Codes and Standards
Title 24 Energy-Efficient Local Ordinances

Climate Zone 9
Energy Cost-Effectiveness Study for Cool Roofs

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Executive Summary

Public Resources Code Section 25402.1(h)2 and Section 10-106 of the Building Energy Efficiency Standards (Standards) establish a process which allows local adoption of energy standards that are more stringent than the statewide Standards. This process allows local governments to adopt and enforce energy standards before the statewide Standards effective date, require additional energy conservation measures, and/or set more stringent energy budgets. Because these energy standards "reach" beyond the minimum requirements of Title 24, Part 6 of the California Building Code, they are commonly referred to as Reach Codes when adopted as a collective set by a local jurisdiction.

The process for adopting a Reach Code requires that local governments apply to the California Energy Commission (CEC) for approval. The applicant jurisdiction must document the supporting analysis for determining that the proposed Reach Code Standards will save more energy than the current statewide Standards. The applicant jurisdiction must also prepare a Cost Effectiveness Study that provides the basis of the local government's determination that the proposed Reach Code Standards are cost-effective. Once the CEC staff has verified that the local Reach Code Standards will require buildings to use no more energy than the current statewide Standards and that the documentation requirements in Section 10-106 are met, the application is brought before the full California Energy Commission for approval.

This Cost Effectiveness Study provides information on product cost, energy savings, cost-effectiveness and greenhouse gas reductions (GHG) to support mandatory reach code requirements for residential and nonresidential Cool Roofs for Climate Zone 9. Climate Zone 9 encompasses all or a portion of 82 jurisdictions, including at least a portion of Santa Clarita, Ventura, Thousand Oaks, Los Angeles, and Pomona counties (see the Appendix for a map and list of jurisdictions). The 2008 Building Energy Efficiency Standards, effective January 1, 2010, have been used as the baseline used in calculating the energy performance of efficiency measures summarized in this study.

Summary of Findings

- The number of products available to meet the 2013 Title 24 Prescriptive reflectance requirements has increased, including products that meet Reach Code Tier 1 and Tier 2 levels of stringency.
- Interviews in March 2014 with several roofers and roof supply distributors in the Los Angeles area found that roofers are currently able to meet the Tier 1 and Tier 2 requirements at little or no additional cost, depending on the product selected.
- Multiple roofers made the statement that there is no additional labor to install cool roof products.
- In some instances, there is even cost savings associated with choosing a low-slope cool roof meeting the Prescriptive or Tier 1 levels of reflectance.
- The energy savings associated with cool roofs have a linear relationship with the roof reflectance. Higher roof reflectance correlates with greater energy savings in Climate Zone 9.
- The use of cool roofs as an Urban Heat Island mitigation strategy brings many benefits, including reduced energy use, reduced air pollution and greenhouse gas emissions, and improved human health and comfort.

Methodology and Assumptions

This document builds upon the 2013 Codes and Standards Enhancement (CASE) reports for cool roof requirements in the Title 24 Building Energy Efficiency Standards (AEC 2011, IOU 2011) to support the reach code requirements for residential and nonresidential Cool Roofs in California Building Climate Zone 9. Please refer to the Energy Commission's website[1] for the full residential and nonresidential Cool Roof CASE reports and all supporting documentation.

The CASE reports proved the cost-effectiveness of aged solar reflectances of 0.67 and 0.24 for low-sloped and steep-sloped roofs, respectively. The stringency of the requirements that were ultimately adopted by the California Energy Commission were relaxed to account for the limited number of available products meeting the proposed requirements. The prescriptive requirements ultimately adopted into the 2013 Title 24 Building Energy Efficiency Standards (Title 24, Part 6) are detailed below in Table 1.

