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# Bright roofs, big city: Keeping L.A. cool through an aggressive cool-roof program

By Cara Horowitz

**Introduction** Los Angeles is one of the best places in the country for a relatively easy and cost-effective measure to improve public health, combat climate change, reduce energy demand, and save money: installing cool roofs. This brief will make a case for accelerating adoption of cool roofs in Los Angeles and will recommend law and policy strategies for achieving that goal.

Using a dataset of L.A. rooftops and some conservative estimates of energy savings, the analysis here shows that Los Angeles residents could save $30 million a year if the city significantly improved its adoption of cool roofs on new and existing buildings. This estimate is based on saved electricity costs alone and does not factor in additional sources of savings, such as increased roof longevity or reduced health care costs from fewer asthma attacks and heat-related injuries and deaths.

This same switch to cool roofs in Los Angeles would also provide a climate change benefit, cooling the atmosphere enough to offset the warming caused by up to 40 million metric tons of emitted $CO_2$ in some scenarios, which is nearly 80% of the city's total annual greenhouse gas emissions and an amount of $CO_2$ emitted by more than seven million cars on the road for a year. (This is a one-time, not annual, benefit.)

To encourage the more aggressive adoption of cool roofs in Los Angeles, I recommend a set of policy changes, from extending incentive payments from the Department of Water and Power for rooftop conversions, to improving local consumer education and resources, to incorporating cool roof requirements into the city's building code for new and replacement roof projects.

### What is a cool roof?

**Cool roofs** are roofing surfaces that reflect relatively more of the sun's light and heat than the average rooftop. Traditional roofing materials are typically dark in color and absorb significant heat, unnecessarily warming buildings and neighborhoods. Traditional roofs thereby increase energy demand, air conditioning costs, pollution, climate change emissions, and threats to public health from poor air quality and heat.

Cool roofs take advantage of smarter roofing surfaces. By reflecting rather than absorbing the sun's energy, they help keep buildings and neighborhoods cool, lowering costs and reducing air pollution. A cool roof can stay 50° F cooler than a traditional roof on a hot summer day, reducing indoor air temperatures and AC costs.[1] If adopted widely enough across a city, cool roofs can significant lower urban temperatures.

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## I. The problems: Hot cities, poor air quality, energy overuse, and threats to public health

Anyone who has walked down a hot city sidewalk in August knows that paved urban spaces can be uncomfortably warm, in part because sidewalks and buildings absorb and radiate heat. What most people don't know is that this radiated heat is enough to warm whole cities by many degrees, via something called the "urban heat island" effect. This extra heat causes a host of problems, from air pollution to greater demand for energy to an increased vulnerability to deadly heat waves.

On a clear summer afternoon, the air temperature in a typical U.S. city can be 5 degrees Fahrenheit (F) hotter than in its surrounding rural areas.[2] A bubble of higher temperatures, or a "heat island," forms in cities because of the replacement of vegetation with buildings, pavements, rooftops, and other warm surfaces.

Los Angeles is a dramatic heat island, having warmed at the rate of almost 1 degree F every decade as the city has grown more urban.[3] Maximum temperatures downtown are now at least six degrees F hotter than they were in the middle of the last century.[4] At the height of a summer afternoon in L.A., the heat island effect and roofing surfaces account for a good portion of this rise.[5]

This urban heat load has tremendous costs.

- L.A.'s higher temperatures are closely linked to its air pollution. As the city's temperature rises, so does the concentration of smog (also called ozone). In Los Angeles, for every degree Fahrenheit the temperature rises, the incidence of smog increases by about 3%.[6] Hotter days are dramatically smoggier days, and "ozone goes from acceptable to terrible [with an increase of] just 10 to 15° C."[7]
- This ozone pollution causes serious health problems, including additional cases of asthma, missed days of work, and hospital visits.[8]
- Rising city temperatures also make L.A. residents vulnerable to heat stroke, heat waves, and heat-related injuries and mortalities.[9]
- Rising urban temperatures mean that we devote more energy to cooling buildings than would otherwise be necessary. When aggregated across the city, this extra energy costs money, raises peak energy demand, raises the risk of power outages, creates additional air pollution from power production, and makes it harder for L.A. to meet its energy-efficiency and clean-energy goals. For every degree Fahrenheit rise in temperature, L.A.'s peak energy load increases by 2%.[10]
- Traditional roofs waste money even at an individual building scale. By transferring heat to interior spaces, they raise indoor temperatures and therefore air conditioning costs for conditioned buildings. They may also reduce rooftop and roof equipment lifespans by subjecting those materials to extreme temperatures.

This set of challenges will worsen over the next few decades as temperatures in southern California rise because of climate change. Climate change is a global problem, but its effects will be felt locally in quite dramatic ways. Here in Los Angeles, it will become more difficult to tackle smog, asthma rates, energy demands, and vulnerability to heat injuries because of temperature increases,[11] which are projected to range from 3° to 10° F statewide within the lifetime of today's children.[12]

Climate change will also bring other difficulties for Los Angeles, including a more constrained water supply, worsening wildfires, and the possibility of coastal flooding.[13] With these and other risks in mind, Los Angeles has committed to reducing both its greenhouse gas emissions and its vulnerability to climate change impacts. The city's 2007 "Green L.A." plan set a goal of transforming the city into a model of energy efficiency, including through improving green building policies and incentives. It committed to reducing the city's greenhouse gas emissions to 35% below 1990 levels by 2030. It also emphasized the need for improving L.A.'s resiliency to climate change

### Definitions of key cool roof properties

**Solar Reflectance** (sometimes called albedo or SR) is the fraction of solar energy that is reflected by a roof, expressed as a number between zero and one. The higher the value, the better the roof reflects solar energy and the easier it keeps cool. For example, white reflective coating or membrane has a reflectance value of 0.85 (reflects 85% of solar energy hitting it and absorbs the remaining 15%), while asphalt has a value of 0.09 (reflects 9%). A material's initial solar reflectance (ISR) often weathers over time to a relatively stable aged solar reflectance.

