COOL ROOF

Design Brief

Pacific Gas and Electric Company®

Cool Roof Design Brief

Summary

On a sunny summer day, a typical roof surface can reach temperatures that are nearly 100°F *above* the ambient temperature [1]. A cool roof, by contrast, stays at or near the ambient temperature due to the characteristics of its outer layer. There are many benefits to keeping a roof's surface cooler, including air-conditioning energy and demand savings, monetary savings, increased human comfort both indoors and outdoors, and other positive impacts on urban environmental quality.

Although the actual benefits of a cool roof on a particular building will depend on many factors, including building type, load, season, and climate zone, cool roofs can significantly reduce summer electrical energy usage. In low-rise buildings, a typical application will achieve air-conditioning energy savings of approximately 10% to 20% [1]. The energy savings achieved through cool roofing translate into monetary gains for building and facility owners, as well as help reduce emissions of atmospheric pollutants and greenhouse gases.

Under the 2005 California Title 24 standards, cool roofs are assumed as a baseline in the model buildings that establish the required energy performance for non-residential buildings with low-slope roofs. However, installing cool roofs is not mandatory for new construction. Although not mandatory, cool roofing is often the least expensive option to achieve the required energy performance; consequently, cool roof technology is gaining more attention in the building industry. Owners, designers, contractors, and other stakeholders need to have a better understanding of how a cool roof can be successfully applied to new construction projects and re-roofing projects.

This design brief provides information about how a cool roof works. Focusing on commercial and industrial low-slope roof applications, the benefits of implementing a cool roof are also described. Design considerations are discussed, and the methods of applying cool roof technology to comply with California Title 24 building requirements are described. Finally, several examples of cool roof applications are provided.

Introduction

Commercial and industrial buildings in California account for over half of the total electricity use in the state [2]. Heating, ventilation, and air-conditioning systems not only comprise almost 30% of the electricity end-use in commercial buildings, but also become a significant source of electricity demand during peak periods [3]. Cool roofing can be a cost-effective way to save air-conditioning-related energy use and to reduce demand usage during peak-periods for those buildings.

How does cool roofing help? Reducing the amount of heat that flows through a building's roof and into the space below can reduce the building's air-conditioning load and thus reduce the building's energy cost. Additionally, when the cooling load is reduced, mechanical air-conditioning equipment can be downsized, which will help minimize up-front capital costs for building owners to purchase air-conditioning equipment.

Since the 1970s, California has established energy efficiency standards to reduce energy consumption in buildings. The 2005 energy standards, commonly referred to as Title 24, consider a cool roof to be the standard roof in California for new construction or retrofit of low-slope roofs on non-residential buildings. A series of energy efficiency incentive programs has been rolled out to encourage adoption of cool roofing technology. As a result, there is growing demand for cool roofing.

This design brief compiles information on state-of-the-art cool roofing technology that can be used by building owners, architects, energy consultants, and contractors to identify the potential benefits and suitability of installing a cool roof at a new facility or on a building undergoing major renovation. The focus of this design brief is commercial and industrial low-slope applications; however, much of the material in this brief can also be applied to residential and steep-slope applications.

What Is Cool Roofing?

Unlike conventional roofs, cool roofs stay at or near ambient temperatures even on the hottest summer day. Cool roofing is defined by the radiative properties known as solar reflectance and thermal emittance, shown schematically in Figure 1, and described in more detail below.

Roof Heat Transfer Mechanism

Several phenomena occur to the incident solar radiation upon striking a roof's surface, as shown in Figure 1. Much of the solar radiation is reflected back toward the sky, but some is absorbed by the roof as heat. A portion of the retained heat will be emitted back to the sky in the form of infrared (IR) radiation. Some heat is also carried away from the roof surface through convection. The remaining heat flows through the roof. The amount of heat that reaches the conditioned space below the roof will be determined by the insulative property of the roof material, and on the difference in temperatures on either side of the roof.

A cool roof has a higher solar reflectance and higher thermal emittance than a non-cool roof. High solar reflectance and high thermal emittance of a cool roof combine to keep the roof surface much cooler than a traditional roof, with peak temperature reductions of 30°F -60°F [1]. Achieving this type of drop in roof surface temperature will reduce the overall heat gain through the roof and reduce a building's annual cooling needs. Studies show cool roofs can typically reduce summer air-conditioning energy use by 10%-20% [1].

