

# Reducing Urban Heat Islands: Compendium of Strategies

## Cool Roofs



# Acknowledgements

*Reducing Urban Heat Islands: Compendium of Strategies* describes the causes and impacts of summertime urban heat islands and promotes strategies for lowering temperatures in U.S. communities. This compendium was developed by the Climate Protection Partnership Division in the U.S. Environmental Protection Agency's Office of Atmospheric Programs. Eva Wong managed its overall development. Kathleen Hogan, Julie Rosenberg, and Andrea Denny provided editorial support. Numerous EPA staff in offices throughout the Agency contributed content and provided reviews. Subject area experts from other organizations around the United States and Canada also committed their time to provide technical feedback.

Under contracts 68-W-02-029 and EP-C-06-003, Perrin Quarles Associates, Inc. provided technical and administrative support for the entire compendium, and Eastern Research Group, Inc. provided graphics and production services.

PositivEnergy provided support in preparing the Trees and Vegetation, Cool Roofs, and UHI Activities chapters under contract PO #2W-0361-SATX.

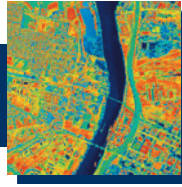
Experts who helped shape this chapter include:

Gregory Chin, Andre Desjarlais, Maury Estes, David Hitchcock, Megan Lewis, Danny Parker, Joyce Rosenthal, Lorraine Ross, Steve Ryan, Rachel Schmeltz, Peter Turnbull, and Barry Zalph.

Suggested Citation: U.S. Environmental Protection Agency. 2008. "Cool Roofs." In: *Reducing Urban Heat Islands: Compendium of Strategies*. Draft. <https://www.epa.gov/heat-islands/heat-island-compendium>.

# Contents

- Cool Roofs .....1**
- 1. How It Works .....2
  - 1.1 Solar Energy .....2
  - 1.2 Solar Reflectance .....3
  - 1.3 Thermal Emittance.....3
  - 1.4 Temperature Effects.....4
- 2. Cool Roof Types .....5
  - 2.1 Low-Sloped Cool Roofs .....5
  - 2.2 Steep-Sloped Cool Roofs.....6
- 3. Benefits and Costs .....8
  - 3.1 Benefits .....8
  - 3.2 Potential Adverse Impacts.....12
  - 3.3 Costs .....12
  - 3.4 Benefit-Cost Considerations.....14
- 4. Other Factors to Consider .....16
  - 4.1 Product Measurement .....16
  - 4.2 Product Labeling .....17
  - 4.3 Installation and Maintenance.....19
  - 4.4 Cool Roofing and Insulation.....19
- 5. Cool Roof Initiatives .....20
- 6. Resources .....22
  - 6.1 Cool Roof Energy Savings Calculators.....22
  - 6.2 Roofing Programs and Organizations.....24
- Endnotes .....26



## Cool Roofs

Cool roofing can help address the problem of heat islands, which results in part from the combined heat of numerous individual hot roofs in a city or suburb. Cool roofing products are made of highly reflective and emissive materials that can remain approximately 50 to 60°F (28-33°C) cooler than traditional materials during peak summer weather. Building owners and roofing contractors have used these types of cool roofing products for more than 20 years. Traditional roofs in the United States, in contrast, can reach summer peak temperatures of 150 to 185°F (66-85°C),<sup>2</sup> thus creating a series of hot surfaces as well as warmer air temperatures nearby.

This chapter provides detailed information that mitigation program organizers can use to understand, plan, and implement cool roofing projects and programs. The chapter discusses:

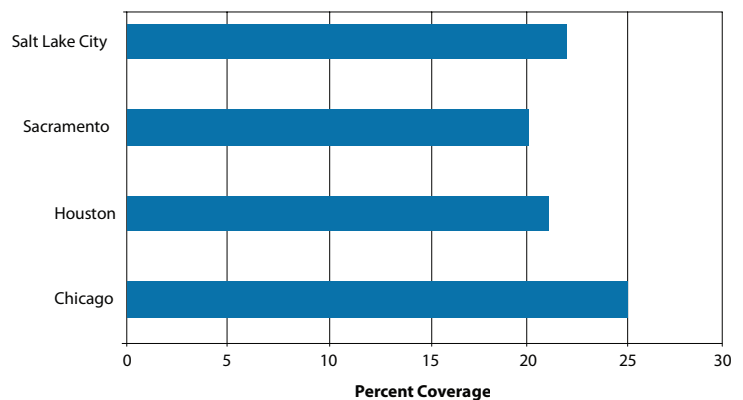
- Key cool roof properties and how they help to mitigate urban heat
- Types of cool roofing
- Specific benefits and costs of cool roofing
- Measurement and certification of cool roof products
- Installation and maintenance of cool roofs
- Tools and resources to further explore this technology.

### Opportunities to Expand Use of Cool Roofs in Urban Areas

Most U.S. cities have significant opportunities to increase the use of cool roofs. As part of the U.S. Environmental Protection Agency's (EPA's) Urban Heat Island Pilot Project, the Lawrence Berkeley National Laboratory conducted a series of analyses to estimate baseline land use and tree cover information for the pilot program cities.<sup>1</sup>

Figure 1 shows the percent of roof cover in four of these urban areas. The data are from 1998 through 2002. With roofs accounting for 20 to 25 percent of land cover, there is a large opportunity to use cool roofs for heat island mitigation.

Figure 1: Roof Cover Statistics for Four U.S. Cities (Below Tree Canopy)



## 1. How It Works

Understanding how cool roofing works requires knowing how solar energy heats roofing materials and how the properties of roofing materials can contribute to warming. This section explains solar energy, the properties of solar reflectance and thermal emittance, and the combined temperature effect of these two properties working together.

### 1.1 Solar Energy

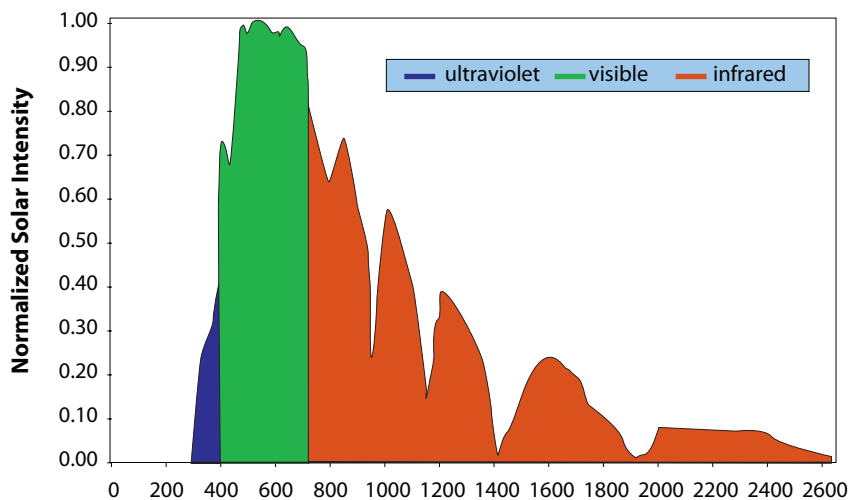
Figure 2 shows the typical solar energy that reaches the Earth's surface on a clear summer day. Solar energy is composed of ultraviolet (UV) rays, visible light, and infrared energy, each reaching the Earth in different percentages: 5 percent of solar energy is in the UV spectrum, including the type of rays responsible for sunburn; 43 percent of solar energy is visible light, in colors ranging from violet to red; and the remaining 52 percent of solar energy is infrared, felt as heat.

## Cool Roof Market

The number of ENERGY STAR® Cool Roof Partners has grown from 60 at the program's inception to nearly 200 by the end of 2007; the number of products has grown even faster, from about 100 to almost 1,600. Based on 2006 data from more than 150 ENERGY STAR Partners, shipments of ENERGY STAR products constitute about 25 percent of the commercial roofing market and about 10 percent of the residential market. The overall market share for these products is rising over time, especially with initiatives such as cool roof requirements in California.

“Cool roofing” refers to the use of highly **reflective and emissive materials**. “Green roofs” refer to rooftop gardens.

Figure 2: Solar Energy versus Wavelength Reaching Earth's Surface



Solar energy intensity varies over wavelengths from about 250 to 2500 nanometers. White or light colored cool roof products reflect visible wavelengths. Colored cool roof products reflect in the infrared energy range.

Many **cool roof products** are bright white. These products get their high solar reflectance primarily from **reflecting in the visible portion of the spectrum** depicted in Figure 2. Given the desire for colored roof products for many buildings, such as the typical single family home, manufacturers are continuing to develop cool colored **products that reflect in the “near-infrared” range**, or the infrared wavelengths from about 700 to 2500 nanometers shown in Figure 2.

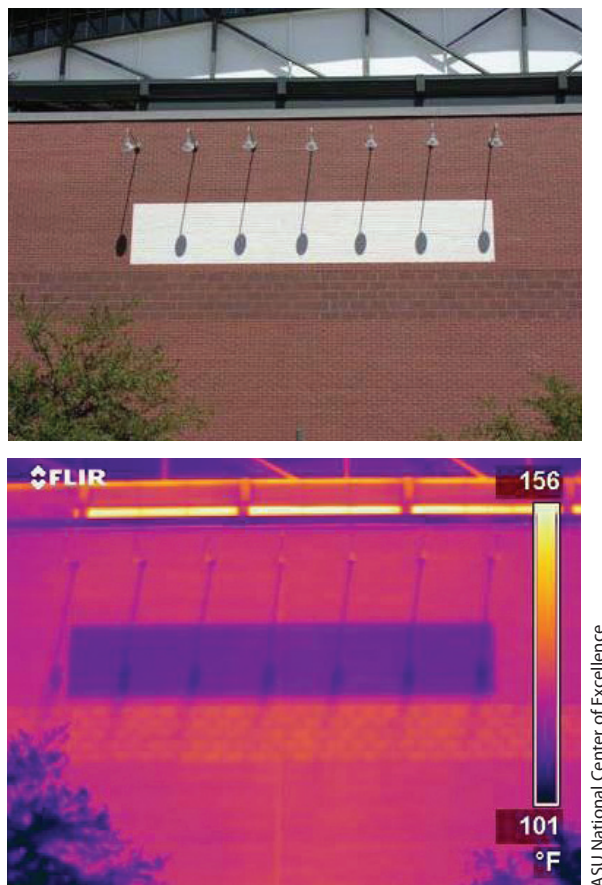
### 1.2 Solar Reflectance

Solar reflectance, or albedo, is the percentage of solar energy reflected by a surface. Researchers have developed methods to determine solar reflectance by measuring how well a material reflects energy at each solar energy wavelength, then calculating the weighted average of these values (see Section 4.1). Traditional roofing materials have low solar reflectance of 5 to 15 percent, which means they absorb 85 to 95 percent of the energy reaching them instead of reflecting the energy back out to the atmosphere. The coolest roof materials have a high solar reflectance of more than 65 percent, absorbing and transferring to the building 35 percent or less of the energy that reaches them. These materials reflect radiation across the entire solar spectrum, especially in the visible and infrared (heat) wavelengths.