**Emittance** (sometimes called thermal emittance or TE) is the amount of absorbed heat that is radiated from a roof, expressed as a number between zero and one. The higher the value, the better the roof radiates heat. Higher emittances help to keep building interiors cool and to lower energy demands.

**Solar Reflectance Index (SRI)** is an alternative measure of a roof's ability to reject solar heat. It is calculated based on a formula that uses the values for solar reflectance and emittance. It is defined so that a standard black is zero (reflectance 0.05, emittance 0.90) and a standard white is 100 (reflectance 0.80, emittance 0.90). Because of the way SRI is defined, very hot materials can have slightly negative SRI values, and very cool materials can have SRI values exceeding 100.

Adapted from California's "Flex your Power" website.[15]

through, among other things, reducing the heat island effect.

For his second term in office, Mayor Villaraigosa announced an aim to get Los Angeles entirely off of coal power by 2020 and to cut the city's energy consumption by 10% over ten years.[14] These goals are interrelated, because managing the city's peak power load is critical for allowing us to shift away from the use of coal for baseload power.

Reducing our energy use and greenhouse gas production, however, becomes harder the hotter our city becomes. Los Angeles, like many other cities, faces a damning feedback loop: The hotter it gets, the more energy we will need to keep L.A. cool, which will, in turn, make it more difficult to combat the greenhouse gas pollution that is raising temperatures.

## II. Cool roofs are a simple fix with big benefits for Los Angeles

The urban-heating and global-warming problems faced by Los Angeles are complex and have no easy solution. But L.A. would benefit greatly from employing cool roofs to reduce urban temperatures, energy demand, air conditioning costs, and public health risks.

### A. What are cool roofs?

Traditional roofs are often gray or dark in color, with an average solar reflectance (defined in the text box on this page) of about 0.2. They are made of materials that absorb heat, unnecessarily warming the buildings and neighborhoods they cover. This, in turn, raises air conditioning costs, energy demand, and public health risks in the ways discussed above.

Cool roofs take advantage of smarter roofing surfaces that reflect rather than absorb the sun's energy. This helps keep buildings and neighborhoods cool. The benefits of this cooling are significant even at a building scale, saving building owners money that they otherwise would have spent on energy to lower indoor air temperatures. A cool roof can result in air conditioning cost savings of 10 to 30 percent.

When aggregated across a city, the benefits of cool roofs are even greater—helping to reduce urban temperatures dramatically and to improve air quality and public health.

There's another benefit of cool roofs that has been recognized only in recent years, by researchers at Lawrence Berkeley National Laboratory and elsewhere. Cool roofs are likely good for the planet too, helping to cool the earth itself by acting as mini-reflectors and reducing the balance of heat in our atmosphere, counteracting the effects of climate change pollution.[16]

### B. Cool roofs are practical, affordable and available

Cool roofs can be installed on flat or sloped roofs, on commercial or residential buildings, and out of materials ranging from paints to tiles to coatings to shingles. And not all cool roofs are white: Many cool roof materials look quite similar to traditional roofing materials and are available in a range of colors. The tiles shown in Figure 1, for example, use special pigments designed to reflect sunlight normally in the visible spectrum but not in the infrared (non-visible) spectrum, yielding much cooler materials with little change in appearance.

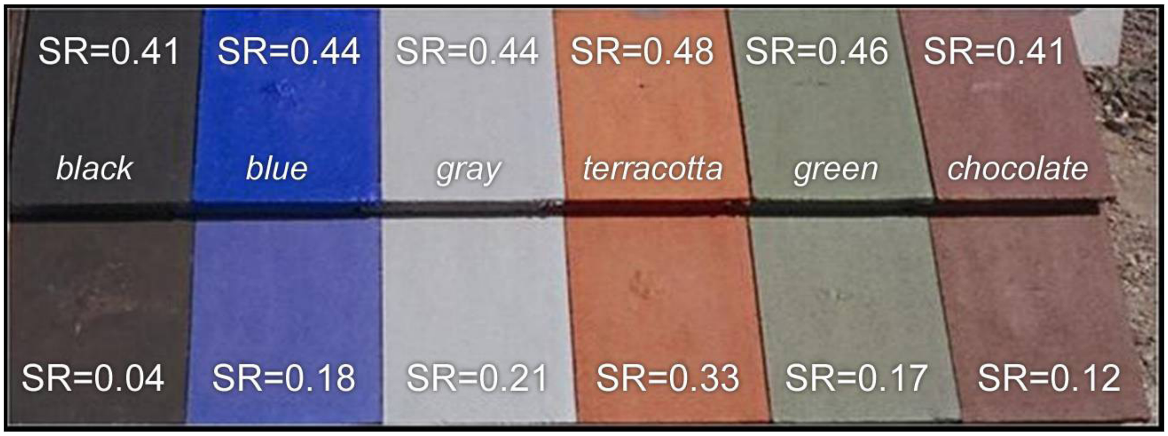
The Cool Roof Rating Council, a non-profit organization that tests and rates the performance of cool roof materials using standardized metrics, has rated and compiled information on many hundreds of cool roof products and grouped them by roof and application type. Its website, www.coolroofs.org, gives a good idea of the variety of cool roof products available.