Table 1: Prescriptive 2013 Title 24 Cool Roof Requirements

2013 Title 24 Part 6, Prescriptive Nonresidential Sect.140.3(a)(1)(A)(i)				
Roof Slope	Climate Zone	Minimum 3-year Aged Solar Reflectance	Thermal Emittance	Minimum SRI
≤ 2 : 12	1-16	0.63	0.75	75
> 2 : 12	1-16	0.20	0.75	16

2013 Title 24 Part 6, Prescriptive High-Rise Residential, Hotel, Motel Sect.140.3(a)(1)(A)(ii)				
Roof Slope	Climate Zone	Minimum 3-year Aged Solar Reflectance	Thermal Emittance	Minimum SRI
≤ 2 : 12	9-11, 13-15	0.55	0.75	64
> 2 : 12	2-15	0.20	0.75	16

2013 Title 24 Part 6, Prescriptive Residential Sect.150.1(c)(11)				
Roof Slope	Climate Zone	Minimum 3-year Aged Solar Reflectance	Thermal Emittance	Minimum SRI
≤ 2 : 12	13-15	0.63	0.75	75
> 2 : 12	10-15	0.20	0.75	16

Please note that voluntary Cool Roof Tier 1 and 2 requirements are incorporated in the 2013 Title 24 CALGreen (Title 24, Part 11) that conflict with Energy Code Title 24 Part 6 prescriptive requirements. This discrepancy is discussed in greater detail in the Appendix (Page 20). According to Chapter 1, Section 101.6.3 of Title 24 Part 11[2]: "When the requirements of CALGreen conflict with the requirements of any other part of the *California Building Standards Code*, Title 24, the most

[1] http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/current/Reports/

[2] http://www.ecodes.biz/ecodes_support/free_resources/2013California/13Green/PDFs/Chapter%201%20-%20Administration.pdf

restrictive requirement shall prevail." The 2013 Title 24, Part 6 and Part 11 Cool Roof requirements collectively are less stringent than the proposed Reach Code Cool Roof requirements that are the subject of this Cost Effectiveness Study. The proposed Reach Code Cool Roof requirements are presented below in Table 2.

Table 2: Proposed Cool Roof Reach Code Requirements

Mandatory Residential Reach Code			
Climate Zone	**Roof Slope**	**Minimum 3-year Aged Solar Reflectance**	**Thermal Emittance**
9	≤ 2 : 12	0.63	0.75
9	> 2 : 12	0.20	0.75
TIER 1 – Residential and Nonresidential Reach Code			
Climate Zone	**Roof Slope**	**Minimum 3-year Aged Solar Reflectance**	**Thermal Emittance**
9	≤ 2 : 12	0.68	0.85
9	> 2 : 12	0.28	0.85
TIER 2 – Residential and Nonresidential Reach Code			
Climate Zone	**Roof Slope**	**Minimum 3-year Aged Solar Reflectance**	**Thermal Emittance**
9	≤ 2 : 12	0.70	0.85
9	> 2 : 12	0.34	0.85

Energy Savings

Estimates of energy savings from cool roofs rely on the impact analysis conducted by the Architectural Energy Corporation on behalf of the California Energy Commission for the 2013 Building Energy Efficiency Standards (CEC 2013) and CASE reports developed by Architectural Energy Corporation on behalf of the California Statewide Codes and Standards Team (AEC 2011, IOU 2011).

Obtainment of Energy Savings

According to the 2013 Case Report for Nonresidential Cool Roofs:

> *Cool roofs reduce cooling energy consumption by reflecting a greater portion of the infrared radiation that strikes the surface of the roof. They are more beneficial for low-sloped roofs, and their benefits decrease in proportion with the amount of roof insulation present. Since less solar radiation is absorbed by the roof, cool roofs do carry a small heating penalty in the winter months; however, for commercial buildings in all California climates the cooling benefits far outweigh the heating penalties.*
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> *Briefly, the prototype building is a 130' X 130', single-floor energy model, with Title 24-2008 minimally compliant walls, roof insulation, and HVAC. Internal loads and schedules were taken from the Title 24-2008 ACM for nonresidential and high-rise residential occupancies. Energy use was modeled with*

roofing reflectance levels ranging from 0.08 to 0.87, including models at 0.55 and 0.67. All models used an emittance of 0.85, in accordance with the default assumptions of the NACM. The model used weather and TDV files updated for the 2013 code change cycle.

For the 2013 Residential Roof Measures CASE report (IOU 2011) a steep-sloped cool roof with an aged reflectance of 0.24 was analyzed as a standalone measure, relative to the base case value of 0.08 for asphalt shingle and 0.15 for tile. Simulations were run for a variety of (aged) roof reflectance values, for both asphalt and tile roofs. Higher reflectance shingle roofs were not considered due to the temporary lack of products with much higher reflectance values. For asphalt shingle, cost effectiveness calculations were run assuming a maximum solar reflectance of 0.24.