### 1.3 Thermal Emittance

Although solar reflectance is the most important property in determining a material's contribution to urban heat islands, thermal emittance is also a part of the equation. Any surface exposed to radiant energy will get

Figure 3: Effect of Albedo on Surface Temperature



Albedo alone can significantly influence surface temperature, with the white stripe on the brick wall about 5 to 10°F (3-5°C) cooler than the surrounding, darker areas.

hotter until it reaches thermal equilibrium (i.e., it gives off as much heat as it receives). A material's thermal emittance determines how much heat it will radiate per unit area at a given temperature, that is, how readily a surface gives up heat. When exposed to sunlight, a surface with high emittance will reach thermal equilibrium at a lower temperature than a surface with low emittance, because the high-emittance surface gives off its heat more readily.

Figure 4: Temperature of Conventional Roofing

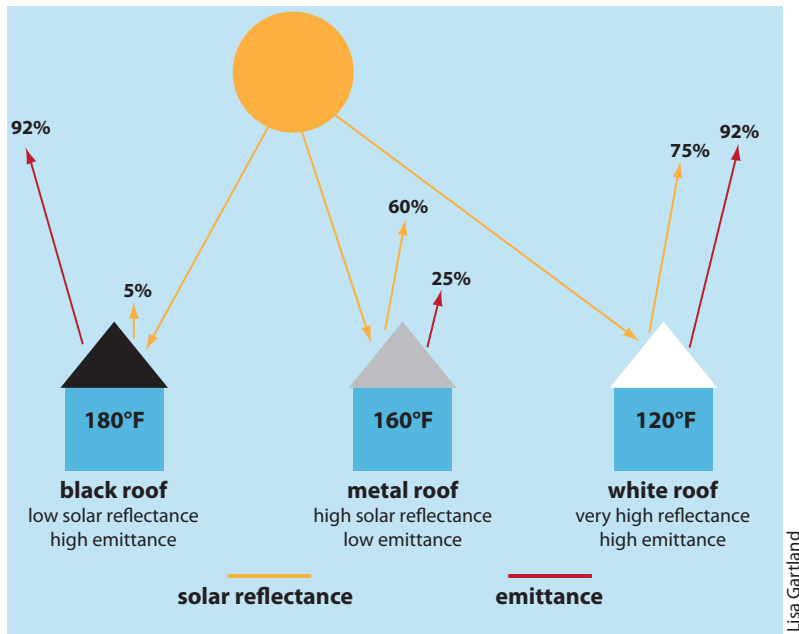


The left half of this traditional bitumen roof in Arizona is shown in visible wavelengths and the right in infrared. The roof's temperature reaches almost 175°F (80°C).

## 1.4 Temperature Effects

Solar reflectance and thermal emittance have noticeable effects on surface temperature. Figure 5 illustrates these differences using three different roof types. Conventional roof surfaces have low reflectance but high thermal emittance; standard black asphalt roofs can reach 165 to 185°F (74 - 85°C) at midday during the summer. Bare metal or metallic surfaced roofs have high reflectance and low thermal emittance and can warm to 150 to 165°F (66 - 77°C). Research has shown that cool roofs with both high reflectance and high emittance reach peak temperatures of only 110 to 115°F (43-46°C) in the summer sun. These peak values vary by local conditions. Nonetheless, research reveals that conventional roofs can be 55 to 85°F (31-47°C) hotter than the air on any given day, while cool roofs tend to stay within 10 to 20°F (6-11°C) of the background temperature.<sup>3</sup>

Figure 5: Example of Combined Effects of Solar Reflectance and Thermal Emittance on Roof Surface Temperature<sup>4</sup>



On a hot, sunny, summer day, a black roof that reflects 5 percent of the sun's energy and emits more than 90 percent of the heat it absorbs can reach 180°F (82°C). A metal roof will reflect the majority of the sun's energy while releasing about a fourth of the heat that it absorbs and can warm to 160°F (71°C). A cool roof will reflect and emit the majority of the sun's energy and reach a peak temperature of 120°F (49°C).

These reduced surface temperatures from cool roofs can lower air temperature. For example, a New York City simulation predicted near-surface air temperature reductions for various cool roof mitigation scenarios. The study assumed 50-percent adoption of cool roofs on available roof space and ran models to evaluate the resulting temperature changes. Averaged over all times of day, the model predicted a city-wide temperature reduction of 0.3°F (0.2°C). The city-wide, 3:00 p.m. average reduction was 0.6°F (0.3°C) and ranged from 0.7 to 1.4°F (0.4 - 0.8°C) in six specific study areas within the city.<sup>5</sup>

## 2. Cool Roof Types

There are generally two categories of roofs: low-sloped and steep-sloped. A low-sloped roof is essentially flat, with only enough incline to provide drainage. It is usually defined as having no more than 2 inches (5 cm) of vertical rise over 12 inches (30 cm) of horizontal run, or a 2:12 pitch. These roofs are found on the majority of commercial, industrial, warehouse, office, retail, and multi-family buildings, as well as some single-family homes.

Figure 6: Low-Sloped Cool Roof



Buildings with a large roof area relative to building height, such as this warehouse, make ideal candidates for cool roofing, as the roof surface area is the main source of heat gain to the building.

Steep-sloped roofs have inclines greater than a 2-inch rise over a 12-inch run. These roofs are found most often on residences and retail commercial buildings and are generally visible from the street.

### 2.1 Low-Sloped Cool Roofs

Low-sloped and steep-sloped roofs use different roofing materials. Traditionally, low-sloped roofs use built-up roofing or a membrane, and the primary cool roof options are coatings and single-ply membranes.

Figure 7: Cool Coating Being Sprayed onto a Rooftop



Cool coating being sprayed onto a rooftop.

**Cool Roof Coatings.** Coatings are surface treatments that are best applied to low-sloped roofs in good condition. They have the consistency of thick paint and contain additives that improve their adhesion, durability, suppression of algae and fungal growth, and ability to self-wash, or shed dirt under normal rainfall. Building owners can apply cool roof coatings to a wide range of existing surfaces, including asphalt capsheet, gravel, metal, and various single-ply materials.



When purchasing cool roof elastomeric coatings, building owners can require that products meet the **ASTM international standard, ASTM D 6083-05e1**, “Standard Specification for Liquid Applied Acrylic Coating Used in Roofing,” to ensure the product achieves certain specifications. There is currently no similar standard for cementitious coatings.

There are two main types of cool roof coatings: cementitious and elastomeric. Cementitious coatings contain cement particles. Elastomeric coatings include polymers to reduce brittleness and improve adhesion. Some coatings contain both cement particles and polymers. Both types have a solar reflectance of 65 percent or higher when new and have a thermal emittance of 80 to 90 percent or more. The important distinction is that elastomeric coatings provide a waterproofing membrane, while cementitious coatings are pervious and rely on the underlying roofing material for waterproofing.

### Common Cool Single-Ply Materials

- **EPDM (ethylene propylene diene monomer)**, a synthetic rubber material, with seams that must be glued or taped together.
- **CSPE (chlorosulfonated polyethylene)**, a polymer material, with seams that can be heat-welded together.
- **PVC (polyvinyl chloride) and TPO (thermoplastic olefins)**, thermoplastic materials, with seams that can be heat-welded together.

**Single-Ply Membranes.** Single-ply membranes come in a pre-fabricated sheet that is applied in a single layer to a low-sloped roof. The materials are generally glued or mechanically fastened in place over the entire roof surface, with the seams sealed by taping, gluing, or heat-welding. A number of manufacturers formulate these products with cool surfaces.

Building owners generally consider cool roof options when their roof begins to fail. They typically use a **cool roof coating** if an existing roof needs only moderate repair, and a **single-ply membrane** for more extensive repairs. The cut-off point between moderate and extensive repairs is not easily determined. In making a choice between these options, however, building owners can gather input from many sources, including roofing consultants and contractors, product manufacturers, and contacts at other facilities that have had cool roofing installed.

## 2.2 Steep-Sloped Cool Roofs

Most cool roof programs focus on the low-sloped roofing sector, but cool roof options are becoming available for the steep-sloped sector as well. Asphalt shingles are the

Figure 8: Conventional and Cool Colored Tiles



Cool roof products can be indistinguishable from their conventional counterparts. The rightmost row of curved tiles uses conventional colored pigments, whereas the other two rows use cool pigments.

most common roofing materials used on steep-sloped roofs. Other products include metal roofing, tiles, and shakes.

The market for steep-sloped cool roofing materials is growing, although the solar reflectance for these products is generally lower than for low-sloped cool roofs. A number of products are available for tiles and painted metal roofing.

The solar reflectance of traditional tiles, typically made of clay or concrete, ranges from 10 to 30 percent. Manufacturers have begun producing “cool colored” tiles that contain pigments that reflect solar energy in the infrared spectrum. The ENERGY STAR Roof Products List as of April 2008

## Cool Colors

The California Energy Commission has sponsored the “Cool Colors Project,” under which LBNL and Oak Ridge National Laboratory (ORNL) are collaborating with roofing industry partners to research and develop cool colored roof products that could expand significantly the use of cool roofing in the residential sector. See <http://coolcolors.lbl.gov/> for more information.

has approved tiles for steep-sloped roofs with initial solar reflectances ranging from 25 to almost 70 percent, depending on color. These tiles come in traditional colors, such as brown, green, and terra cotta. They are durable and long-lasting, but not widely used. Where tiles are used, the cool tile alternatives can be available at little or no incremental cost over traditional tiles.<sup>6</sup>

Figure 9: Cool Metal Roofing



CRR/Custom-Bit Metals

Cool colored metal roofs lend themselves readily to the steep-sloped market, as this house demonstrates.