Cool roofs are cost-competitive with traditional roofs, with prices ranging from equal to about 20 cents per square foot more.[17] In air conditioned buildings, any incremental costs of cool roofs are quickly recouped due to lower energy bills and other cost savings.[18] But cool roofs make sense even in buildings without air conditioning, because widespread adoption of cool roofs can reduce overall city temperatures, in turn slowing smog formation, reducing energy requirements in other buildings, and increasing comfort both outdoors and in unconditioned buildings.

**Figure 1 | Roofing tiles are now available in "cool" materials and traditional colors**

**Bottom row shows traditional tiles with poor solar reflectance. Top row shows advanced "cool" tiles with much better solar reflectance.**

*Image courtesy of American Rooftile Coatings.*




### C. The benefits of cool roofs for Los Angeles

Cool roofs make particular sense in Los Angeles. We have hot summers, mild winters, and a dramatic urban heat island. We struggle with air quality problems, especially smog. And we have committed to an aggressive set of climate, energy-efficiency, and clean-energy goals. Cool roofs can help achieve these goals with very little downside.

In one study, Los Angeles ranked second (behind only Phoenix) in net dollar savings that would be achieved if cool roofs were adopted city-wide, out of eleven major U.S. metropolitan areas examined.[19] L.A. ranked first, by a considerable margin, in potential peak electricity demand savings.[20]

Many studies have attempted to quantify the potential benefits of cool roofs, including several that have focused on Los Angeles or California as a whole.[21] This brief uses conservative estimates from those studies and examines low, medium, and high scenarios for aggressive cool roof adoption in L.A. I employ a dataset of all L.A. city rooftops that was created a few years ago by Los Angeles County. My aim was to survey the relevant literature to give some sense of the benefits of cool roofs, while acknowledging unknowns.

Some key assumptions and estimates in this analysis are as follows, with citations to the papers from which they are derived:

- In line with conservative estimates in the literature, the analysis here assumes an average aged rooftop albedo improvement of 0.25.[22]
- It uses a figure for total rooftop area in Los Angeles City of 249,442,670 square meters, compiled from a database of rooftops created by L.A. County.[23]
- It assumes that 30% of the total roof area in Los Angeles covers air conditioned space.[24]
- It estimates annual direct electricity savings of 3 kWh per square meter of converted rooftop over air conditioned space.[25] By direct electricity savings, I refer to decreases in AC load due to a cool roof's lowering of individual building temperatures. Direct savings are accrued only by air conditioned buildings with cool roofs.
- It estimates indirect electricity savings equal to 15% of direct electricity savings.[26] Indirect electricity savings are decreases in AC load due to the overall reduction in ambient urban temperatures. Indirect savings are accrued by all air conditioned buildings in the city. I acknowledge considerable uncertainty in this estimate of indirect savings.
- It uses 13 cents/kWh as the average annual retail rate for electricity in L.A.[27] It uses 0.52 $kgCO_2$/kWh as the average

## Table 1 | Electricity savings from cool roofs

| Scenario | Roof area converted ($m^2$) | Roof area converted over AC ($m^2$) | Direct electricity savings (GWh/yr) *using 3kWh/$m^2$ | Indirect electricity savings (GWh/yr) *using .15 factor | Total electricity savings (GWh/yr) | Cost savings from total electricity savings ($M/yr) |
|---|---|---|---|---|---|---|
| **Low (50% of roofs)** | 124,721,335 | 37,416,400 | 112.3 | 16.8 | 129.1 | 16.8 |
| **Med (70% of roofs)** | 174,609,869 | 52,382,961 | 157.2 | 23.6 | 180.7 | 23.5 |
| **High (90% of roofs)** | 224,498,403 | 67,349,521 | 202.1 | 30.3 | 232.4 | 30.2 |

## Table 2 | CO2 effects of cool roof albedo changes

| Scenario | Roof area converted ($m^2$) *Δ albedo=.25 | Equivalent emitted $CO_2$ (million metric tons) *using -61kg $CO_2/m^2$ | Equivalent emitted $CO_2$ (million metric tons) *using -175kg $CO_2/m^2$ |
|---|---|---|---|
| **Low (50% of roofs)** | 124,721,335 | 7.6 MMT | 21.8 MMT |
| **Med (70% of roofs)** | 174,609,869 | 10.7 MMT | 30.6 MMT |
| **High (90% of roofs)** | 224,498,403 | 13.7 MMT | 39.3 MMT |

greenhouse gas emissions intensity for L.A. city power.[28]

- It presents two sets of estimates for the amount of emitted $CO_2$ offset by the cool roof albedo change. In one, I start with a value generated by Richard VanCuren of the California Air Resources Board for the radiative forcing of cool roofs in climate zone 9, the Los Angeles zone. I use that value and his "Akbari" methodology to generate an equivalency of -61kg emitted $CO_2/m^2$ of cool roof, given an albedo improvement of 0.25.[29] In the second set of estimates, I use the much higher offset value generated by other researchers for the general U.S. domain, of -175kg emitted $CO_2/m^2$ of cool roof.[30] The true value likely lies between these estimates.

Based on the literature and these estimates, if Los Angeles were to install cool roofs on 50%, 70%, or 90% of its rooftops, it could save between $16 and $30 million in electricity costs each year. It could simultaneously reduce atmospheric heat by an amount equivalent to the heat generated by between 7.6 and 39.3 million metric tons of emitted $CO_2$. See Tables 1 and 2.