The results below show the present value of energy savings in dollars per square foot (1 square of roofing product is 100 ft²), the incremental cost in dollars per square, and the net present value. The measure is cost effective if its life-cycle cost relative to the base case is less than $0. An asphalt shingle roof with an aged reflectance of 0.24 was found to be cost effective in all California climate zones except CZ 1, 2, 3 and 5.

Table 3. Life Cycle Cost Analysis, High Reflectance (0.24) Asphalt Shingle Roof

Climate Zone	kTDV/ft² roof	PV $/ft² roof	Cost $/ft² roof	Change in LCC $/ft²
9	**5.06**	**0.88**	**0.32**	**($0.56)**

For tile roofs, a solar reflectance of 0.40 was found to be cost effective in all climates except CZ 1 (Arcata, North Coast) and CZ 5 (Santa Maria, Central Coast), due to the lack of a cooling load in those climates.

Table 4. Energy Simulation Results for High Reflectance Tile Roof

	kTDV/ft2-yr				
Climate Zone	Refl=0.15	Refl = 0.24	Refl = 0.40	kTDV/ft²-yr Savings 0.15 to 0.24	kTDV/ft² *roof* Savings
9	**74.73**	**73.67**	**71.65**	**1.06**	**1.974**

The life-cycle cost analysis for a tile roof with an aged solar reflectance of 0.24 compared to the base case of a tile roof with reflectance of 0.15 is shown in Table 5.

Table 5. Life Cycle Cost Analysis for Medium Reflectance (0.24) Tile Roof

Climate Zone	Savings, kTDV/ft² roof	PV $ft² roof	Cost/ft² roof	Change in LCC, $ft²
9	**1.974**	**$0.34**	**$0.02**	**($0.32)**

For a higher reflectance tile roof, the energy savings and the change in life-cycle costs are shown below. The energy savings are much higher than for the medium reflectance (0.24) tile roof. Incremental costs are assumed to be at the high end of surveyed data, $0.06/ft² ($6.00 per square).

The high reflectance tile roof is cost effective in all climate zones except 1 and 5, which have no cooling load.

Table 6. Life Cycle Cost Analysis for High Reflectance (0.40) Tile Roof

Climate Zone	Savings kTDV/ft² (0.15 to 0.40)	PV $/ft²	Cost $/ft²	Change in LCC, $/ft²
9	**3.08**	**0.99**	**0.06**	**(0.93)**

Cost Analysis

The 2013 CASE reports (AEC 2011, IOU 2011) proved that aged solar reflectances of 0.67 and 0.24 for low-sloped and steep-sloped roofs, respectively, are cost effective. The stringency of the requirements ultimately adopted were relaxed to account for the limited number of products available to meet the proposed requirements.

Since that time, the number of products available to meet the 2013 Tile 24 Prescriptive reflectance requirements has increased, including products that meet the Reach Code Tier 1 and Tier 2 levels of stringency. Interviews in March 2014 with several roofers and roof supply distributors in the Los Angeles area found that roofers are currently able to meet the Tier 1 and Tier 2 requirements at little or no additional cost, depending on the product selected. In some instances, there is even cost savings associated with choosing a low-slope cool roof meeting the Prescriptive or Tier 1 levels of reflectance. Multiple roofers made the statement that there is no additional labor to install cool roof products.

The EPA document "Reducing Urban Heat Islands: Compendium of Strategies" (EPA 2011) provides Table 7 below, which depicts typical cost implications for standard and cool roof options.

Table 7: Comparison of Traditional and Cool Roof Options (EPA 2011)