Cool colored metal roofing products also use infrared-reflecting pigments and have high durability and long life. About one-half of the products on the ENERGY STAR Roof Products List as of April 2008 were metal roofing products for steep-sloped roofs, with initial solar reflectances ranging from about 20 to 90 percent.

Asphalt shingles are the most commonly used material for steep-sloped roofs, with a market share of about 50 percent, depending on the region,<sup>7</sup> and a low initial cost of just over \$1.00 per square foot (0.930 m<sup>2</sup>). As of April 2008, several manufacturers offered a line of asphalt shingles on the ENERGY STAR Roof Products List, with initial solar reflectances ranging from about 25 to 65 percent. Other shingle products on the list are metal. Manufacturers, researchers, and other stakeholders are working together to develop additional, cool-colored shingle products that use infrared-reflecting pigments.<sup>8</sup>

### 3. Benefits and Costs

The use of cool roofs as a mitigation strategy brings many benefits, including lower energy use, reduced air pollution and greenhouse gas emissions, and improved human health and comfort. At the same time, there can be a cost premium for some cool roof applications versus traditional roofing materials. This section highlights some of the key benefits and costs of cool roof programs and individual projects. Section 6 also introduces cool roof energy savings calculators that community planners or individual building owners can use to help determine whether to pursue cool roofs as a mitigation option.

#### 3.1 Benefits

**Reduced Energy Use.** A cool roof transfers less heat to the building below, so the building stays cooler and more comfortable and uses less energy for cooling. Every building responds differently to the effects of a cool roof. For example, Table 1 lists examples of the general characteristics and cooling energy savings of different one-story buildings in California, Florida, and Texas. The measured savings varied from 10 to almost 70 percent of each building's total cooling energy use. In addition, a 2004 report summarized more than 25 articles about the cooling energy used by buildings with cool roofs and identified energy savings ranging from 2 to over 40 percent, with average savings of about 20 percent.<sup>9</sup>

Local climate and site-specific factors, such as insulation levels, duct placement, and attic configuration, play an important role in the amount of savings achieved (see the range in Table 1). Other site-specific variables also can strongly influence the amount of energy a particular building will save. For example, a study of a San Jose, California, drug store documented

cooling energy savings of only 2 percent. The cooling demands in this store were driven by the design of the building, including a radiant barrier under the roof and a well ventilated plenum space, so that heat transfer through the roof contributed little to the store's cooling demand.<sup>10</sup> Thus, in gauging potential energy savings for a particular building, the building owners will need to consider a range of factors to make cool roofing work for them.

Another benefit of cool roofing is that it saves energy when most needed—during peak electrical demand periods that generally occur on hot, summer weekday afternoons, when offices and homes are running cooling systems, lights, and appliances. By reducing cooling system needs, a cool roof can help building owners reduce peak electricity demand. The last column in Table 1 lists reductions in the peak demand for cooling energy that range from 14 to 38 percent after installation of a cool roof.

Lower peak demand not only saves on total electrical use but also can reduce demand fees that some utilities charge commercial and industrial building owners. Unlike residential customers, who pay for only the amount of electricity they use, commercial and industrial customers often pay an additional fee based on the amount of peak power they demand. Because cool roofing helps reduce their peak demand, it lowers these costs.

#### Insulation and R-Values

The “R-value” of building insulation indicates its ability to impede heat flow. Higher R-values are correlated with greater insulating properties.

Researchers have conducted in-depth modeling to assess how building-level energy savings can affect city-wide energy usage. The Lawrence Berkeley National Laboratory (LBNL) ran simulations to evaluate the net energy impacts of applying cool roofing in 11 U.S. cities.<sup>11</sup> The original study was based on 1993 energy prices and buildings that use electrical cooling systems and gas furnaces. Figure 10 uses 2003 state-level prices for electricity and natural gas, based on Energy Information Administration data for the commercial sector.

Cool roofs reflect solar energy year round, which can be a disadvantage in the winter as they reflect away desirable wintertime heat gain. The net effect is generally

positive, though, because most U.S. cities have high cooling and peak cooling demand, and electricity is expensive. Figure 10 presents the total anticipated cooling energy savings and the net savings after considering increased heating costs. Although northern and mid-Atlantic cities with relatively long heating seasons, such as Chicago, Philadelphia, and Washington D.C., still reap net savings, the net benefits for New York City remain particularly high because of the high price of electricity in that area. (See Section 3.2 for further discussion of the heating penalty.)

This same LBNL study extrapolated the results to the entire United States and estimated that widespread use of cool roofs

**Table 1: Reported Cooling Energy Savings from Buildings with Cool Roofs<sup>12</sup>**

| Building            | Location           | Citation                               | Size (ft <sup>2</sup> ) | Roof Insulation* | Roof Space | Annual Cooling Saved | Peak Demand Savings |
|---------------------|--------------------|--|-------------------------|------------------|------------|----------------------|---------------------|
| Residence           | Merritt Island, FL | (Parker, D., S. Barkaszi, et al. 1994) | 1,800                   | R-25             | Attic      | 10%                  | 23%                 |
| Convenience Retail  | Austin, TX         | (Konopacki, S. and H. Akbari 2001)     | 100,000                 | R-12             | Plenum     | 11%                  | 14%                 |
| Residence           | Cocoa Beach, FL    | (Parker, D., J. Cummings, et al. 1994) | 1,795                   | R-11             | Attic      | 25%                  | 28%                 |
| Residence           | Nobleton, FL       | (Parker, D., S. Barkaszi, et al. 1994) | 900                     | R-3              | Attic      | 25%                  | 30%                 |
| School Trailer      | Volusia County, FL | (Callahan, M., D. Parker, et al. 2000) | 1,440                   | R-11             | None       | 33%                  | 37%                 |
| School Trailer      | Sacramento, CA     | (Akbari, H., S. Bretz, et al. 1993)    | 960                     | R-19             | None       | 34%                  | 17%                 |
| Our Savior's School | Cocoa Beach, FL    | (Parker, D., J. Sherwin, et al. 1996)  | 10,000                  | R-19             | Attic      | 10%                  | 35%                 |
| Residence           | Cocoa Beach, FL    | (Parker, D., J. Cummings, et al. 1994) | 1,809                   | None             | Attic      | 43%                  | 38%                 |
| Residence           | Sacramento, CA     | (Akbari, H., S. Bretz, et al. 1993)    | 1,825                   | R-11             | None       | 69%                  | 32%                 |

\* Note: These insulation levels are lower than the energy efficiency levels recommended by ENERGY STAR. If insulation levels were higher, the cooling savings likely would be less.

could reduce the national peak demand for electricity by 6.2 to 7.2 gigawatts (GW),<sup>13</sup> or the equivalent of eliminating the need to build 12 to 14 large power plants that have an energy capacity of 500 megawatts each.

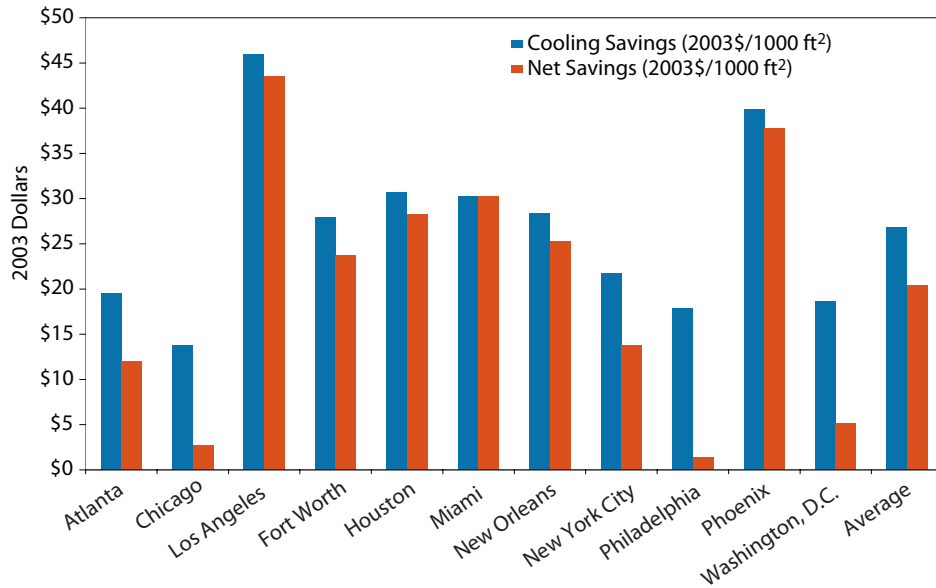
**Reduced Air Pollution and Greenhouse Gas Emissions.** The widespread adoption of heat island mitigation efforts such as cool roofs can reduce energy use during the summer months. To the extent that reduced energy demand leads to reduced

burning of fossil fuels, cool roofs contribute to fewer emissions of air pollutants, such as nitrogen oxides (NO<sub>x</sub>), as well as greenhouse gases, primarily carbon dioxide (CO<sub>2</sub>). The CO<sub>2</sub> reductions can be substantial. For example, one study estimated potential CO<sub>2</sub> reductions of 6 to 7 percent in Baton Rouge and Houston from reduced building energy use.<sup>14</sup> Reductions in air pollutant emissions such as NO<sub>x</sub> generally provide benefits in terms of improved air quality, particularly ground-level ozone

## Case Examples of Building Comfort Improvements

- **“Big-box” retailer Home Base, Vacaville, California.**<sup>15</sup> Installing a cool roof at this store helped solve the problem created by an incorrectly sized cooling system. This store used an undersized evaporative cooling system that was unable to meet the building’s cooling loads. Indoor temperatures above 90°F (32°C) were recorded, even with the building coolers working around the clock. After adding a cool roof, peak indoor temperatures were reduced to 85°F (29°C) or lower, and 10 more shopping hours a week were deemed comfortable (below 79°F (26°C) and 60 percent humidity) inside the store. Although the evaporative coolers were still not powerful enough to meet the hottest conditions, the cool roof helped reduce temperatures inside the store.
- **Apartment complex, Sacramento, California.**<sup>16</sup> Adding cool roofs at these residences lowered indoor air temperatures, improving resident comfort. These non-air conditioned buildings were composed of two stories and an attic, with an R-38 level of insulation above the second story and below the attic space. Adding a cool roof lowered peak air temperatures in the attic by 30 to 40°F (17-22°C). Generally, the higher the insulation level, the less effect a cool roof will have on the space beneath it; however, in this case, even with high insulation levels, the cool roof reduced second-story air temperatures by 4°F (2°C) and first floor temperatures by 2°F (1°C).
- **Private elementary school, Cocoa Beach, Florida.**<sup>17</sup> Cool roof coatings at this school improved comfort and saved energy. This 10,000-square foot (930 m<sup>2</sup>) facility had an asphalt-based roof, gray modified bitumen, over plywood decking with a measured solar reflectance of 23 percent. The dropped ceiling was insulated to R-19 levels, and insulated chiller lines were used in the hot roof plenum space. Once the roof was covered by an acrylic white elastomeric coating, the solar reflectance rose to 68 percent. The classrooms became cooler and the chiller electric use was reduced by 10 percent. School staff noticed improved comfort levels due to the new roof.