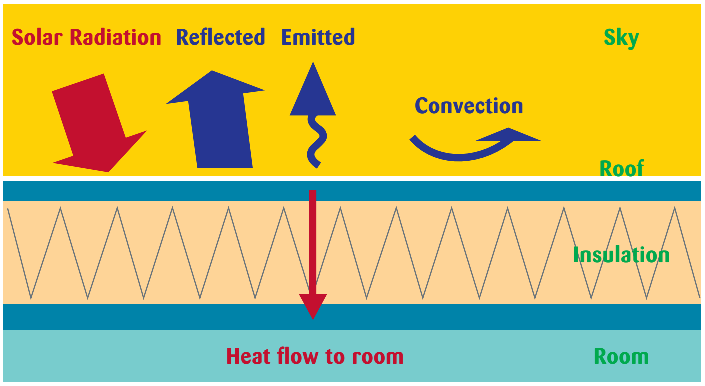

Figure 1: Heat Transfer through a Roof

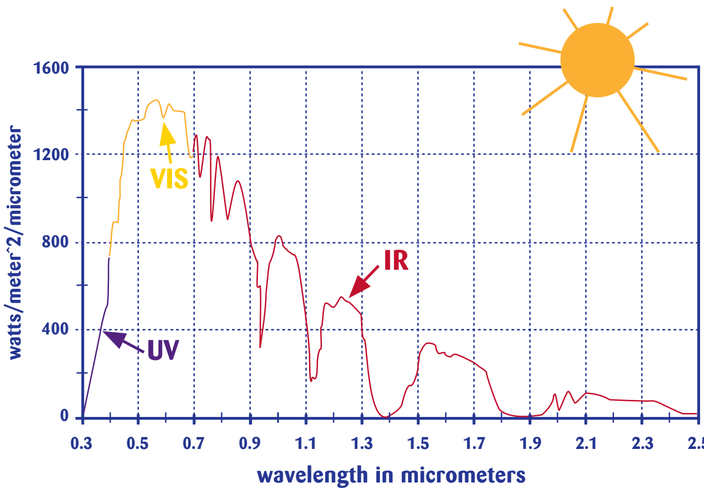

Figure 2: Solar Energy Distribution

Solar Reflectance

Solar reflectance, or *albedo*, is the fraction of the incident solar energy that is reflected by the surface material. Solar energy consists of a spectrum of wavelengths, including ultraviolet, visible, and infrared light. The solar energy distribution as a function of wavelength is shown below in Figure 2. Surface materials that reflect solar energy over all wavelengths (i.e., that have a higher solar reflectance of surface material), will have better performance in reducing roof solar heat gain.

Color is a good indicator of solar reflectance only in the visible light range, with reflectance typically increasing from a dark-colored to a light-colored surface. For example, traditional dark-colored roofing materials have a solar reflectance of about 0.04 to 0.18, whereas light-colored roof surfaces have a reflectivity of 0.70 or higher [4]. "Cool color" technologies can increase the solar reflectance of roofing materials in the infrared range through the application of a special coating. In this application, the roof has the same visual appearance, but is much cooler. Thus it is possible to have relatively dark-colored roofs with relatively "cool" properties. Figure 3 illustrates the influence of a roof coating on the solar reflectance [5]. In this example, the solar reflectance in the visible portion of the spectrum is the same for both products; however, the product employing "cool color" technology remains cooler by having much higher reflectance in the IR range.

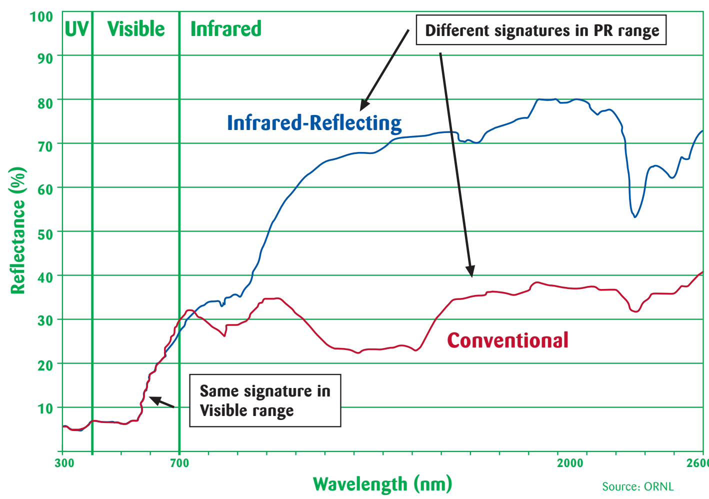

Figure 3: Solar Reflectance Effect of a Cool Colored Coating

Thermal Emittance

No roof is a perfect reflector, as all surfaces absorb some solar energy as heat. Part of the retained heat will be emitted back to the environment in the form of infrared radiation. Thermal emittance is a ratio between what a warm or hot surface emits and what a perfect blackbody emitter would emit at the same temperature. It has a value between 0 and 1, with a low emittance roof becoming relatively hotter than a high emittance roof since it is not as effective at getting rid of the retained heat.