Studies simulating widespread cool roof adoption in Los Angeles have also shown significant reductions in urban ambient temperatures, on the order of 1° to 3.5° F on hot summer afternoons;[31] peak electricity demand savings of 320 to 600 megawatts;[32] and significant air quality improvements. Regarding air quality, simulations predict a reduction in population-weighted smog in Los Angeles of 10-12% resulting from a 2.7-3.6° F cooling in ambient temperature.[33]

To put some of these benefits in perspective:

- An electricity savings of 230 GWh per year represents about 1% of LADWP's total retail sales in 2010 and is more energy than was generated by all LADWP energy efficiency measures and solar installations that year.[34]
- 22 million metric tons of emitted $CO_2$, which is the estimated $CO_2$ equivalency for the low adoption case using Millstein's radiative forcing estimate, is the amount of $CO_2$ emitted by almost 4 million vehicles driving on the road for a year.[35] It is also nearly half of L.A.'s total annual greenhouse gas emissions.[36] This is a one-time, not annual, benefit.

## What about solar roofs and green roofs?

Installing cool roofs just is one way to make smarter, better rooftops in Los Angeles. **Solar roofs** and **"green" (vegetated) roofs** are also vast improvements over traditional roofs. Increasing rooftop solar installations in L.A. would help achieve climate change goals, strengthen renewable and distributed energy generation capacity, and reduce peak energy demand. Green roofs serve to reduce building energy demand, cool neighborhoods, and protect water quality by cutting down on urban runoff.

This brief acknowledges the benefits of each type of roof and sees the three rooftop strategies as complementary. In the short- and perhaps even mid-term, cool roofs are the quickest, easiest and cheapest of the three "smart" roofing types to adopt. Their energy-saving and climate benefits are immediate, and while ramping up adoption of solar roofs and green roofs may take years, cool roofs can be installed now on a host of building types. Even in the longer term, cool roof coatings can and should be used on the rooftops, or portions of rooftops, on which building owners decline to install solar installations or green roofing materials. Increasing cool roofs becomes even more important if solar roof arrays gain widespread use, since those panels are themselves very dark,[39] and could therefore use offsetting.

- A 10-12% reduction in ozone is comparable to that obtained by replacing all gasoline on-road motor vehicles with electric cars.[37]

Others have attempted to monetize the gains to public health, ozone abatement, the $CO_2$ offset, and other benefits.[38] This brief does not estimate monetary savings from those gains. Thus, its cost savings estimates are conservative.

### D. Current programs and regulations don't go far enough to advance adoption of cool roofs in L.A.

The benefits of cool roofs have been understood for many years, and some programs are already in place to encourage their adoption in California and Los Angeles. But today's programs do not go far enough.

Through its state-wide Title 24 energy efficiency standards, California has made some good progress on cool roofs. In 2005, it adopted cool roof standards for commercial buildings, mandating cool roof technology on most new, low-slope (i.e., flat) commercial roofs. Starting in 2010, it expanded these requirements to include some modest new-construction steep roof standards, as well as standards for some reroofing projects. However, several of Title 24's most stringent cool roof mandates apply only to a handful of California's hottest inland climate zones, notably excluding Los Angeles. Even where they apply in L.A., the requirements are often quite modest and in some cases can be satisfied by materials with an aged solar reflectance level of only 0.15. Lastly, the residential cool roof requirements can sometimes be avoided through trade-offs that increase other elements of a building's energy efficiency but don't have the same benefits for urban or atmospheric cooling.[40]

In part to fill some of these gaps, the Los Angeles Department of Water and Power has offered since October 2010 a rebate to encourage residential cool roof installations and conversions. The program is funded by a one-time block grant from the U.S. Department of Energy. The performance requirements of the program are more stringent: For low-sloped roofs, qualifying roofing materials must have an initial solar reflectance of at least 0.70 and a thermal emittance of at least 0.85. Steep roofs must have an initial solar reflectance of at least 0.40 and a thermal emittance of at least 0.85.[41] The rebate is generous enough to cover all expected incremental costs of cool roof installation. According to LADWP staff, however, the rebate has been underutilized. Only about 200,000 square feet of cool roof area has been funded by the program so far, and DWP does not anticipate reaching its initial expectation of creating ten times

## Cool roof programs spread across the U.S.

Other U.S. cities have begun adopting aggressive programs to encourage cool roofs and provide some good models for Los Angeles.

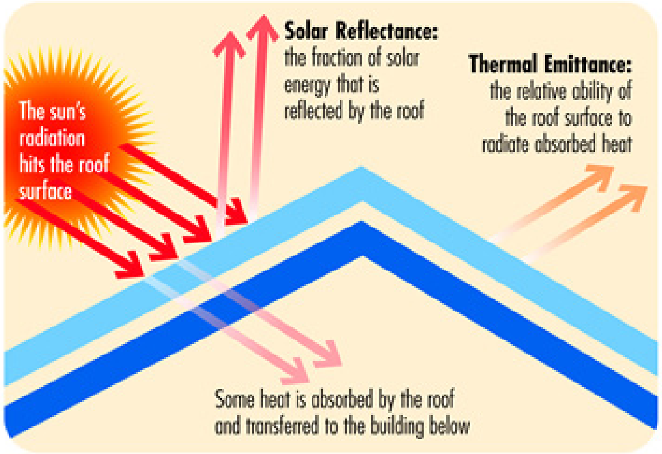
New York City has done much in recent years to encourage cool roof construction and conversions. The City recently amended its building code to require at least 75 percent of the roof area of certain new buildings to be covered by a cool (or green) roof. That ordinance will take effect in January 2012. Its Department of Design and Construction also created a Cool and Green Roofing Manual to provide information and resources to encourage cool and green roofs. And its NYC°CoolRoofs program is a highly publicized and successful effort to encourage cool roof conversions, surpassing its goals for 2010 by coating a total of 1,168,369 square feet of rooftops in the city.[48]

Miami recently passed an ordinance amending its zoning code to require the use of cool roofs as part of an overall strategy to reduce heat islands. The law covers both new construction and reroofing projects affecting at least 50% of an existing roof. It applies to both low-slope and steep-slope roofs, residential and commercial. Its requirements exempt those portions of roofs that are covered by green roofing or by photovoltaic or solar equipment.