Figure 10: Modeled Net Energy Cost Savings\* (\$/1,000 ft<sup>2</sup>) in Various U.S. Cities from Widespread Use of Cool Roofing<sup>18</sup>



Costs are based on state-specific data applied to each city, using 2003 Energy Information Administration reported prices for the commercial sector.<sup>19</sup>

(smog). The relationships between pollutant reductions and improved air quality are complex, however, and require air quality modeling to demonstrate the benefits in specific urban areas.

**Improved Human Health and Comfort.**

Ceilings directly under hot roofs can be very warm. A cool roof can reduce air temperatures inside buildings with and without air conditioning.

For residential buildings without air conditioning, cool roofs can provide an important public health benefit during heat waves. For example, Philadelphia operates a program to add cool roofs and insulation to residential buildings that lack air conditioning to prevent heat-related illnesses and deaths. A study measured significant cooling benefits from this program.<sup>20</sup> The study controlled for differences in outside temperature before and after the installing the cool roofs and insulation; these treatments lowered the daily maximum ceiling surface temperature by about 4.7°F (2.6°C), while daily maximum

Figure 11: Cool Roofing on Urban Row Homes



Energy Coordinating Agency, Philadelphia

Philadelphia reduced temperatures in row houses by installing cool roofs, which improves the comfort for occupants and may help reduce deaths from excessive heat events. Baltimore, with similar building stock, took similar steps following the success in Philadelphia.

room air temperatures dropped by about 2.4°F (1.3°C). The study noted that on a 95°F (35°C) day, these types of reductions represent large reductions in heat gain to the room and significantly improve perceived human comfort.

### 3.2 Potential Adverse Impacts

Cool roofs can have a wintertime heating penalty because they reflect solar heat that would help warm the building. Although building owners must account for this penalty in assessing the overall benefits of cool roofing strategies, in most U.S. climates this penalty is not large enough to negate the summertime cooling savings because:

- The amount of useful energy reflected by a cool roof in the winter tends to be less than the unwanted energy reflected in the summer. This difference occurs primarily because winter days are shorter, and the sun is lower in the sky. The sunlight strikes the Earth at a lower angle, spreading the energy out over a larger area and making it less intense. In mid-Atlantic and northern states with higher heating requirements, there also are more cloudy days during winter, which reduces the amount of sun reflected by a cool roof. Snow cover on roofs in these climates also can reduce the difference in solar reflectivity between cool and non-cool roofs.
- Many buildings use electricity for cooling and natural gas for heating. Electricity has traditionally been more expensive than natural gas per unit of energy, so the net annual energy savings translate into overall annual utility bill savings. Note, however, that natural gas and electricity prices have been volatile in some parts of the country, particularly since 2000. As shown in Figure 10, with elevated natural gas prices in recent years, the net benefit in terms of cost savings might be small in certain northern cities with high heating demands.

California-based research indicates a **cost premium ranging from zero to 20 cents per square foot** for cool roof products.

### 3.3 Costs

A 2006 report (see Table 2) investigated the likely initial cost ranges for various cool roof products.<sup>21</sup> The comparisons in Table 2 are indicative of the trade-offs in cost and reflectance and emittance factors between traditional and cool roof options. For low-sloped roofs, the report noted that:

- Cool roof coatings might cost between \$0.75 and \$1.50 per square foot for materials and labor, which includes routine surface preparation like pressure-washing, but which does not include repair of leaks, cracks, or bubbling of the existing roof surface.
- Single-ply membrane costs vary from \$1.50 to \$3.00 per square foot, including materials, installation, and reasonable preparation work. This cost does not include extensive repair work or removal and disposal of existing roof layers.
- For either type of cool roof, there can be a cost premium compared to other roofing products. In terms of dollars per square foot, the premium ranges from zero to 5 or 10 cents for most products, or from 10 to 20 cents for a built-up roof with a cool coating used in place of smooth asphalt or aluminum coating.
- As with any roofing job, costs depend on the local market and factors such as the size of the job, the number of roof penetrations or obstacles, and the ease of access to the roof. These variables often outweigh significantly the difference in costs between various roofing material options.<sup>22</sup>

Table 2: Comparison of Traditional and Cool Roof Options<sup>23</sup>

| Warmer Roof Options  |   |   |                            | Cooler Roof Options   |   |   |                            |
|--|---|---|----------------------------|---|---|---|----------------------------|
| Roof Type  | Reflectance                             | Emittance                               | Cost (\$/ft <sup>2</sup> ) | Roof Type   | Reflectance                             | Emittance                               | Cost (\$/ft <sup>2</sup> ) |
| <b>Built-up Roof</b><br>With dark gravel<br>With smooth asphalt surface<br><br>With aluminum coating | 0.08-0.15<br>0.04-0.05<br><br>0.25-0.60 | 0.80-0.90<br>0.85-0.95<br><br>0.20-0.50 | <b>1.2-2.1</b>             | <b>Built-up Roof</b><br>With white gravel<br>With gravel and cementitious coating<br><br>Smooth surface with white roof coating | 0.30-0.50<br>0.50-0.70<br><br>0.75-0.85 | 0.80-0.90<br>0.80-0.90<br><br>0.80-0.90 | <b>1.2-2.15</b>            |
| <b>Single-Ply Membrane</b><br>Black (PVC)  | 0.04-0.05                               | 0.80-0.90                               | <b>1.0-2.0</b>             | <b>Single-Ply Membrane</b><br>White (PVC)<br>Color with cool pigments   | 0.70-0.78<br>0.40-0.60                  | 0.80-0.90<br>0.80-0.90                  | <b>1.0-2.05</b>            |
| <b>Modified Bitumen</b><br>With mineral surface capsheet (SBS, APP)                                  | 0.10-0.20                               | 0.80-0.90                               | <b>1.5-1.9</b>             | <b>Modified Bitumen</b><br>White coating over a mineral surface (SBS, APP)  | 0.60-0.75                               | 0.80-0.90                               | <b>1.5-1.95</b>            |
| <b>Metal Roof</b><br>Unpainted, corrugated<br>Dark-painted, corrugated                               | 0.30-0.50<br>0.05-0.08                  | 0.05-0.30<br>0.80-0.90                  | <b>1.8-3.7</b>             | <b>Metal Roof</b><br>White painted<br>Color with cool pigments  | 0.60-0.70<br>0.40-0.70                  | 0.80-0.90<br>0.80-0.90                  | <b>1.8-3.75</b>            |
| <b>Asphalt Shingle</b><br>Black or dark brown with conventional pigments                             | 0.04-0.15                               | 0.80-0.90                               | <b>0.5-2.0</b>             | <b>Asphalt Shingle</b><br>"White" (light gray)<br>Medium gray or brown with cool pigments                                       | 0.25-0.27<br>0.25-0.27                  | 0.80-0.90<br>0.80-0.90                  | <b>0.6-2.1</b>             |
| <b>Liquid Applied Coating</b><br>Smooth black  | 0.04-0.05                               | 0.80-0.90                               | <b>0.5-0.7</b>             | <b>Liquid Applied Coating</b><br>Smooth white<br>Smooth, off-white<br>Rough white   | 0.70-0.85<br>0.40-0.60<br>0.50-0.60     | 0.80-0.90<br>0.80-0.90<br>0.80-0.90     | <b>0.6-0.8</b>             |
| <b>Concrete Tile</b><br>Dark color with conventional pigments  | 0.05-0.35                               | 0.80-0.90                               | <b>1.0-6.0</b>             | <b>Concrete Tile</b><br>White<br>Color with cool pigments   | 0.70<br>0.40-0.50                       | 0.80-0.90<br>0.80-0.90                  | <b>1.0-6.0</b>             |
| <b>Clay Tile</b><br>Dark color with conventional pigments  | 0.20                                    | 0.80-0.90                               | <b>3.0-5.0</b>             | <b>Clay Tile</b><br>White<br>Terra cotta (unglazed red tile)<br><br>Color with cool pigments                                    | 0.70<br>0.40<br><br>0.40-0.60           | 0.80-0.90<br>0.80-0.90<br><br>0.80-0.90 | <b>3.0-5.0</b>             |
| <b>Wood Shake</b><br>Painted dark color with conventional pigment                                    | 0.05-0.35                               | 0.80-0.90                               | <b>0.5-2.0</b>             | <b>Wood Shake</b><br>Bare   | 0.40-0.55                               | 0.80-0.90                               | <b>0.5-2.0</b>             |



### 3.4 Benefit-Cost Considerations

Based on the benefits of cool roofs and the cost premiums noted in Table 2, a community can develop a benefit-cost analysis to determine whether a cool roof project or program will provide overall net benefits in a given area. For example, the cost study referenced in Table 2 also evaluated the cost effectiveness of low-sloped cool roofs for commercial buildings in California by quantifying five parameters (see summary results in Table 3):<sup>24</sup>

- Annual decrease in cooling electricity consumption
- Annual increase in heating electricity and/or gas
- Net present value (NPV) of net energy savings
- Cost savings from downsizing cooling equipment
- Cost premium for a cool roof

The study recognized that other parameters can provide benefits or reduce costs that were not part of the analysis. These include:

- Reduced peak electric demand for cooling
- Financial value of rebates or energy saving incentives that can offset the cost premiums for cool roofing materials
- Reduced material and labor costs over time resulting from the extended life of the cool roof compared to a traditional roof

Given the information at hand, the study found that expected total net benefits, after considering heating penalty costs, should range from \$0.16 to \$0.66/square foot (average \$0.47/ft<sup>2</sup>) based on the California

climate zones studied (see Table 3). California relied in part on this benefit-cost analysis to establish mandatory statewide low-sloped cool roof requirements.

