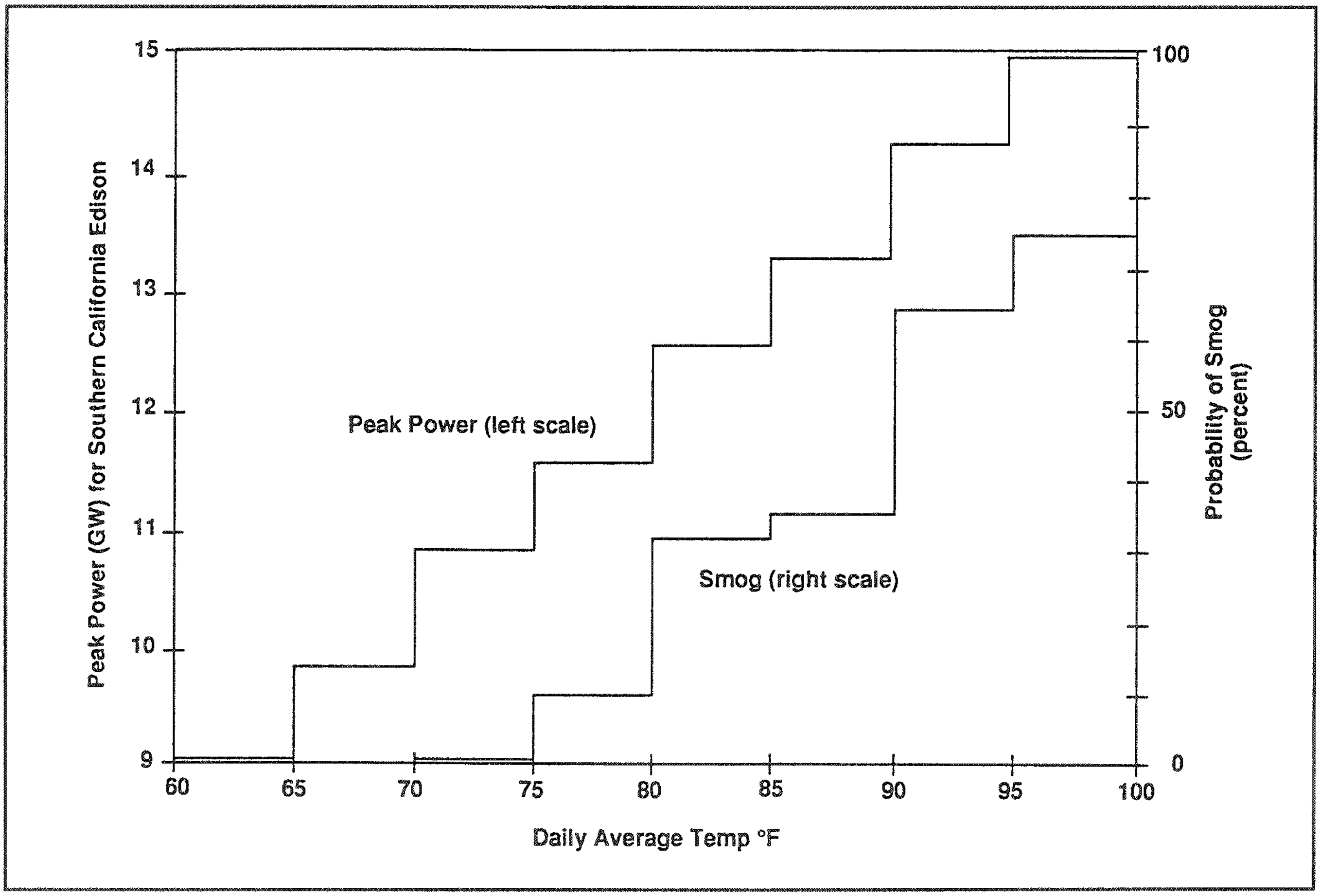

Figure 1. Ozone Level and Peak Power in Los Angeles, CA. Below 70°F there are almost never smog "episodes" in Los Angeles, i.e. the ozone level stays below the National Ambient Air Quality Standard (NAAQS) of 12 pphm. Starting at about 73°F, smog episodes begin and exceed 50% by 90°F. In Los Angeles, summer temperatures average 78°F. If the 7°F heat island were eliminated, the average temperature would drop to 71°F and smog incidents would greatly decrease.

Table 1 presents the Cost of Conserved Energy (CCE) for lightening measures for a prototypical 150 m^2 (1500 ft^2) house located in a hot urban area. It is assumed that this house uses ~1250 kWh/year in cooling energy and that the annual cooling energy use would decrease by 0.4% for each 0.01 increase in the albedo of the building and by 3% for each 0.01 increase in the albedo of the surroundings (Taha et al. 1988).

Implementation

We estimate that heat island reduction savings of $1 billion could be realized through utility-sponsored demand-side management (DSM) programs that promote the whitening and greening of cities. Assuming these utilities are permitted to retain 10% of program savings, then they could earn about $100 million/year.

Two barriers to implementation remain, however. First, monitored experiments are needed to demonstrate to regulators the savings of lightening of roofs and roads. Lawrence Berkeley Laboratory (LBL) is seeking innovative developers to build half of the homes in a development conventionally and the other half with light roofs and light-colored surfaces. LBL researchers will then measure and demonstrate the reduction in air temperature and the savings in air conditioning.