The thermal emittance of most common roofing materials is approximately 0.80. Metallic surfaces are the exception, since bare metals become extremely hot in the sun. For example, in one outdoor experiment, a bare clean sheet of galvanized steel with a solar reflectance of about 0.38 reached temperatures nearly as high as a reference black surface [4]. Thermal emittances of metallic surfaces vary widely between 0.20 and 0.60, depending on surface conditions [4].

The reflectance and emittance of bare metals are very sensitive to the smoothness of the surface and the presence of surface oxides, oil, film, etc. Metal roofing is available with pigmented polymeric coatings, similar to paint, that are factory applied. These coatings are used to protect the metal panels, and sometimes also to provide a more appealing appearance; they can also keep the roof cooler. For example, metal roofing with cool white coatings (MBCI Siliconized Polyester White and Atlanta Metal Products Kynar Snow White) have emittances as high as 0.85 [4].

Table 1: Cool Roof Definitions

Code	Minimal Initial Values	
	Solar Reflectance	Thermal Emittance
Title 24	0.7	0.75
Energy Star	0.65	N/A

Note: A low-slope roof is defined as a surface with a pitch less than or equal to 2:12. Non-residential buildings include all non-residential occupancies, as well as high-rise residential, and all hotel and motel occupancies. They do not apply to CBC Group I buildings such as hospitals, daycare facilities, nursing homes, and prisons, or mobile structures. EPA's Energy Star program specifies a solar reflectance of 0.25 or higher for steep-slope roofs.

California Title 24

Title 24, the Energy Efficiency Standards for Residential and Nonresidential Buildings in California, was established in 1978 by the California Energy Commission in response to a legislative mandate to reduce California's energy consumption. The standards are updated periodically to allow consideration and possible incorporation of new energy efficiency technologies and methods. The latest standards became effective October 1, 2005. This is the first year in which Title 24 has addressed cool roofing with a prescriptive requirement. With experience, and the possible development of new materials or methods, it is likely that cool roof standards will be updated and also expanded to possibly include residential applications in 2008.

This document provides a non-inclusive description of the Title 24 Standards and its compliance approaches. Consult the more authoritative description at http://energy.ca.gov/title24 to ensure proper compliance.

Cool Roofing Standards

According to California Title 24, the Energy Efficiency Standards for Buildings in California, a qualifying low-slope cool roof for non-residential buildings must have an initial solar reflectance of 0.70 or greater and an initial thermal emittance of 0.75 or greater, as rated by the Cool Roof Rating Council (CRRC). Title 24 requirements are more stringent than EPA's Energy Star program, which specifies a solar reflectance of 0.65 or higher for low-slope applications, with no specifications of thermal emittance. The comparison of these two definitions is shown in Table 1.

Benefits of Cool Roofing

As outlined below, the installation of a cool roof can result in energy and demand savings, monetary savings, increased human comfort both indoors and outdoors, and significant positive impacts on urban environmental quality.

Energy and Demand Savings

Energy savings due to installation of cool roofs have been demonstrated and measured over a wide range of climates and roof types. Typical air-conditioning electrical savings have been in the range of 7% to 34% [5]. Cooling energy savings are greater in hot and sunny locations. A cooling energy demand reduction as high as 38% has been measured in a field test [5]. Demand savings are slightly higher. A reasonable energy savings expectation for a typical low-rise commercial building is 10% to 20% of the air-conditioning electricity usage [1].

Monetary Savings

Reduced energy usage from the installation of a cool roof naturally translates into monetary savings for building owners.[1] Further, maintaining a roof system can cost as much as 90% of the total envelope maintenance cost in spite of its relative low initial construction cost [6]. Applying a cool coating can reduce the peak temperature and daily temperature swing experienced by the roof membrane. Reduced thermal cycling enhances the durability of some materials, and may extend the life of the roof and produce less roofing waste. These effects reduce the life cycle cost of the roof. In addition, monetary savings can be achieved when installing or replacing air-conditioning equipment. Since less cooling is required with a cool roof, the air-conditioning equipment can often be downsized, resulting in lower procurement costs.