The U.S. Department of Energy has also recently weighed in in favor of cool roofs, directing its departments to implement cool roofs on all of its buildings whenever practicable[49] and publishing a very useful consumer guide to understanding and selecting cool roofs.[50]

**Figure 2 | The solar reflectance and thermal emittance of a rooftop determine how "cool" it is**

*Image courtesy of the Cool Roof Rating Council.*




that amount by rebate's end, in July 2012.[42]

Why hasn't the DWP cool roof rebate attracted more participation? There are a few potential reasons. The tough economy has certainly played a role in discouraging building improvements of any sort. But there is also evidence of a lag in public awareness and education about the program: Some early applications failed to meet program specifications, and overall applications have been dominated by multi-family residences, rather than individual homeowners. Permitting requirements may also have discouraged applicants. Most cool roof conversions cannot proceed without a permit from the L.A. Department of Building and Safety, and the permitting process can be intimidating to individual homeowners and costly (with permit fees of as much as 5% of the total project cost).[43] DWP requires proof that necessary permits have been obtained before issuing rebates.

Recently, applications to the DWP cool roof rebate program have reflected a better understanding of the program and have been submitted by individual homeowners in greater proportion.[44] Nonetheless, the current rebate will expire in July 2012 and it is unclear, given DWP's fiscal challenges, whether the rebate will be extended.

Another local initiative relevant to cool roofs has been Los Angeles's landmark green building ordinance, adopted in 2009, which creates an energy retrofit program for city-owned buildings. The new Green Retrofit and Workforce Program in L.A. has attracted millions of dollars in federal stimulus funding, aimed at improving the city's energy efficiency while meeting social justice and job-creation goals. The program is retrofitting a slate of city-owned buildings and includes cool roofs as among the elements to be considered in designing retrofits. The program is laudable but limited, affecting only city properties and stopping short of requiring retrofit projects to adopt cool roofs.[45] The Los Angeles Green Building Code, which applies to private buildings and contains important energy efficiency requirements, similarly does not mandate cool roofs.

Given the limitations of these current programs, more can be done to ensure aggressive cool roof adoption in L.A. In particular, we are not doing enough to encourage the conversion of older roofs to cool roofs during routine reroofing projects. Roofs are replaced, on average, every ten to 25 years. Reroofing projects account for the bulk of all roofing projects each year in California, representing nearly three times the sales volume of new roofing projects.[46] Failing to convert these older roofs leaves a large proportion of the benefits discussed above unattained. And older buildings are likely to save the most money and energy from cool roofs because of their generally less efficient air conditioning systems and less effective insulation.[47]

**Figure 3 | Cool roof being applied to flat commercial rooftop, adjacent to photovoltaic panels**

*Image courtesy of author.*


## III. Recommendations: Strategies for Los Angeles to become the cool-roof capital

The benefits of significantly ramping up the adoption of cool roofs in Los Angeles suggest we should be doing more to encourage them. If L.A. adopts a strong program now to deploy cool roofs on new construction and in reroofing projects, the city will be well on its way to broad adoption within a couple of decades, the typical lifespan of a roof – in time to help us adapt to the much higher temperatures projected for the city by mid-century.

To improve rates of cool roof installation and conversion in the city of Los Angeles, I recommend the following.

- **Do more to capitalize on the current DWP cool roof rebate:** The Los Angeles Department of Water and Power is currently offering a robust cool-roof rebate of 30 cents per square foot of residential rooftop. The rebate is funded through a federal stimulus grant supporting local efforts to improve energy efficiency. As discussed above, the rebate has been a modest success but will expire in July 2012 and is not on pace to meet expectations for total cool roof conversions.

  In the next six months, Los Angeles should do more to capitalize on this one-time extraordinary grant funding for cool roofs. LADWP and other city officials should improve consumer outreach and education about the rebate; coordinate with the Department of Building and Safety to inform contractors and others seeking reroofing permits about rebate options; and create and publicize goals and metrics for cool roof adoption by neighborhood. New York City's NYC°CoolRoofs program is a good model for ramping up program visibility and participation, including through the involvement of volunteer networks and non-profit organizations that can help spread the word. The city has about six months left on this rebate and should maximize its value.
- **Extend DWP's cool roof rebate:** LADWP's budget situation heading into next year is difficult. But since 2010, good progress has been made, and hopefully will continue to be made, in

educating L.A. homeowners about cool roofs and incentives for their adoption. The city should consider extending some form of a DWP rebate for cool roofs beyond July 2012 so that we don't lose this momentum. As rooftop solar installations increase, the city might link a cool roof rebate to a solar rebate, providing a bonus or escalation factor for combinations of the two.