In 2006, California began evaluating whether to extend the state's mandatory cool roof requirements to the steep-sloped market. One analysis in support of this approach anticipated positive cost effectiveness in many but not all California climate zones.<sup>25</sup> The state will consider that analysis, as well as public comments on benefits and costs in deciding what final action to take on steep-sloped roof requirements. A final rule is expected in 2008.

Although the results of Table 3 are specific to California in terms of electricity rates and typical cooling and heating energy use, the cost effectiveness approach can be replicated by other communities considering cool roof projects or programs.

Figure 12: Cool Roof on a Condominium



Homeowners can also reap the benefits of cool roofs.

Table 3: Example Cool Roof Cost/Benefit Summary for California<sup>26</sup>

| California Climate Zone | Roof R-Value | Annual Energy/1000 ft <sup>2</sup> |       |             | Peak Power/1000 ft <sup>2</sup> |         | Net Present Value (NPV)/1000 ft <sup>2</sup> |         |          |         |
|-------------------------|--------------|------------------------------------|-------|-------------|---------------------------------|---------|--|---------|----------|---------|
|                         |              | kWh                                | therm | Source MBTU | kW                              | \$equip | \$kWh  | \$therm | \$energy | \$total |
| 1                       | 19           | 115                                | -8.3  | 0.3         | 0.13                            | 67      | 157  | -62     | 95       | 162     |
| 2                       | 19           | 295                                | -5.9  | 2.4         | 0.20                            | 100     | 405  | -43     | 362      | 462     |
| 3                       | 19           | 184                                | -4.9  | 1.4         | 0.15                            | 76      | 253  | -35     | 218      | 294     |
| 4                       | 19           | 246                                | -4.2  | 2.1         | 0.18                            | 90      | 337  | -31     | 306      | 396     |
| 5                       | 19           | 193                                | -4.7  | 1.5         | 0.17                            | 83      | 265  | -35     | 230      | 313     |
| 6                       | 11           | 388                                | -4.1  | 3.6         | 0.22                            | 111     | 532  | -29     | 503      | 614     |
| 7                       | 11           | 313                                | -2.6  | 2.9         | 0.25                            | 125     | 428  | -20     | 408      | 533     |
| 8                       | 11           | 413                                | -3.7  | 3.9         | 0.25                            | 125     | 565  | -28     | 537      | 662     |
| 9                       | 11           | 402                                | -4.5  | 3.7         | 0.20                            | 101     | 552  | -33     | 519      | 620     |
| 10                      | 19           | 340                                | -3.6  | 3.1         | 0.18                            | 89      | 467  | -26     | 441      | 530     |
| 11                      | 19           | 268                                | -4.9  | 2.3         | 0.15                            | 75      | 368  | -37     | 331      | 406     |
| 12                      | 19           | 286                                | -5.3  | 2.4         | 0.19                            | 95      | 392  | -39     | 353      | 448     |
| 13                      | 19           | 351                                | -5.1  | 3.1         | 0.19                            | 96      | 480  | -37     | 443      | 539     |
| 14                      | 19           | 352                                | -4.7  | 3.1         | 0.21                            | 105     | 483  | -33     | 450      | 555     |
| 15                      | 19           | 380                                | -1.7  | 3.7         | 0.16                            | 82      | 520  | -13     | 507      | 589     |
| 16                      | 19           | 233                                | -10.6 | 1.3         | 0.18                            | 90      | 319  | -78     | 242      | 332     |
| min                     |              | 115                                | -10.6 | 0.3         | 0.13                            | 67      | 157  | -78     | 95       | 162     |
| max                     |              | 413                                | -1.7  | 3.9         | 0.25                            | 125     | 565  | -13     | 537      | 662     |
| avg                     |              | 297                                | -4.9  | 2.6         | 0.19                            | 94      | 408  | -36     | 372      | 466     |

\* This table presents dollar savings from reduced air conditioning use (in kWh) and reduced air conditioning equipment sizing (\$equip), offset by natural gas heating penalty costs (measured in therms). The "Net Present Value (NPV)/1000 ft<sup>2</sup>" column uses the kWh and therm information to project savings for energy only and in total (energy plus equipment).

## 4. Other Factors to Consider

### 4.1 Product Measurement

To evaluate how “cool” a specific product is, ASTM International has validated test methods to measure solar reflectance and thermal emittance (see Table 4). The Cool Roof Rating Council (CRRC) also has developed a test method for variegated roof products such as composite shingles, including laboratory and field tests. Laboratory measurements help determine the properties of new material samples, while field measurements are useful for evaluating how well a roof material has withstood the test of time, weather, and dirt.

The final method listed in Table 4 is not an actual test but a way to calculate the “solar reflectance index” or SRI. The SRI is a value that incorporates both solar reflectance and thermal emittance in a single value to represent a material’s temperature in the sun. This index compares how hot a surface would get compared to a standard black and a standard white surface. In physical terms, this scenario is like laying a roof material next to a black surface and a white surface and measuring the temperatures of all three surfaces in the sun. The SRI is a value between zero (as hot as a black surface) and 100 (as cool as a white surface) and calculated as follows:

$$SRI = \frac{(T_{black} - T_{surface})}{(T_{black} - T_{white})} \times 100$$

Table 4: Test Methods to Evaluate Coolness of Roofing Materials

| Property                | Test Method   | Equipment Used                       | Test Location       |
|-------------------------|---|--------------------------------------|---------------------|
| Solar reflectance       | ASTM E 903 - Standard Test Method for Solar Absorbance, Reflectance, and Transmittance of Materials Using Integrating Spheres                       | Integrating sphere spectrophotometer | Laboratory          |
| Solar reflectance       | ASTM C 1549 - Standard Test Method for Determination of Solar Reflectance Near Ambient Temperature Using a Portable Solar Reflectometer             | Portable solar reflectometer         | Laboratory or field |
| Solar reflectance       | ASTM E 1918 - Standard Test Method for Measuring Solar Reflectance of Horizontal and Low-Sloped Surfaces in the Field                               | Pyranometer                          | Field               |
| Solar reflectance       | CRRC Test Method #1 (for variegated roof products, [i.e. products with discrete markings of different colors]); used in conjunction with ASTM C1549 | Portable solar reflectometer         | Laboratory or field |
| Thermal emittance       | ASTM E 408-71 - Standard Test Method for Total Normal Emittance of Surfaces Using Inspection-Meter Techniques                                       | Reflectometer or emissometer         | Laboratory          |
| Thermal emittance       | ASTM C 1371 - Standard Test Method for Determination of Emittance of Materials Near Room Temperature Using Portable Emissometers                    | Emissometer                          | Field               |
| Solar reflectance index | ASTM E 1980 - Standard Practice for Calculating Solar Reflectance Index of Horizontal and Low-Sloped Opaque Surfaces                                | None (calculation)                   | ---                 |

The U.S. Green Building Council, as part of its **Leadership in Energy and Environmental Design (LEED) Rating System**, has developed an SRI Calculator to assist project sponsors in calculating a roof's SRI under "LEED-NC, Version 2.2, Sustainable Site Credit 7.2: Heat Island Effect: Roof." See <[www.usgbc.org](http://www.usgbc.org)>.

#### 4.2 Product Labeling

ENERGY STAR for Roof Products and the Cool Roof Rating Council (CRRC) both operate voluntary labeling programs for manufacturers. Many building codes and energy efficiency rebate programs require that cool roofing materials meet recognized specifications and standards, and that a vendor's product be listed with either or both of these voluntary labeling programs.

Figure 13: Olympic Oval, Salt Lake City, Utah



The Olympic Oval features a cool roof covering almost 205,000 square feet (19,000 m<sup>2</sup>). ENERGY STAR partners, who helped build the oval's roof, have played key roles in advancing cool roofing technology.

**ENERGY STAR for Roof Products.** Manufacturers can participate voluntarily in the ENERGY STAR for Roof Products program. A product qualifies for ENERGY STAR if it meets the solar reflectance criteria expressed in Table 5. The program uses significantly different criteria for low-sloped versus steep-sloped roof products. Highly reflective products, which are currently bright white for the most part, are available for low-sloped roofs. For aesthetic reasons, bright white options are generally not marketable for steep-sloped roofs. Instead, steep-sloped cool roof products generally use moderately reflective, colored options.

Version 2.0 of the program guidelines became effective in January 2008. The guidelines require manufacturers to test their products' initial solar reflectance and maintenance of solar reflectance after at least three years of service. For the initial testing, manufacturers can rely on tests conducted for purposes of certifying a product under the Cool Roof Rating Council's Product Rating Program, if applicable. To ensure the long-term integrity of reflective products, ENERGY STAR also requires products to maintain warranties comparable to those offered for non-reflective roof products. Finally, the Version 2.0 guidelines also require manufacturers to report a product's initial emissivity as part of the application process. There is no emissivity level required, but this information can provide valuable information on the potential savings and benefits

The most up-to-date list of **ENERGY STAR qualified roof products**, and current, proposed, and prior specifications, can be found on the ENERGY STAR Web site at <[www.energystar.gov](http://www.energystar.gov)>.

Table 5: ENERGY STAR for Roof Products (Version 2.0) Qualifying Criteria

| Type of Roof Product | Initial Solar Reflectance |                             | Maintenance of Solar Reflectance* |                            |
|----------------------|---------------------------|-----------------------------|-----------------------------------|----------------------------|
|                      | Standard                  | Test Methods                | Standard                          | Test Methods               |
| Low-sloped           | 65% or higher             | ASTM E 903 or ASTM C 1549** | 50% or higher                     | ASTM E 1918 or ASTM C 1549 |
| Steep-sloped         | 25% or higher             | ASTM E 903 or ASTM C 1549** | 15% or higher                     | ASTM C 1549                |

\* Maintenance of solar reflectance is measured on a roof that has been in service for three years or more.

\*\* Manufacturers can also use CRRC Test Method #1 for variegated roof products and can use results from tests conducted as part of CRRC Product Rating Program certification.

of a specific product in the region where it will be used.