Increase in Human Comfort

Cool roofs reduce the heat transfer into a building. For buildings with no air-conditioning cooling, such as many warehouses, it can significantly increase building

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[1] Energy savings accrue even though cool roofs cause a slightly increased need for heating during the winter months. During winter or in a cold climate, use of a cool roof will increase heating energy use by up to 3% [1]. In heating-dominated climates, reflective roofing can create a very slight increase in heating demand. However, simulations show that air-conditioning savings easily outweigh the heating penalty, even in northerly climates. This is because in summer the solar altitude is high, and shines mainly on the roof of a building, whereas in winter the lower sun shines on the walls and through the windows. The roof plays less of a role in winter than, for example, having large south-facing windows.

occupants' comfort. Measurements in an unconditioned two-story Sacramento apartment building showed that adding a cool roof kept the second floor cooler by 4°F, and the first floor cooler by 2°F [5].

Cool roofing increases human comfort both indoors and outdoors. Cool roofs transfer less heat to the outdoor environment than do typical roofs. Reduced outdoor air temperatures increase general comfort for pedestrians and residences in summer.

Environmental Impacts

Installing cool roofs also has positive environmental impacts. At a community scale, increasing the solar reflectance of roofs can effectively and inexpensively mitigate an urban heat island [7]. An urbanized area can be about 2-9°F hotter than the surrounding rural area. Increasing the solar reflectance of roofs transfers less heat to the ambient environment than do non-cool roofs. The resulting lower outdoor air temperatures can slow urban smog formation. Simulations predict a reduction in ozone of 10-20% resulting from a 3-4°F cooling in ambient temperature [8]. Urban air temperature elevation also aggregates air-conditioning use by adding 5-10% of peak electric demand, at a direct cost of several billion dollars annually [7]. Widespread use of cool roofs could be a significant contributor to a reduction in urban ambient temperature. A 10-20% reduction in ozone would be comparable to that obtained by replacing all gasoline on-road motor vehicles with electric cars [9].

Electricity savings and peak demand reductions yielded by cool roofs can reduce power-plant emissions of NOx, carbon-dioxide and undesirable particulate matter, especially when peak demand reduction decreases the use of inefficient peak-power plants.

How to Achieve Title 24 Compliance

The 2005 Title 24 standards include prescriptive requirements for cool roofing for most low-slope roofing applications. Although a cool roof is not mandated under 2005 Title 24, a cool roof is assumed as a baseline in establishing the allowed energy budget for a building. In other words, the allowed energy budget for a building is based on that building having a cool roof. If a cool roof is not installed, the "lost" energy savings that will result must be saved by other means, such as installing additional insulation or more efficient mechanical equipment in order to comply. This concept of "making up" the "lost" energy savings is applied somewhat differently based upon the Title 24 compliance method chosen for the building.

Most building renovations, including re-roofing jobs, are also subject to Title 24 requirements. With some exceptions, the cool roof requirements must be met when half of the roof or 2,000 ft^2, whichever is less, is being re-roofed.

Compliance details and forms can be found in the Title 24 compliance manual at http://energy.ca.gov/title24. The manual provides two alternative approaches for complying with non-residential energy budgets: prescriptive and performance. Within the prescriptive approach, there are two compliance paths: the *envelope component* and the *overall envelope* approaches. The envelope component approach is the simpler method, but provides little flexibility. The overall envelope approach allows some limited trade-offs. The second main category, the performance approach, is more complicated, but offers the greatest degree of design flexibility. All methods are available for new construction or for re-roofing projects.

Prescriptive Approach: Envelope Component

Under the envelope component approach, each baseline component of the envelope assemblies (walls, roofs, floors, windows, skylights) must comply individually with its requirement. If one component of the envelope does not comply, then the entire envelope does not comply. So, for this "prescriptive checklist" Title 24 compliance method, a cool roof is required. The cool roof requirement does not overlap the insulation requirement of the roof. That is, the insulation requirements must be met separately.

This approach is the easiest way to comply with Title 24. It involves only completing a checklist and filling out two forms. This approach is generally the easiest and most expedient although it provides little flexibility.