- **Create a local guide to cool roof options, local suppliers, and contractors:** Los Angeles consumers looking to purchase and install cool roofs could use better access to information about local cool roof options, materials, suppliers, and contractors. The city should facilitate (perhaps with the help of a third-party nonprofit) the creation of a detailed guide to cool roof material selection and sourcing in Los Angeles, and then publicize it widely.
- **Reconsider reroof permitting requirements for cool roofs:** A potential barrier to cool roof conversions is the requirement that most reroofing projects secure a permit from the Los Angeles Department of Building and Safety. Though reroofing projects often qualify for expedited permitting, that process can still be burdensome. It adds a potential city inspection and as much as 5% of the total project cost in permit fees.[51] To reduce barriers to cool roof conversions, especially for single-family homeowners, L.A. should consider exempting certain cool-roof projects from permitting requirements altogether or waiving permit fees.
- **Incorporate CALGreen's cool roof requirements into L.A.'s building code:** California's Title 24 green building standards, also known as CALGreen, include voluntary cool roof measures for commercial and residential buildings that go well beyond Title 24's mandatory measures.[52] Cities have the option to adopt these measures and to make them mandatory within local jurisdictions, and Los Angeles has already done this for some CALGreen measures. Los Angeles should incorporate CALGreen's cool roof Tier 2 standards as requirements in its building code. Those standards apply to both commercial and residential buildings and are reasonably but not unduly stringent, calling for materials with a three-year aged solar reflectance of 0.65 for low-sloped roofs and of 0.23 for steep-sloped roofs. All materials must have an emittance of at least 0.85.[53]

  In adopting these measures, Los Angeles should ensure that they apply not only to new construction projects but also to the bulk of the reroofing market, at least as to air conditioned buildings. Ideally, this effort could be part of an overall L.A. City Council ordinance providing a vision for smarter Los Angeles rooftops that incorporates cool roof, green roof and solar roof options.
- **Explore cool pavements next:** Like roofs, traditional paved urban surfaces (such as roads and parking lots) absorb unnecessary heat and contribute significantly to the urban heat island effect. Lightening them through the use of smarter materials yields many of the same benefits as cool roofs.

## Conclusion

Los Angeles could and, by many accounts, should be the cool roof capital of the country. Relatively simple and inexpensive changes to the materials we use for roofing would spell big benefits for L.A. today, and would help us gird against the difficulties of a warmer future.

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## Endnotes


1 For a review of some of the literature on individual building energy savings, see Levinson et al., "Inclusion of cool roofs in nonresidential Title 24 prescriptive requirements," Energy Policy 33 (2005) 151-170 at 153.

2 Akbari et al., "Cool Surfaces and Shade Trees to Reduce Energy Use and Improve Air Quality in Urban Areas," Solar Energy 70(3) (2001) at 295-296.

3 Akbari, "Energy Saving Potentials and Air Quality Benefits of Urban Heat Island Mitigation," Lawrence Berkeley National Laboratory LBNL-58285 (2005).

4 Akbari et al., "Summer heat islands, urban trees, and white surfaces," Lawrence Berkeley Laboratory LBL-28308 (1990); see also Rosenfeld et al., "Cool communities: Strategies for heat island mitigation and smog reduction," Energy and Buildings 28 (1998) 51-62, at 52.

5 Rosenfeld et al., "Cool communities," Energy and Buildings 28, at 52.

6 Sailor, "Simulated urban climate response to modifications in surface albedo and vegetative cover," 34 Journal of Applied Meteorology (1995) 1694 at 1694.

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8 See, e.g., Neidell and Kinney, "Esimates of the association between ozone and asthma hospitalizations that account for behavioral responses to air quality information," Environmental Science & Policy 13 (2010) 97-103.

9 See, e.g., Basu et al., "Characterizing temperature and mortality in nine California counties," Epidemiology 19 (2008) 138.

10 Akbari et al., "Summer heat islands, urban trees, and white surfaces," Lawrence Berkeley Laboratory LBL-28308 (1990), at Figure 4.

11 See, e.g., Ostro et al., "Quantifying the health impacts of future changes in temperature in California," Environ. Res. (2011).

12 Moser et al., "The Future Is Now: An Update on Climate Change Science Impacts and Response Options for California," at 41-42. California Energy Commission, PIER Energy□Related Environmental Research Program. CEC-500-2008-071 (2009).

13 Ibid. at 39-58.

14 A statement of Mayor Villaraigosa's environmental agenda is available on the city's "Environment" webpage (http://mayor.lacity.org/Issues/Environment/Next4/index.htm).

15 State of California's Flex your Power program, "Cool Roofs" (available at http://www.fypower.org/inst/tools/products_results.html?id=100123).

16 For a discussion of this effect, see Akbari et al., "Global cooling: increasing world-wide urban albedos to offset $CO_2$," Climatic Change (2009) 94:275-286. This effect is still uncertain. See Jacobsen and Ten Hoeve, "Effects of Urban Surfaces and White Roofs on Global and Regional Climate," in press September 2011 (available at http://www.stanford.edu/group/efmh/jacobson/Articles/Others/HeatIsland+WhiteRfs0911.pdf).

17 Akbari, "Energy Saving Potentials and Air Quality Benefits of Urban Heat Island Mitigation," Lawrence Berkeley National Laboratory (2005) at 5; Akbari et al., "Inclusion of solar reflectance and thermal emittance prescriptive requirements for residential roofs in Title 24," California Energy Commission, at Table 4 (May 2006 draft) (available at http://www.energy.ca.gov/title24/2008standards/prerulemaking/documents/2006-05-18_workshop/2006-05-17_RESIDENTIAL_ROOFS.PDF ).