Warmer Roof Options				Cooler Roof Options			
Roof Type	Reflectance	Emittance	Cost ($/ft²)	Roof Type	Reflectance	Emittance	Cost ($/ft²)
Built-up Roof			**1.20- 2.10**	**Built-up Roof**			**1.20 – 2.15**
With dark gravel	0.08 – 0.15	0.80 – 0.90		With white gravel	0.30 – 0.50	0.80 – 0.90	
With smooth asphalt surface	0.04 – 0.05	0.85 – 0.95		With gravel and cementitious coating	0.50 – 0.70	0.80 – 0.90	
With aluminum coating	0.25 – 0.60	0.20 – 0.50		Smooth surface with white roof coating	0.75 – 0.85	0.80 – 0.90	
Single-Ply Membrane			**1.00 – 2.00**	**Single-Ply Membrane**			**1.00 – 2.05**
Black (PVC)	0.04 – 0.05	0.80 – 0.90		White (PVC)	0.70 – 0.78	0.80 – 0.90	
				Color with cool pigments	0.40 – 0.60	0.80 – 0.90	
Modified Bitumen			**1.50 – 1.90**	**Modified Bitumen**			**1.50 – 1.95**
With mineral surface capsheet (SBS, APP)	0.10 – 0.20	0.80 – 0.90		White coating over a mineral surface (SBS, APP)	0.60 – 0.75	0.80 – 0.90	
Metal Roof			**1.80 – 3.70**	**Metal Roof**			**1.80 – 3.75**
Unpainted, corrugated	0.30 – 0.50	0.05 – 0.30		White painted	0.60 – 0.70	0.80 – 0.90	
Dark-painted, corrugated	0.05 – 0.08	0.80 – 0.90		Color with cool pigments	0.40 – 0.70	0.80 – 0.90	
Asphalt Shingles			**0.50 – 2.00**	**Asphalt Shingle**			**0.60 – 2.10**
Black or dark brown with conventional pigments	0.04 – 0.15	0.80 – 0.90		"White" (light gray)	0.25 – 0.27	0.80 – 0.90	
				Medium gray or brown with cool pigments	0.25 – 0.27	0.80 – 0.90	
Liquid Applied Coating			**0.50 – 0.70**	**Liquid Applied Coating**			**0.60 – 0.80**
Smooth black	0.04 – 0.05	0.80 – 0.90		Smooth white	0.70 – 0.85	0.80 – 0.90	
				Smooth, off-white	0.40 – 0.60	0.80 – 0.90	
				Rough white	0.50 – 0.60	0.80 – 0.90	
Concrete Tile			**1.00 – 6.00**	**Concrete Tile**			**1.00 – 6.00**
Dark color with conventional pigments	0.05 – 0.35	0.80 – 0.90		White	0.70	0.80 – 0.90	
				Color with cool pigments	0.40 – 0.50	0.80 – 0.90	
Clay Tile			**3.00 – 5.00**	**Clay Tile**			**3.00 – 5.00**
Dark color with conventional pigments	0.20	0.80 – 0.90		White	0.70	0.80 – 0.90	
				Terra cotta (unglazed red tile)	0.40	0.80 – 0.90	
				Color with cool pigments	0.40 – 0.60	0.80 – 0.90	

STEEP-SLOPED ROOFS FOR RESIDENTIAL BUILDINGS

Figure 1: Conventional and Cool Colored Tiles (EPA 2011)

The base case solar reflectance of steep-sloped roofs on single family houses is estimated to be approximately 0.15. The new Reach Code requirements increase the required reflectance to 0.28 and 0.34 for Tier 1 and Tier 2, respectively. The 2013 Title 24 update recently increased the statewide prescriptively required reflectance for steep sloped roofs to 0.20.

According to the 2013 Case Report for Residential Roof Measures (AEC 2011):

> *An asphalt shingle roof with an aged solar reflectance of 0.24 is cost effective in all climate zones except CZ 1, 2, 3, and 5. For tile roofs, a solar reflectance of 0.40 is cost effective in all climate zones except CZ 1 (Arcata, North Coast) and CZ 5 (Santa Maria, Central Coast), due to the lack of a cooling load in those climate zones.*
>
> …
>
> *For* ***high reflectance roofs****, the primary finding is that while higher reflectance roofs (reflectance of 0.35 to 0.4) are readily available for tile, reflectance of shingles is limited to 0.25 to 0.30, and few products exist with an aged reflectance greater than 0.24. Rather than provide separate, more stringent requirements for tile roofs, we recommend a single reflectance of 0.24, regardless of roofing product, simplifying the prescriptive requirements.*
>
> *For this measure, increased roof solar reflectance, we first reviewed the availability of high reflectance products for a variety of roofing types. The summary graph below shows that higher reflectance cool roof options do exist for steep-sloped roofing. Figure 2 shows product availability for several roof types. For tile, a number of products are available with reflectance of 0.35 or higher. For asphalt shingle, product availability decreases when aged reflectance exceeds 0.25 and no products are available above 0.30. Since the current prescriptive reflectance requirement for tile is 0.15, many products are receiving a compliance credit, even though they are standard practice.*