Based on data from almost 90 percent of the ENERGY STAR Partners, the market share of cool roof products from these manufacturers has grown in recent years. In 2004, cool roof products represented 8 percent of these manufacturers' shipments in the commercial roofing sector and 6 percent in the residential. In 2006, their shipments of commercial cool roof product tripled to represent more than 25 percent of their commercial roof products, and the residential share almost doubled, reaching 10 percent.

**Cool Roof Rating Council.** CRRC is a non-profit organization with members from the business, consulting, and research fields. The CRRC was formed in 1998 and applied to join the American National Standards Institute (ANSI) ten years later. In September 2002, CRRC launched its product rating program with a list of solar reflectance and thermal emittance values of roofing materials. As of February 2007, this list included only initial or new values of roofing material properties, but work is underway to add three-year weathered values to the list. The weathered values of solar reflectance and thermal emittance will come from

test farms located in different areas of the country, where roof materials are exposed to the elements for three years.

See the **CRRC Rated Product Directory** at <[www.coolroofs.org](http://www.coolroofs.org)>.

Manufacturer participation in the CRRC program is entirely voluntary. Participating manufacturers must adhere to stringent requirements; however, to ensure accurate reported values, only agencies or laboratories accredited by CRRC can perform tests, and their test programs must use the ASTM and CRRC standards listed in Table 4.

A material does not need to meet a solar reflectance or thermal emittance value to appear on the CRRC Rated Product Directory roofing products list. Because any product can be listed, regardless of how cool it might be, it is up to the consumer to check the values on the CRRC list and decide which products meet their own criteria for cool materials. Building owners and heat island mitigation groups can use the CRRC ratings in conjunction with the ENERGY STAR guidelines to help to identify cool materials on the basis of solar reflectance.

### 4.3 Installation and Maintenance

A coating or single-ply membrane on a low-sloped roof can serve as the top surface of a roofing assembly and can be applied directly over a roof deck or on top of other existing materials. Proper installation is important to the long-term success of a cool roof project. For example, when applied properly, many cool roof coatings have been shown to last more than 20 years. When applied poorly, cool roof coatings can peel or flake off the roof within a couple of years. To ensure good product performance, building owners can seek appropriate warranties for both the product and the installation service.

On **steep-sloped roofs**, professionals do not recommend using cool coatings over existing shingles. This technique can cause moisture problems and water damage because the coating can inhibit normal shingle drying after rain or dew accumulation, allowing water to condense and collect under the shingles.

A key concern for cool roofs is maintaining their high solar reflectance over time. If a building's roof tends to collect large amounts of dirt or particulate matter, washing the roof according to the manufacturer's recommended maintenance procedures can help retain solar reflectance. Also, smoother surfaces and higher sloped surfaces tend to withstand weathering better. With proper maintenance, coatings are able to retain most of their solar reflectance, with decreases of only about 20 percent, usually in the first year after application of the coating.<sup>27</sup>

Figure 14: Installation of a Cool Single-Ply Membrane



Lisa Gartland/PositiveEnergy

Cool roofs can be applied to existing buildings or designed into new ones.

### 4.4 Cool Roofing and Insulation

Cool roofing and roof insulation are not comparable options for saving building energy—they work very differently. Building owners must make separate decisions to upgrade roof insulation levels or install cool roofing.

Some studies have evaluated the insulation levels needed to produce the same summertime energy savings as a cool roof.<sup>28,29,30</sup> These studies have been used to support building codes that allow less roof insulation if cool roofing is installed.<sup>31,32</sup> The conditions for choosing levels of roof insulation or cool roofing vary based on climate, utility prices, building use, building and fire code considerations, and preference. Thus, the following factors for choosing insulation or cool roofing are general approximations. Building owners might consider adding roof or ceiling insulation if:

- There is less roof insulation than called for in the latest state or local building codes

- The building is in a climate with significant cold weather or heating needs
- The roof accounts for much of the building's envelope (i.e., the roof area equals or exceeds one-fourth of the building's exterior surface area, calculated as the walls plus the roof).

Cool roofing can be used on any building, but is especially useful if:

- The building is in a climate with hot and sunny weather during at least part of the year (80°F or hotter weather with clear skies for at least three months of the year)
- Significant cooling energy is used (three or more months of cooling use)
- The duct system is in the attic or plenum space
- There are problems maintaining indoor comfort in the summer (if air conditioning equipment cannot maintain the desired temperature, or without air conditioning, if indoor temperatures exceed 80°F)
- The roof accounts for much of the building's envelope (i.e., the roof area equals or exceeds one-fourth of the building's exterior surface area, calculated as the walls plus the roof)
- The roof materials tend to crack and age prematurely from sun damage (if damage begins before the warranty period or the roof life ends).

Generally, adding roof insulation means adding insulation under the roof or above the ceiling, which can be disruptive to building occupants. Another option on the market is to spray insulating foam or affix rigid insulation onto the top of the roof surface. Each of these products adds approximately an R-6 level of long-term thermal resistance for each inch (2.5 cm)

of thickness added. These technologies by themselves are not cool roofing materials; however, they are often applied as part of a complete roofing system, where the top surface is a cool coating or single-ply membrane.

## 5. Cool Roof Initiatives

Communities have developed cool roof programs by taking action in their own buildings, often called leading by example; through voluntary incentives; and through mandatory requirements.

Local governments have frequently started by installing cool roofs in public buildings. Their efforts have included launching demonstration projects and adapting public building procurement practices to require cool roofs for new public buildings and roofing renovation projects. Beginning with the public sector allows a community to demonstrate the technology, make contractors aware of the products available, and promote the use of cool roof materials in other building sectors.

In many communities, voluntary cool roof incentives have been provided by local energy companies as part of their demand-side management programs. A few local government agencies also offer incentives to assist low-income or other households with installing cool roofs.

Some governments have mandated implementation of cool roofs in certain areas. These actions generally require adopting specific energy code provisions that require cool roofs or include cool roofs in the calculation of how much insulation is required to meet minimum energy efficiency requirements.

Mandatory requirements for cool roofs have played an increasingly significant role in implementation. Before 1995, the only regulations affecting cool roofing mandated that roof color not cause undue glare. The American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE) has since developed energy-efficient design standards that provide minimum requirements for both commercial and residential buildings. ANSI/ASHRAE/IESNA Standard 90.1-1999, *Energy Standards for Buildings Except Low-Rise Residential Buildings* and ANSI/ASHRAE Standard 90.2-2001, *Energy-Efficient Design of Low-Rise Residential Buildings* provide guidelines for new equipment, systems, and buildings. These standards were originally developed in response to the 1970s energy crisis and now serve as the generally accepted basis for many state building and energy codes. Both ASHRAE standards include credits pertaining to cool roofing. An example of a cool roofing credit is Addendum f to 90.2-2001, which allows the use of high-albedo roofs in hot and humid climates as part of the energy efficiency ceiling calculation for a residential building.<sup>33</sup>

A number of states and localities now have developed specific energy code requirements to encourage or require cool roofing. For example:

- In 1995, Georgia was the first state to add cool roofs to its energy code. The code allowed building owners to reduce roof insulation if they installed a cool roof that had a minimum solar reflectance of 75 percent and a minimum thermal emittance of 75 percent.<sup>34</sup> Note that if a building owner uses less insulation when installing a cool roof, he may not accrue net energy savings.
- Florida is using a similar approach to Georgia in its energy code.<sup>35</sup> Because of the energy efficiency gains from cool roofs, the Florida code allows commercial and multi-family residential buildings using a roof with at least 70 percent solar reflectance and 75 percent thermal emittance to reduce the amount of insulation required to meet building energy efficiency standards. The adjustment does not apply for roofs with ventilated attics or semi-heated spaces.
- In January 2003, Chicago amended its energy code requirements for low-sloped roofs.<sup>36</sup> This code applies to all buildings except separated buildings that have minimal peak rates of energy use and buildings that are neither heated nor cooled. Low-sloped roofs installed on or before December 31, 2008, must achieve a minimum solar reflectance (both initial and weathered) of 0.25 when tested in accordance with ASTM standards E 903 and E 1918 or by testing with a portable reflectometer at near ambient conditions. For low-sloped roofs installed after that date, roofing products must meet or exceed the minimum criteria to qualify for the ENERGY STAR Roof Products label.
- In 2001, in response to electrical power shortages, California updated its building energy code (Title 24), adding cool roofing as an energy efficiency option.<sup>37</sup> A cool roof is defined as having minimum solar reflectance of 70 percent and minimum thermal emittance of 75 percent, unless it is a concrete or clay tile, in which case it can have a minimum solar reflectance of 40 percent. This 40 percent rating incorporates new cool colored residential products. Owners must use specific methods to verify building energy use to account for cool roofing as an energy efficiency option. In this case, the heat



gain of the roof is reduced to account for use of a cool roof. In 2005, these cool roof provisions became mandatory for all new non-residential construction and re-roofing projects that involve more than 2,000 square feet (190 m<sup>2</sup>) or 50 percent replacement. The code also provides alternatives to the standard criteria as additional compliance options. In 2006, California began considering planned 2008 updates to Title 24 and is studying the possibility of extending cool roof requirements to the steep-sloped market.<sup>38</sup>

For further information on **California Title 24**, see <[www.energy.ca.gov/efficiency/blueprint/index.html](http://www.energy.ca.gov/efficiency/blueprint/index.html)>.

Table 6 lists many of the primary types of cool roof activities. The “Heat Island Reduction Activities” chapter provides more detailed examples.

## 6. Resources

### 6.1 Cool Roof Energy Savings Calculators

Federal agencies have developed two Web-based calculators that compare energy and cost savings from different cool roof technologies for various building types. Consumers also can find calculator tools on Web sites of cool roof product manufacturers. All of these tools use different assumptions and formulas and generate different results; therefore, they provide a range of potential impacts rather than precise statements of the savings any individual building owner will obtain.

Figure 15: Aerial View of Sacramento, California, with Capitol



California’s Title 24 has accelerated the diffusion of cool roofing across the state. The reflective roof of the capitol in Sacramento and other buildings around Capitol Park stand out among the vegetation, pavement, and darker roofs.