The required compliance forms for this approach are ENV-1-C Certificate of Compliance; and ENV-2-C Envelope Component Method. A Cool Roof Rating Council (CRRC) label for the roof product must be submitted. If a cool roof is installed and roof insulation is involved, the insulation level must be brought up to existing code.

Prescriptive Approach: Overall Envelope

The overall envelope approach allows the performance of some building envelope components to be increased while the performance of others is reduced, as long as overall heat gain and loss are no greater than a building in minimum compliance with the prescriptive requirements. The calculations of overall heat gain and loss of the proposed building must be considered. The formula for calculating overall heat loss and gain for a standard building and for the proposed building are provided in Equations 143-B, C, D, E of the Standards.

If the new roof is not a qualified cool roof, and improvements are made to the other building envelope components to compensate, this compliance approach must be used. The required forms are ENV-1-C Certificate of Compliance and ENV-3-C Overall Envelope Method. In the case that a non-qualifying cool roof is installed, envelope insulation must be upgraded to compensate. More about the trade-off between a cool roof and the envelope will be discussed in the design consideration section.

Performance Approach

The performance approach is the most complicated method of complying with Title 24, yet it permits the most trade-offs among all envelope components, as well as trade-offs between the building envelope and mechanical and lighting systems. With this approach, building and HVAC systems working together meet or are better than the baseline building's total energy budget. The performance approach requires use of an approved computer software program that models the proposed building, determines its allowed energy budget, calculates its energy use, and determines whether it complies with the budget.

Some new construction projects take advantage of roof space for other uses, such as garden roofs, decks, patios, and photovoltaic (PV) panels. For these applications, the performance approach should be used. Cool roof regulations apply to PV systems that are embedded or integrated into the roof, as well as designs in which PV panels are mounted on racks above the roof surface. Note that the electricity produced by PV solar electric systems cannot be used as a trade-off in meeting a building's energy budget.

For complicated new construction projects, the performance approach is often chosen. An energy simulation specialist is generally required to correctly model the building with the computer software.

How to Estimate Energy Savings

There are three simple calculators available to estimate the energy savings for a typical building. The estimates provided by these calculators do not, however, apply to Title 24 compliance.

- The U.S. Department of Energy (DOE) web calculator (http://www.ornl.gov/sci/roofs+walls/facts/CoolCalcPeak.htm) provides an estimation of annual electricity savings and demand reduction. It has limited insulation and location choices.
- The U.S. Environmental Protection Agency (EPA) Energy Star Roof Calculator (available at http://roofcalc.cadmus-dev.com) provides only annual electricity savings, but it applies to any location in the U.S.
- The Standard Performance Contract (SPC) Application Software (http://www.pge.com/spc) is similar to EPA's Calculator, but it is specialized for calculating the incentives for installing a cool roof under PG&E's or SCE's SPC program.

All three calculators are simple to use, but all tend to underestimate the savings. When the cost-benefit ratio in a particular project is a concern, a detailed building energy simulation should be used. These energy simulation software programs are available at: http://www.eere.energy.gov/buildings/tools_directory/.

How to Get LEED Credits

Leadership in Energy and Environmental Design (LEED) is a voluntary program formed by the U.S. Green Building Council to help professionals across the country improve the quality of buildings and their impact on the environment. Participation is highly encouraged by a growing list of city, state, and federal agencies. Credits toward LEED certification are available for installing cool roofs in new construction and major retrofits. The LEED program periodically updates and revises their standards, and the program should be consulted to ensure that the most up-to-date values are used. There are distinct LEED standards for new construction and for existing buildings, as explained below.

LEED-EB

For an existing building, a cool roof in the LEED system is defined with the Solar Reflectance Index (SRI) value of the roof material. The SRI is required to be equal to or greater than 78 for low-slope roofs and 29 for steep-slope roofs. It is defined so that a standard black (reflectance 0.05, emittance 0.90) is 0 and a standard white (reflectance 0.80, emittance 0.90) is 100. Both the reflectance and emittance value are necessary to calculate SRI for a material. SRI is calculated according to ASTM[2] -specified methods.

LEED-NC

For new construction under LEED-NC 2.2, in the sustainable sites area, installation of cool roofing on over 75% of the roof will result in 1 point; in the materials and resources area, maintaining 75% of

[2] American Society for Testing and Materials

the building shell will result in 1 point; maintaining 100% of the building shell will result in more than 1 point. Details of the LEED crediting system are available on the USGBC's website at http://www.usgbc.com. A LEED-accredited professional should be consulted in order to receive project certification.