18 Many studies demonstrate net energy and cost savings from cool roofs on conditioned buildings, including Levinson et al., "Inclusion of cool roofs in nonresidential Title 24 prescriptive requirements," Energy Policy 33 (2005) 151-170; Rosenfeld et al., "Cool communities," Energy and Buildings 28; and Konopacki et al., "Cooling energy savings potential of light-colored roofs for residential and commercial buildings in 11 U.S. metropolitan areas," Lawrence Berkeley National Laboratory LBNL-39433 (May 1997). In addition to savings from direct energy use reductions, building owners also save money because of lower ambient city temperatures; because they can install smaller HVAC systems; and because cool roofs are likely more durable than traditional roofs since they have to withstand far lower temperatures. Rosenfeld et al., "Cool communities," Energy and Buildings 28.

19 Konopacki et al., "Cooling energy savings potential of light-colored roofs for residential and commercial buildings in 11 U.S. metropolitan areas," Lawrence Berkeley National Laboratory LBNL-39433 (May 1997), at Figure 5-1.

20 Ibid. at Figure 5-4.

21 See, for example, ibid.; Rosenfeld et al., "Cool communities," Energy and Buildings 28; Sailor, "Simulated urban climate response to modifications in surface albedo and vegetative cover," 34 Journal of Applied Meteorology; and Levinson et al., "Inclusion of cool roofs in nonresidential Title 24 prescriptive requirements," Energy Policy 33.

22 Much of the literature uses an average rooftop albedo improvement of .35. See Levinson et al., "Inclusion of cool roofs in nonresidential Title 24 prescriptive requirements," Energy Policy 33; VanCuren, "The radiative forcing benefits of 'cool roof' construction in California: Quantifying the climate impacts of building albedo modification," in press, Climatic Change; Rosenfeld et al., "Cool communities," Energy and Buildings 28. I conservatively assume an average roof albedo improvement of .25 following Akbari et al., and in acknowledgement of the more modest albedo improvements achieved on steep slope residential buildings and of the progress already made on commercial rooftops. Akbari et al., "Global cooling: increasing world-wide urban albedos to offset CO2," Climatic Change (2009) 94:275-286; Millstein and Menon, "Regional climate consequences of large-scale cool roof and photovoltaic array deployment," Environ. Res. Lett. 6 (2011).

23 Rooftop data from the County of Los Angeles 2006 Solar Radiation Model (available at http://solarmap.lacounty.gov).

24 Estimates of the fraction of air-conditioned buildings in L.A. and California range dramatically, up to 50% or more depending on building type and age. I took the low range of the estimates. See Akbari et al., "Equivalent $CO_2$ Avoided by Reflective Roofs and Pavements in California," memorandum to the California Air Resources Board (revised Oct. 21, 2008) (assuming that 50% of California buildings are air conditioned); Rosenfeld et al., "Cool communities," Energy and Buildings 28, at 52 (estimating that 36% of Los Angeles residences are air conditioned); Akbari et al., "Inclusion of solar reflectance and thermal emittance prescriptive requirements for residential roofs in Title 24," California Energy Commission, at 13 (estimating that 36% of California residential floor area is air conditioned); and Konopacki et al., "Cooling energy savings potential of light-colored roofs for residential and commercial buildings in 11 U.S. metropolitan areas," Lawrence Berkeley National Laboratory, at Table C-3 (giving AC saturation percentages in Los Angeles, by building type).

25 This rate is the same as used in Akbari et al., "Equivalent $CO_2$ Avoided by Reflective Roofs and Pavements in California," memorandum to the California Air Resources Board. It is in line with other estimates and modeled findings in the literature. Compare with Levinson et al., "Inclusion of cool roofs in nonresidential Title 24 prescriptive requirements," Energy Policy 33; Akbari et al., "Inclusion of solar reflectance and thermal emittance prescriptive requirements for residential roofs in Title 24," California Energy Commission, at 13; and Akbari et al., "Monitoring the energy-use effects of cool roofs on California commercial buildings," Energy and Buildings 37 (2005) 1007-1016 (results for climate zone 9).

26 This is a conservative but uncertain estimate based on a finding in Rosenfeld (1998) that indirect AC energy savings from cool roofs in L.A. total about 45% of direct AC energy savings in a scenario of 3° C total cooling. Rosenfeld et al., "Cool communities," Energy and Buildings 28, at Table 3.

27 Los Angeles Dept. of Water and Power, "2010 Power Integrated Resource Plan," at Figure 5.5 (using 2011 rate).

28 Ibid. at App. C, Table C-2.

29 VanCuren, "The radiative forcing benefits of 'cool roof' construction in California: Quantifying the climate impacts of building albedo modification," in press, Climatic Change, at Table 1. I used VanCuren's site specific RF01 value for climate zone 9 (-1.22 $w/m^2$), calculated an average cool roof forcing for an albedo change of .25 (-30.5 $w/m^2$), and employed the so-called Akbari method to generate an equivalency of -61 $kgCO_2/m^2$ of cool roof.

30 Millstein and Menon, "Regional climate consequences of large-scale cool roof and photovoltaic array deployment," Environ. Res. Lett. 6 at Table 3.

31 See Sailor, "Simulated urban climate response to modifications in surface albedo and vegetative cover," 34 J. of Applied Meteorology at1700; Akbari, "Energy Saving Potentials and Air Quality Benefits of Urban Heat Island Mitigation," Lawrence Berkeley National Laboratory at 7 (citing potential for 2° C reduction on a hot summer afternoon); Millstein and Menon, "Regional climate consequences of large-scale cool roof and photovoltaic array deployment," Environ. Res. Lett. 6 at Table 1 (predicting a .5° C drop in LA temperatures from cool roofs and pavements combined); Rosenfeld et al., "Cool communities," Energy and Buildings 28 (predicting a 1.5° C drop in L.A. temperatures from cool roofs and pavements combined).