### **ENERGY STAR Roofing Comparison**

**Calculator.** The Web-based ENERGY STAR Roofing Comparison Calculator helps to estimate the energy and money that can be saved by using ENERGY STAR roofing products on air-conditioned buildings of at least 3,000 square feet (280 m<sup>2</sup>). This calculator estimates savings of typical building types with non-metallic-surfaced roofs under typical weather conditions.

This EPA calculator requires input on the age, type, and location of the building; the efficiency of the heating and cooling systems; the local cost of energy; and information about the roof area, insulation levels, and type of roofing systems used. Based on these factors, the tool provides an estimate of annual electricity savings in kWh and dollars per 1,000 square feet (93 m<sup>2</sup>). The annual effects of any heating penalties are included, given in therms and dollars per 1,000 square feet if natural gas is used to fuel the heating system, or subtracted from the annual electricity savings if an electric heat pump is used. This calculator does not model electric resistance heating systems.

Table 6: Examples of Cool Roof Initiatives

| Type of Initiative      | Description   | Links to Examples   |
|-------------------------|---|---|
| Research                | National laboratories   | < <a href="http://eetd.lbl.gov/HeatIsland">http://eetd.lbl.gov/HeatIsland</a> > - The Heat Island Group at Lawrence Berkeley National Laboratory provides research and information about cool roofing and other heat island mitigation measures. The Cool Roofing Materials Database lists the solar reflectance and thermal emittance of numerous roof products, including cool colored roofing. |
|                         |   | < <a href="http://www.ornl.org">www.ornl.org</a> > - ORNL conducts research on reflective roofing and solar radiation control. Its Web site includes fact sheets, a cool roof calculator, background information about cool roofing, and research publications.   |
| Voluntary efforts       | Demonstration programs  | < <a href="http://www.swenergy.org/casestudies/arizona/tucson_topsc.htm">www.swenergy.org/casestudies/arizona/tucson_topsc.htm</a> > - Tucson, Arizona, Cool Roof Demonstration Project (city office building).   |
|                         | Incentive programs  | < <a href="http://www.pge.com/res/rebates/cool_roof/index.html">www.pge.com/res/rebates/cool_roof/index.html</a> > - Pacific Gas & Electric's utility rebate program for cool roofs.  |
|                         |   | < <a href="http://www.sce.com/RebatesandSavings/Residential/_Heating+and+Cooling/CoolRoof/">www.sce.com/RebatesandSavings/Residential/_Heating+and+Cooling/CoolRoof/</a> > - Southern California Edison's Cool Roof Rebate Program.   |
|                         |   | < <a href="http://www.austinenergy.com/Energy%20Efficiency/Programs/Rebates/Commercial/Commercial%20Energy/buildingEnvelope.htm">www.austinenergy.com/Energy%20Efficiency/Programs/Rebates/Commercial/Commercial%20Energy/buildingEnvelope.htm</a> > - Austin Energy's Reflective Roof Coating and Roof and Ceiling Insulation rebate information.  |
|                         |   | < <a href="http://egov.cityofchicago.org/">http://egov.cityofchicago.org/</a> > - Chicago announced in Fall 2007 that it was expanding a green roof grant program to include cool roofs, with up to 55 \$6,000 grants targeted per year; see information under Department of Environment portion of the City's website.   |
|                         | Outreach & education  | < <a href="http://www.epa.gov/heatisland/">www.epa.gov/heatisland/</a> > - EPA's Heat Island Reduction Initiative provides information on the temperature, energy, and air quality impacts from green roofs and other heat island mitigation strategies.  |
| Weatherization programs | < <a href="http://www.ecasavesenergy.org/ses/whiteroof.html">www.ecasavesenergy.org/ses/whiteroof.html</a> > - Philadelphia cool roof incentive program for low-income housing. |   |
| Policy efforts          | State and municipal energy codes that require or provide recognition of cool roofs  | < <a href="http://www.energy.ca.gov/title24/index.html">www.energy.ca.gov/title24/index.html</a> > - California building energy code that requires cool roofs on nonresidential low-sloped roofs; applies to new and retrofit projects over certain size thresholds.  |
|                         |   | < <a href="http://rules.sos.state.ga.us/docs/110/11/1/03.pdf">http://rules.sos.state.ga.us/docs/110/11/1/03.pdf</a> > - Georgia Energy Code revision applicable to cool roofs.  |
|                         |   | < <a href="http://egov.cityofchicago.org/">http://egov.cityofchicago.org/</a> > - See Energy Code listings under Chicago Department of Construction and Permits under local government portion of the website.  |

Access these **calculators on the Web:**

ENERGY STAR Calculator:  
<[www.energystar.gov](http://www.energystar.gov)>,  
under “Roof Products.”

ORNL Calculator:  
<[www.ornl.gov/sci/roofs+walls/facts/CoolCalcEnergy.htm](http://www.ornl.gov/sci/roofs+walls/facts/CoolCalcEnergy.htm)>.

For information on an effort begun in 2007 to develop an integrated EPA/Department of Energy (DOE) calculator, see: <[www.govforums.org/e&w](http://www.govforums.org/e&w)>.

The roofing calculator is intended to estimate the savings that a reflective roof can offer to a typical building and to aid in the decision of whether to choose an ENERGY STAR-qualified roof product. It is only one of many tools that can be used in the decision making process. A more detailed building energy simulation would be needed to estimate savings for a particular building or calculate specific benefit-cost ratios for a project.

Note that the ENERGY STAR calculator estimates could underpredict the energy savings from a cool roof in some cases. This is because the equations used in the ENERGY STAR calculator were derived from multiple runs of a DOE building energy analysis model, which does not consider the effects of widely varying roof temperatures or duct location. These effects include changes in the thermal conductivity of the insulation, thermal radiation in the attic or plenum, and conduction gains to cooling ducts.

**ORNL Cool Roof Calculator.** This cool roof calculator is a Web-based tool that helps estimate the energy and financial impacts from installing cool roofs on buildings with low-sloped roofs that do not have ventilated attics or plenums.

To generate the equations used in this tool, researchers ran a computer model of a roof and ceiling assembly over a range of climates for roofs with varying levels of insulation, solar reflectance, and thermal emittance. This model was calibrated to emulate heat transfer measurements made on a special roof and ceiling test assembly at ORNL.<sup>39</sup>

This calculator requires input on building location (a choice of 235 different U.S. cities is provided); information about the insulation, solar reflectance, and thermal emittance of the proposed roof; and the cost of energy and efficiency of the heating and cooling systems. The tool provides the annual cost savings on a square-foot basis in comparison to a black roof, as well as annual heating energy savings or penalty, also in dollars per square foot.

## 6.2 Roofing Programs and Organizations

Table 7 lists a number of programs that actively promote cool roofs or that are currently involved in cool roof research.

Table 7: Cool Roof Programs and Organizations

| Program/Organization                            | Role  | Web Address  |
|---|---|--|
| Cool Metal Roofing Coalition                    | This industry group educates architects, building owners, specifiers, code and standards officials, and other stakeholders about the sustainable, energy-related impacts of cool metal roofing.   | < <a href="http://www.coolmetalroofing.org">www.coolmetalroofing.org</a> > |
| Cool Roof Rating Council (CRRC)                 | Created in 1998 as a nonprofit, educational organization, CRRC's members include manufacturers, utilities, researchers, and consultants. CRRC maintains a product rating program and associated product directory.  | < <a href="http://www.coolroofs.org">www.coolroofs.org</a> >               |
| ENERGY STAR                                     | ENERGY STAR is a joint EPA and DOE program that helps consumers save money and protect the environment through energy-efficient products and practices. Regarding cool roofs, the Web site provides information on qualified roofing products, industry partners, and case studies. | < <a href="http://www.energystar.gov">www.energystar.gov</a> >             |
| National Roofing Contractors Association (NRCA) | This trade association includes roofing, roof deck, and waterproofing contractors and industry-related associate members. It provides technical and safety information, news, and calendars of industry events.   | < <a href="http://www.nrca.net">www.nrca.net</a> >                         |
| Roof Consultants Institute (RCI)                | This international, nonprofit association includes professional roof consultants, architects, and engineers. It hosts trade conventions and develops standards for professional qualifications.   | < <a href="http://www.rci-online.org">www.rci-online.org</a> >             |
| Roof Coatings Manufacturers Association (RCMA)  | RCMA is a national trade association representing the manufacturers of cold-applied coatings and cements for roofing and waterproofing. It promotes the availability and adaptation of energy-efficient materials.  | < <a href="http://www.roofcoatings.org">www.roofcoatings.org</a> >         |
| Single Ply Roofing Industry (SPRI)              | SPRI is a trade organization representing sheet membrane and component suppliers to the commercial roofing industry. It provides information about and forums to discuss industry practices, workforce training, and other concerns.  | < <a href="http://www.spri.org">www.spri.org</a> >                         |