Design Considerations

To achieve compliance with the Title 24 Standards, the solar reflectance and emittance of the roof product must have been tested and listed with the Cool Roof Rating Council (CRRC) http://coolroofs.org. CRRC is an advisory entity formed in 1998 responsible for establishing and maintaining a rating system for cool roof products. The initial values of solar reflectance and thermal emittance of roofing materials are tested by CRRC-designated agencies using ASTM procedures. CRRC has listed over 600 rated roofing products as of early 2006.

Low-Slope Roof Options

Traditional low-slope roofs commonly use Built-Up Roofing (BUR), Single-Ply Membrane, or Modified Bitumen Roofing. Each of these roofing options is described below in more detail.

- **BUR** is the least expensive roofing material in the California market. BUR roofs mostly appear light gray or tan and have a solar reflectance of 0.15-0.25. They are usually applied hot and topped with aggregate rocks or capsheets.
- **Single-Ply Membranes** are 35- to 60-mil membranes made of various materials, including EPDM, CSPE, PVC, and TPO. A number of bright white Single-Plys are in the market which meet the Title 24 definition for cool roofs (CRRC reflectance ≥ 0.7, emittance ≥ 0.75); but traditional black, gray, and tan membranes are generally not cool with lower reflectance values. To secure the membranes to the substrate, adhesive, mechanically fastened, or ballasted methods are used. Seams must be sealed with thermoset or thermoplastic, adhesive bond, heat-welded, or taped.
- **Modified Bitumen Roofing** is similar to both BUR and Single-Ply membrane. Materials are either plastic or rubber. The colors are black or gray with a solar reflectance of only about 0.05 to 0.2. Modified Bitumen Roofing consists of composite sheets of asphalt bitumen modified with polymers. They are installed in single or multiple layers, and the layers are adhered with hot asphalt, torching down, or cold adhesive.

Hundreds of cool roof products are available for low-slope applications. They generally have a solar reflectance over 0.70 and a thermal emittance over 0.80. There are two types of cool roofs: *single-ply membrane* with bright white color (as shown in Figure 4), or *coatings* applied to the traditional roof membranes or a mineral cap sheet. Installations are generally roll-over or spray, as shown in Figure 5.

Figure 4: Single-Ply Membrane Cool Roof

Figure 5: Typical Cool Roof Spray Installation

Cool Single-Ply Roofing. Cool single-ply roofing has high solar reflectance integrated in its material. These products are best used for new construction projects or existing roofs that are beyond repair.

- ***Poly Vinyl Chloride (PVC).*** The most commonly used cool single-ply is PVC, which has seams that are typically heat-welded to give a very secure seal. PVCs have good flame resistance, but if burned they tend to smoke with extremely toxic hydrogen chloride gas. Plasticizers are added for flexibility; when they are leached out over the years, the roof material becomes brittle and discolored.
- ***Thermoplastic Poly Olefin (TPO).*** Another thermoplastic type of cool single-ply roofing material is Thermoplastic Poly Olefin (TPO). No plasticizer is used in the material and they tend to be more dirt resistant than PVC. TPOs are rapidly gaining market share. But no ASTM standard exists yet to gauge quality, and heat welding is tricky, as the material can overheat. For fire resistance, some additives must be added and their usage has brought up many environmental concerns.
- ***White Ethylene Propylene Diene Monomer (EPDM).*** EPDM is a thermoset type of cool single-ply roofing material. It consists of two layers with a black base and a white top. EPDM is the least expensive among all cool single-ply roofing materials, but it is less durable due to its lack of UV protection and is not very commonly used.
- ***Chloro Sulfonated Poly Ethylene (CSPE).*** CSPE is the most expensive cool single-ply roofing material. It provides good weather resistance, fire resistance, and durability. The material is thermoplastic when installed, so heat welds are applied to the seams; the roofing cures to thermoset within days.

Cool Roof Coatings. Cool roof coatings are commonly used in re-roofing projects. They apply mostly bright white paint-like materials to traditional roofs or metallic surfaces. The coating extends the life of the underlying roof materials and greatly increases the solar reflectance. Cementitious coatings use cement or ceramic particles to enhance solar reflectance. They can be sprayed, rolled, or brushed on the rooftop. Properly selected and installed, they perform well; however, they can be brittle and crack, flake, or peel from surfaces over time. An example is shown in Figure 6.