The second barrier is that paints and road surface materials need to be labeled or rated for albedo. For both roof and road surfaces the albedo and emissivity of the material must be measured since the surface temperature is a function of these two parameters. (Albedo is hemispherical reflectivity integrated over a specified wavelength range, e.g. solar spectrum. Emissivity is the ratio of the rate of longwave radiation from a body at a

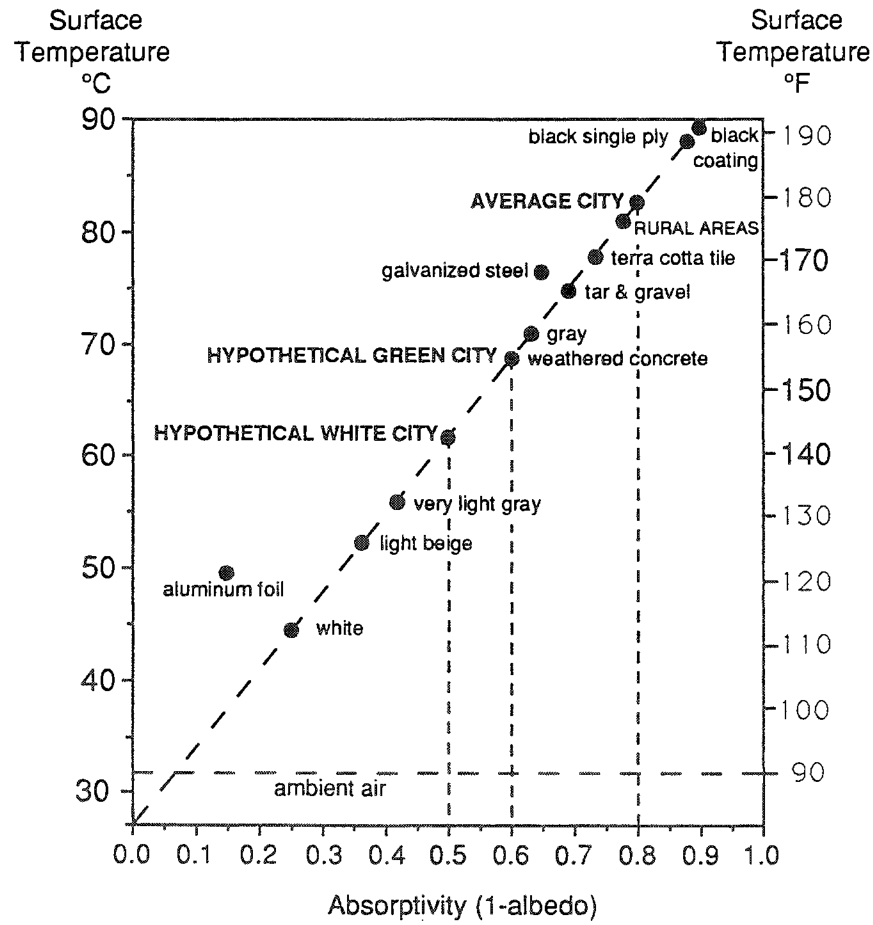

Figure 2. Absorptivity vs. Surface Temperature of Horizontal Surfaces: Paints, roofing materials, roadways, and cities, adjusted to noon on a clear, windless summer day in Austin TX.

There are large temperature spreads of about 70°F between white and black surfaces, and of 40°F between concrete and asphalt. Asphalt surfaced with crushed oyster shells or sand is probably 60°F cooler than the traditional black version. There is also a large temperature spread between aluminum (or white) and galvanized steel. Both metals run hotter than paint because they radiate heat poorly (have a low "emissivity"); in addition galvanized steel has a high absorptivity.

As surface temperatures change, so does air temperature, but with less sensitively. Nevertheless the average city's surface temperature is higher than its rural surroundings, and thus the air is warmed. The figure shows a hypothetical light-roofed "green city" with surface temperatures 25°F lower than surrounding rural areas because of the combination of white roofs, light streets and parking lots, and urban vegetation. In the hypothetical "white city," there is less existing urban vegetation (such as in Phoenix where scarce water means fewer lawns), and the surface temperature is further reduced.

Source: Taha, Sailor, and Akbari, 1992 (LBL-31721), Fig. 6. and Table 11.

Table 1. Cost of Conserved Energy (CCE) for Changing the Albedo of Buildings, Roads, and Parking Lots. Buildings need to be re-roofed every 15-20 years; at the time of re-roofing we recommend using high albedo materials. Similarly, street and parking lots need to be re-paved every 5-10 years and high albedo materials should be used at the time of re-paving.

Measures	CCE (¢/kWh)
Repaint walls white	~0
Replace dark asphalt shingles with light (steep roof)	~0
Replace dark asphalt shingles with roll roof & reflective coating (steep roof)	2.3
Replace dark built-up flat roof with light gravel	~0
Replace dark built-up flat roof with reflective coating	~0
Replace dark built-up flat roof with single ply with white polymer	~0
Resurface dark asphalt pavement with light aggregates	3.4
Resurface with whitetopping	~0
Repave dark asphalt with light aggregates	1.1
Repave with white cement whitetopping	4.4
Repave concrete with white cement	6.0

given temperature to the longwave radiation from a black body under same conditions.) Road surface materials, such as light-colored aggregate topped with light sand or oyster shells, also need to be tested for traction and durability.

Acknowledgments

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