## Endnotes

- <sup>1</sup> Rose, L.S., H. Akbari, and H. Taha. 2003. Characterizing the Fabric of the Urban Environment: A Case Study of Greater Houston, Texas. Paper LBNL-51448. Lawrence Berkeley National Laboratory, Berkeley, CA.
- <sup>2</sup> These temperature ranges are compiled from the following individual reports:
  - Konopacki, S., L. Gartland, H. Akbari, and I. Rainer. 1998. Demonstration of Energy Savings of Cool Roofs. Paper LBNL-40673. Lawrence Berkeley National Laboratory, Berkeley, CA.
  - Gartland, L. n.d. Cool Roof Energy Savings Evaluation for City of Tucson.
  - Miller, W.A., A. Desjarlais, D.S. Parker, and S. Kriner. 2004. Cool Metal Roofing Tested for Energy Efficiency and Sustainability. CIB World Building Congress, May 1-7, 2004. Toronto, Ontario.
  - Konopacki, S. and H. Akbari. 2001. Measured Energy Savings and Demand Reduction from a Reflective Roof Membrane on a Large Retail Store in Austin. Paper LBNL-47149. Lawrence Berkeley National Laboratory, Berkeley, CA.
- <sup>3</sup> Ibid.
- <sup>4</sup> Konopacki, S., L. Gartland, H. Akbari, and I. Rainer. 1998. Demonstration of Energy Savings of Cool Roofs. Paper LBNL-40673. Lawrence Berkeley National Laboratory, Berkeley, CA.
- <sup>5</sup> Rosenzweig, C., W. Solecki, L. Parshall, S. Gaffin, B. Lynn, R. Goldberg, J. Cox, and S. Hodges. 2006. Mitigating New York City's Heat Island with Urban Forestry, Living Roofs, and Light Surfaces. Sixth Symposium on the Urban Environment and Forum on Managing our Physical and Natural Resources, American Meteorological Society. Atlanta, GA.
- <sup>6</sup> Chen, Allan. Cool Colors, Cool Roofs, part 2. Science Beat Berkeley Lab. 27 August 2004. Retrieved 14 April 2008 from <[http://www.lbl.gov/Science-Articles/Archive/sb/Aug-2004/3\\_cool-roofs-2.html](http://www.lbl.gov/Science-Articles/Archive/sb/Aug-2004/3_cool-roofs-2.html)>.
- <sup>7</sup> Pacific Gas and Electric Company. 2006. Inclusion of Solar Reflectance and Thermal Emittance Prescriptive Requirements for Residential Roofs in Title 24. Pacific Gas and Electric Company. Sacramento, CA.
- <sup>8</sup> Public Interest Energy Research Program. At Home with Cool-Colored Roofs. Technical Brief, CEC-500-2005-164-F111005. California Energy Commission. Sacramento, CA.
- <sup>9</sup> Haberl, J., and S. Cho. 2004. Literature Review of Uncertainty of Analysis Methods (Cool Roofs), Report to the Texas Commission on Environmental Quality. Energy Systems Laboratory, Texas A&M University, College Station, TX.
- <sup>10</sup> Konopacki, S., L. Gartland, H. Akbari, and L. Rainer. 1998. Demonstration of Energy Savings of Cool Roofs. Paper LBNL-40673. Lawrence Berkeley National Laboratory, Berkeley, CA.
- <sup>11</sup> Konopacki, S., H. Akbari, M. Pomerantz, S. Gabersek, and L. Gartland. 1997. Cooling Energy Savings Potential of Light-Colored Roofs for Residential and Commercial Buildings in 11 U.S. Metropolitan Areas. Paper LBNL-39433. Lawrence Berkeley National Laboratory, Berkeley, CA.
- <sup>12</sup> See the following reports for individual results:
  - H. Akbari, S. Bretz, J. Hanford, D. Kurn, B. Fishman, H. Taha, and W. Bos. 1993. Monitoring Peak Power and Cooling Energy Savings of Shade Trees and White Surfaces in the Sacramento Municipal Utility District (SMUD) Service Area: Data Analysis, Simulations, and Results. Paper LBNL-34411. Lawrence Berkeley National Laboratory, Berkeley, CA.
  - Callahan, M., D. Parker, J. Sherwin, and M. Anello. 2000. Demonstrated Energy Savings of

- Efficiency Improvements to a Portable Classroom. American Council for an Energy Efficient Economy. ACEEE Summer Study on Energy Efficiency in Buildings. Pacific Grove, CA.
- Konopacki, S. and H. Akbari. 2001. Measured Energy Savings and Demand Reduction from a Reflective Roof Membrane on a Large Retail Store in Austin. Paper LBNL-47149. Lawrence Berkeley National Laboratory, Berkeley, CA.
- Parker, D.S., J.B. Cummings, J.R. Sherwin, T.C. Stedman, and J.E.R. McIlvaine. 1994. Measured Residential Cooling Energy Savings from Reflective Roof Coatings in Florida. ASHRAE Transactions, Paper 3788. 100(2):36-49.
- Parker, D.S., J.R. Sherwin, J.K. Sonne, S.F. Barkaszi. 1996. Demonstration of Cooling Savings from Light Colored Roof Surfacing in Florida Commercial Buildings: Our Savior's School. Florida Solar Energy Center, Cocoa, FL.
- Parker, D., S.F. Barkaszi, and J.K. Sonne. 1994. Measured Cooling Energy Savings from Reflective Roof Coatings in Florida: Phase II Report. Florida Solar Energy Center, Cape Canaveral, FL.
- 13 Konopacki, S., H. Akbari, M. Pomerantz, S. Gabersek, and L. Gartland. 1997. Cooling Energy Savings Potential of Light-Colored Roofs for Residential and Commercial Buildings in 11 U.S. Metropolitan Areas. Paper LBNL-39433. Lawrence Berkeley National Laboratory, Berkeley, CA.
- 14 Konopacki, S., and H. Akbari 2002. Energy Savings for Heat Island Reduction Strategies in Chicago and Houston (Including Updates for Baton Rouge, Sacramento, and Salt Lake City). Paper LBNL-49638. Lawrence Berkeley National Laboratory, Berkeley, CA.
- 15 Gartland, L. 1998. Roof Coating Evaluation for the Home Base Store in Vacaville, California. PositivEnergy, 27. Oakland, CA.
- 16 Vincent, B., and J. Huang. 1996. Analysis of the Energy Performances of Cooling Retrofits in Sacramento Public Housing Using Monitored Data and Computer Simulations. Contract No. 500-93-053. Prepared for the California Energy Commission, Sacramento, CA.
- 17 Parker, D. 1997. Cool Roofs. FSEC-PF-323-97. Roofer Magazine. 17(7).
- 18 Konopacki, S., H. Akbari, M. Pomerantz, S. Gabersek, and L. Gartland. 1997. Cooling Energy Savings Potential of Light-Colored Roofs for Residential and Commercial Buildings in 11 U.S. Metropolitan Areas. Paper LBNL-39433. Lawrence Berkeley National Laboratory, Berkeley, CA.
- 19 See Energy Information Administration. 2003. Retrieved February 11, 2008, from <<http://www.eia.doe.gov/>>. Electricity prices are reported as cents per kilowatt-hour. Natural gas prices were converted from dollars per 1,000 cubic feet (28,300 liters) of gas to cents per thousand Btu (1.1 MJ) based on a conversion factor of 1,021 Btu/cubic foot of gas.
- 20 Blasnik, M. 2004. Impact Evaluation of the Energy Coordinating Agency of Philadelphia's Cool Homes Pilot Project. M. Blasnik & Associates, Boston, MA.
- 21 Levinson, R., H. Akbari, S. Konopacki, and S. Bretz. 2002. Inclusion of Cool Roofs in Nonresidential Title 24 Prescriptive Requirements. Paper LBNL-50451. Lawrence Berkeley National Laboratory, Berkeley, CA.
- 22 Mattison, K. 1998. Factors Affecting Roof System Costs. Perspectives. 34 (December). Retrieved 9 October 2007 from <[www.benchmark-inc.com/articles/Perspective%20Articles/issue34a.html](http://www.benchmark-inc.com/articles/Perspective%20Articles/issue34a.html)>.
- 23 Levinson, R., H. Akbari, S. Konopacki, and S. Bretz. 2002. Inclusion of Cool Roofs in Nonresidential Title 24 Prescriptive Requirements. Paper LBNL-50451. Lawrence Berkeley National Laboratory, Berkeley, CA.
- 24 Ibid.

- <sup>25</sup> Pacific Gas and Electric Company. 2006. Inclusion of Solar Reflectance and Thermal Emittance Prescriptive Requirements for Residential Roofs in Title 24. Draft Report, May 17, 2006. Sacramento, CA.
- <sup>26</sup> See the following study which includes an analysis of annual energy peak demand reductions, cooling equipment savings, and net present value savings from expanding California cool roof requirements to portions of the residential sector:
- Pacific Gas and Electric Company. 2006. Inclusion of Solar Reflectance and Thermal Emittance Prescriptive Requirements for Residential Roofs in Title 24. Draft Report, May 17, 2006. Sacramento, CA.
- <sup>27</sup> Bretz, S., and H. Akbari. 1997. Long-Term Performance of High-Albedo Roof Coatings. *Energy & Buildings*. 25(2):159-167.
- <sup>28</sup> Akbari, H., S. Konopacki, C. Eley, B. Wilcox, M. Van Geem and D. Parker. 1998. Calculations in Support of SSP90.1 for Reflective Roofs. Paper LBNL-40260. Lawrence Berkeley National Laboratory, Berkeley, CA.
- <sup>29</sup> Akbari, H., S. Konopacki, and D. Parker. 2000. Updates on Revision to ASHRAE Standard 90.2: Including Roof Reflectivity for Residential Buildings. American Council for an Energy Efficient Economy. ACEEE Summer Study on Energy Efficiency in Buildings. Pacific Grove, CA.
- <sup>30</sup> Konopacki, S., and H. Akbari. 1998. Trade-off between cool roofs and attic insulation in new single-family residential buildings. American Council for an Energy Efficient Economy. ACEEE Summer Study on Energy Efficiency in Buildings, Pacific Grove, CA.
- <sup>31</sup> California Energy Commission. 2006. 2005 Building Energy Efficiency Standards for Residential and Non-residential Buildings. Title 24, Publication No. CEC-400-2006-015.
- <sup>32</sup> Georgia Energy Code. 1995. Georgia Amendment to the 1995 CABO Model Energy Code for Section 704.
- <sup>33</sup> ASHRAE. 2003. ANSI/ASHRAE Addendum f to ANSI/ASHRAE Standard 90.2-2001, ASHRAE Standard: Energy-Efficient Design of Low-Rise Residential Buildings. ISSN 1041-2336. Atlanta, GA.
- <sup>34</sup> Georgia Energy Code. 1995. Georgia Amendment to the 1995 CABO Model Energy Code for Section 704.
- <sup>35</sup> Florida. 2004. Florida Building Code, Chapter 13: Efficiency. Retrieved 13 November 2007 from <[http://www2.iccsafe.org/states/2004\\_florida\\_codes/](http://www2.iccsafe.org/states/2004_florida_codes/)>.
- <sup>36</sup> Chicago, Illinois. 2003. Municipal Code, ch. 8-13.
- <sup>37</sup> California Energy Commission. 2006. 2005 Building Energy Efficiency Standards for Residential and Nonresidential Buildings. No. CEC-400-2006-015 (replaces P400-03-001F).
- <sup>38</sup> Pacific Gas and Electric Company. 2006. Inclusion of Solar Reflections and Thermal Emittance Prescriptive Requirements for Steep-Sloped Nonresidential Roofs in Title 24. Draft Report, May 18, 2006. Sacramento, CA.
- <sup>39</sup> Wilkes, K. 1991. Thermal Model of Attic Systems with Radiant Barriers. Oak Ridge National Laboratory, ORNL/CON-262. Oak Ridge, TN.