Thermoplastic coatings are new to the California market. They have very good UV resistance, a hard surface, and are dirt resistant. The clear coat finish increases durability and extends the life of the coating. These products have been used in New Zealand and Australia for over 25 years. An example is shown in Figure 7. Elastomeric coatings are also available, with various polymers used for different types of substrates.

Figure 6: Cementitious Coating Cool Roof

Figure 7: Thermoplastic Coating Cool Roof

Costs

The cost of cool single-ply roofing is between $1.50 and $3.00/ft^2. The cost of cool coatings is between $0.75 and $1.50/ft^2. These costs include materials, installation, and basic preparation [5]. The incremental cost of adding a cool roof coating to a traditional roof is less than $0.20/ft^2. Table 2 compares cool roofing costs to traditional roofing [8].

Table 2: Traditional and Cool Roof Options for Low-Slope Roofs

Traditional Roof				Cool Roof			
Type	Reflectance	Emittance	Cost ($/ft2)	Type	Reflectance	Emittance	Cost ($/ft2)
BUR			1.2 - 2.1	BUR			1.2 - 2.15
w/ dark gravel	0.08 - 0.15	0.80 - 0.90		w/ white gravel	0.30 - 0.50	0.80 - 0.90	
w/ smooth asphalt,	0.04 - 0.05	0.85 - 0.95		w/ gravel and cementi-	0.50 - 0.70	0.80 - 0.90	
surface	0.25 - 0.60	0.20 - 0.50		tious	0.75 - 0.85	0.85 - 0.95	
Single-Ply			1.0 - 2.0	Single-Ply			1.0 - 2.05
black (EPDM, CPE, CSPE,				white (EPDM, CPE,			
PVC	0.04 - 0.05	0.85 - 0.95		CSPE, PVC	0.70 - 0.78	0.85 - 0.95	
gray EPDM	0.15 - 0.20	0.85 - 0.95					
Modified Bitumen			1.5 - 1.9	Modified Bitumen			1.5 - 1.95
w/ mineral surface				white coating over a			
capsheet (SBS, APP)	0.10 - 0.20	0.85 - 0.95		mineral surface	0.60 - 0.75	0.85 - 0.95	

Steep-Slope Roof Options

Given that low-rise residential buildings account for more than sixty percent of the roof area in California [10], and that steep-slope roofs may be included in the 2008 Title 24 update, consideration of the electricity usage of the residential sector becomes increasingly important. Steep-slope cool roof considerations will thus be briefly discussed here.

Traditional steep-slope roofing prevalently uses asphalt shingles, followed by metal roofs, concrete tiles, clay tiles, slate, and wood. These roofs mostly appear in dark colors. Most of today's cool roofs have a light-colored surface that commercial facilities with flat or low-slope roofs find acceptable. Homeowners, however, have not adopted the cool-roof approach because they typically prefer the aesthetics of darker colors for their steep-slope roofs. Solar reflectance of traditional steep-slope roof materials ranges from 0.05 – 0.3 [11].

Relatively few products on the market qualify as a cool steep-slope roofing materials at this point. However, some manufacturers have developed dark-colored pigments for roofing materials that reflect sunlight instead of absorbing it. These pigments are now being used in coatings for metal roofs, in clay and concrete tiles, and in the multi-colored granules of which shingles are comprised. The tiles with coatings made from cool-colored pigments look similar to conventional tiles, but they offer improved solar reflectance values. The steep-slope non-white roof can have a solar reflectance around 40% or 50%, but that is not sufficient to qualify it as a cool roof under the 2005 Title 24 standards [11]. The overall envelope approach or the performance approach can be used to allow this kind of roof to be used to achieve Title 24 compliance. In future updates of Title 24, a separate definition of "cool roof" applicable to steep slope buildings—a definition with a much lower reflectance requirement—could be considered.

Long-Term Performance

Cool roofs, like traditional ones, will suffer weathering and wear. Over time, the solar reflectance will gradually degrade. Various studies show that a cool roof can lose up to 30% of its reflectance over a period of two years, although considerably less degradation is typical for most materials [10]. The consensus view based on a number of research findings is that the largest portion of the reflectance loss happens relatively quickly, such that most of the ultimate long-term loss occurs within the first year or two.