32 Konopacki et al., "Cooling energy savings potential of light-colored roofs for residential and commercial buildings in 11 U.S. metropolitan areas," Lawrence Berkeley National Laboratory, at Figure 5-4; Rosenfeld et al., "Cool communities," Energy and Buildings 28, at Table 3.

33 Levinson et al., "Inclusion of cool roofs in nonresidential Title 24 prescriptive requirements," Energy Policy 33 at 158.

34 Los Angeles Dept. of Water and Power, "2010 Power Integrated Resource Plan," Section 2 at Table 2-2.

35 U.S. Environmental Protection Agency greenhouse gas equivalencies calculator (available at http://www.epa.gov/cleanenergy/energy-resources/calculator.html#results ).

36 City of Los Angeles, "Climate L.A." (2008) at 4 (available at http://www.ci.la.ca.us/ead/pdf/ClimateLA_v5.pdf ).

37 Levinson et al., "Inclusion of cool roofs in nonresidential Title 24 prescriptive requirements," Energy Policy 33 at 158.

38 See, e.g., Rosenfeld et al., "Cool communities," Energy and Buildings 28 (estimating cost savings of public health gains and ozone abatement); Akbari et al., "Global cooling: increasing world-wide urban albedos to offset CO2," Climatic Change 94 (estimating worth of CO2 offsets).

39 Millstein and Menon, "Regional climate consequences of large-scale cool roof and photovoltaic array deployment," Environ. Res. Lett. 6.

40 Cal. Code of Reg., Title 24, Part 6, Building Energy Efficiency Code (2008). Cool roof requirements can be found in sections 118, 141, 142, 143, 149, 151, and 152.

41 Los Angeles Dept. of Water and Power consumer rebate program (details and application available at http://www.ladwp.com/ladwp/cms/ladwp000478.jsp).

42 Telephone interview with Craig Tranby, LADWP consumer rebate program staff (Sept. 29, 2011).

43 Los Angeles Dept. of Building and Safety fee schedule for express permit fees (available at http://ladbs.org/LADBSWeb/fee-schedule.jsf ).

44 Telephone interview with Craig Tranby, LADWP consumer rebate program staff (Sept. 29, 2011).

45 For an account of the program's startup, see "Wesson and Villaraigosa Kickoff Green Retrofit Program," Los Angeles Sentinel (Feb. 17, 2011) (available at http://www.lasentinel.net/Wesson-and-Villaraigosa-Kickoff-Green-Retrofit-Program.html).

46 Levinson et al., "Inclusion of cool roofs in nonresidential Title 24 prescriptive requirements," Energy Policy 33 at 164. See also Akbari et al., "Inclusion of solar reflectance and thermal emittance prescriptive requirements for residential roofs in Title 24," California Energy Commission (estimating a reroofing-to-new-roofing ratio of 3.85:1).

47 Konopacki et al., "Cooling energy savings potential of light-colored roofs for residential and commercial buildings in 11 U.S. metropolitan areas," Lawrence Berkeley National Laboratory, at 36 (finding that houses built before 1980 account for almost 55% of annual electricity and net energy savings achieved from widespread cool roof adoption).

48 NYC°CoolRoofs Annual Review 2010, at 2 (available at http://www.nyc.gov/html/coolroofs/downloads/pdf/3-29-11_coolroofs_annual_report_2010.pdf ).

49 "Installation of cool roofs on Department of Energy buildings," memorandum from Steven Chu, Secretary of Energy, U.S. Dept.of Energy (June 2010).

50 "Guidelines for Selecting Cool Roofs," U.S. Dept. of Energy Building Technologies Program (July 2010) (available at http://www1.eere.energy.gov/femp/pdfs/coolroofguide.pdf ).

51 Los Angeles Dept. of Building and Safety fee schedule for express permit fees (available at http://ladbs.org/LADBSWeb/fee-schedule.jsf ).

52 California Green Building Standards Code, Cal. Code of Reg. Title 24, Part 11, at A4.106.5 (voluntary residential cool roof measures) and A5.106.11.2 (voluntary nonresidential commercial measures) (2010).

53 California Green Building Standards Code, Cal. Code of Reg. Title 24, Part 11, at A4.106.5 (voluntary residential cool roof measures) and A5.106.11.2 (voluntary nonresidential commercial measures) (2010).

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# Anthony Pritzker Environmental Law and Policy Briefs

This policy paper is the second of the Anthony Pritzker Environmental Law and Policy Briefs. The Pritzker Policy Briefs are published by UCLA School of Law and the Emmett Center on Climate Change and the Environment in conjunction with researchers from a wide range of academic disciplines and the broader environmental law community. They are intended to provide expert analysis to further public dialogue on important issues impacting the environment.

## About the Emmett Center on Climate Change and the Environment

*http://www.law.ucla.edu/emmett*

Founded in 2008 with a generous gift from Dan A. Emmett and his family, the Emmett Center was established as the nation's first law school center focused exclusively on climate change. The Emmett Center is dedicated to studying and advancing law and policy solutions to the climate change crisis and to training the next generation of leaders in creating these solutions. The Center works across disciplines to develop and promote research and policy tools useful to decision-makers locally, statewide, nationally and beyond.

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