Generally, the main factors which contribute to the degradation are dirt pick-up and biological growth (including mildew and algae). Contributing factors include material properties such as surface smoothness and the degree to which the material itself is a suitable substrate for biological growth. It is worth noting that physical deterioration of the roofing material is generally *not* a leading contributor to the loss of radiative performance.Various macro- and micro-climatic conditions related to the presence of ambient particulate (such as dust and pollutants), humidity, rainfall, and temperature have a significant impact on long-term performance. Generally, manufacturers and roofing consultants have the ability to select materials and product formulations based upon known local conditions.

At present, Title 24 requires *initial* minimum values (only) for solar reflectance and thermal emittance. In the cool roof rulemaking, a degradation allowance for performance was included: that is, in determining cost-effectiveness, the CEC assumed a long-term solar reflectance value of 0.55, rather than a nominal value of 0.70, in calculating energy savings over the life of the product. For minimally-compliant materials rated at 0.70, this reduction is about 21%; for materials initially rated at 0.80, this reduction amounts to about 31% degradation. This approach is expected to be conservative based upon extant research. Once three-year values become available based on the CRRC rating program, the CRRC database will include both initial and three year values for solar reflectance and thermal emittance.

Washing a cool roof can effectively restore its performance, but the cost of washing could be higher than the value of the energy savings. "Self-cleaning" roofing products show promise for maintenance of surfaces.

Cool Roofing Examples

Listed below are cool roof project summaries that can be utilized by building owners, architects, energy consultants, and contractors as examples of successful new construction and re-roofing applications.

Figure 8: Kaiser Medical Building, Davis, CA

Example 1: Re-roof (Coating) Application

Location: Davis, California

Floor Area: 31,000 ft^2, one story

Application: Medical office building

Owner: Kaiser Permanente

Heating/cooling System Type: AC

Existing Roof Type: light gray capsheet (reflectance 24%)

Roof Insulation: R8

Cool Roof Type: white reflective paint coating (reflectance 60%)

Capital Cost: $0.20/$ft^2$ or less

Indoor Temperature: 75°F

Electricity Savings: monitored 1094 kWh/day to 915 kWh/day

Normalized energy savings: 198 kWh/day, 18% savings

Simple payback: 31000*$0.20/(198*260*0.1)=1.2 years. Such fast payback is not typical for cool roof projects, however.

Source: LBNL Heat Island demonstration project, 1996-1997

***Figure 9: Cool Roof Application with Rooftop Garden and Solar Panels** (Note: the roof surfaces containing the rooftop garden and the solar panels do not constitute part of the cool roof)*

Example 2: New Construction Application

Location: Rockford, Minneapolis

Floor Area: 50,000 ft^2

Application: Combined commercial office, manufacturing plant, and test facility

Owner: TTJK, LLC

Roof Contractor: Elastomeric Roofing Systems, Inc.

Garden Roof: 5,000 ft^2 prairie garden roof (exclusive of the cool roof area)

Cool Roof Type: 40,000 ft^2 white reflective coating (reflectance 85%)

Solar Array: 5 kW net-metered photovoltaic array on roof top generates about 5800 kWh/yr

Electricity Savings: 15% due to high-reflective roof

Cost: $\$50/ft^2$ (total new construction)

Source: *EDC Magazine*, April 2005

For More Information

- Cool Roof Rating Council (CRRC): www.coolroofs.org
- CRRC-Rated Product Directory: www.coolroofs.org/ratedproducsdirectory.html
- Title 24: www.energy.ca.gov/title24
- Lawrence Berkeley National Laboratory, Heat Island Research Group, http://eetd.lbl.gov/HeatIsland/PROJECTS/
- Oakridge National Laboratory, Building Technology Center, Building Envelopes Program, http://www.ornl.gov/sci/roofs+walls/
- Environmental Design + Construction, http://www.edcmag.com/CDA/Articles/Cool_Roof
- Cool Roof Workshop at Pacific Energy Center, 2005. Dr. Lisa Gartland, http://207.67.203.54/p40007staff/opac/index.asp
- U.S. Green Building Council LEED credits: http://www.usgbc.com
- EERE energy simulation programs: http://www.eere.energy.gov/buildings/tools_directory/.

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10. High Albedo (Cool) Roofs, Codes and Standards Enhancement (CASE) Study, Pacific Gas and Electric Company, November 17, 2000.
11. Cool Roofs and Title 24: Now and 2008, Peter Turnbull, Cool Roof Rating Council Presentation for CSI.