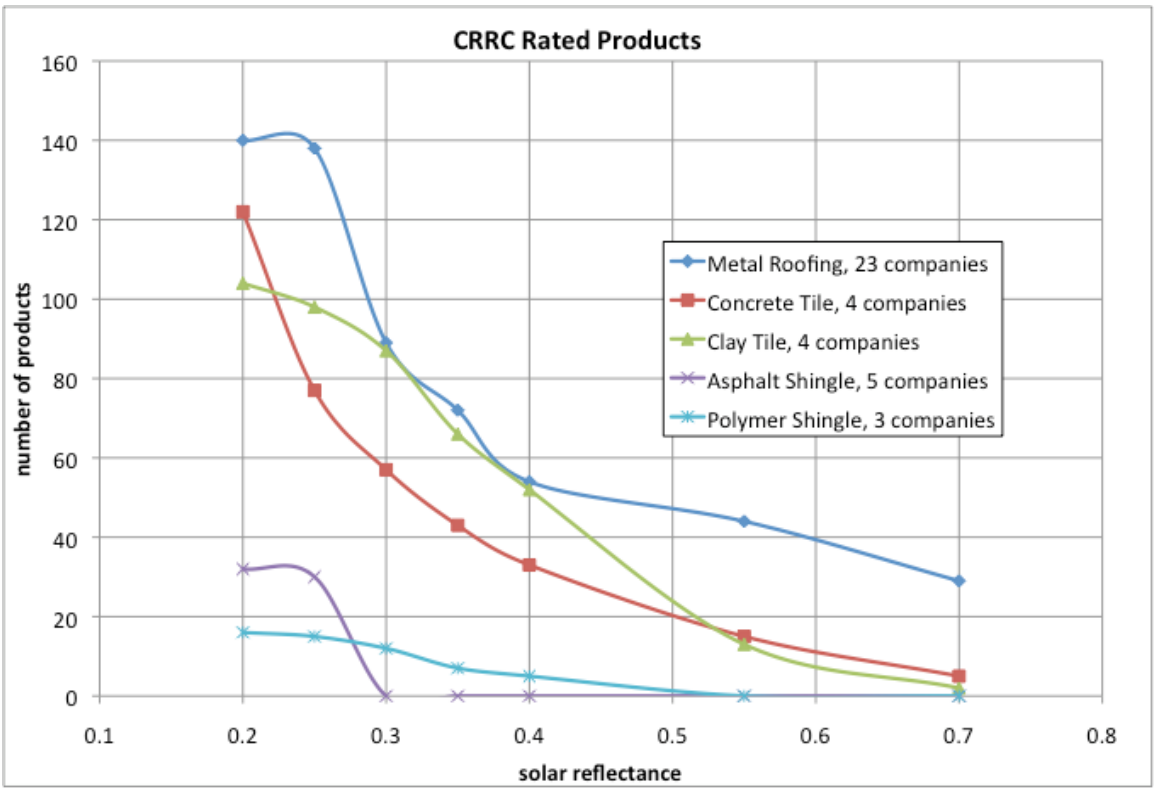

Figure 2. Steep-sloped Roofing Product Availability

Source: 2013 Case Report for Residential Roof Measures (AEC 2011)

Recent data collection in March of 2014 has revealed an increase in the number of products that meet Tier 1 and Tier 2 requirements. The Cool Roofs Rating Council's (CRRC) product directory[3] contains more concrete tiles with an aged solar reflectance exceeding 0.34 than there are in the range between 0.28 and 0.34. However, perhaps more impactful is the increased availability of higher-reflectance asphalt shingles. There are 23 asphalt shingle products found in the CRRC product directory that meet Tier 1 requirements, with an aged solar reflectance greater than 0.28, four of which meet Tier 2 with an initial solar reflectance of 0.4 or higher.

The list of products available in the CRRC product directory may not be a fully comprehensive representation of the products available on the market; the directory only represents products that manufacturers have had tested and labeled. Many of these products may not be currently stocked in distribution centers, but input from several distributors is that these products can be ordered upon request at no additional cost.

As represented in the stacked chart below in Figure 3, there are multiple shingle and tile products available meeting both Tier 1 and Tier 2 requirements for steep-sloped roofs.

[3] http://coolroofs.org/products/results

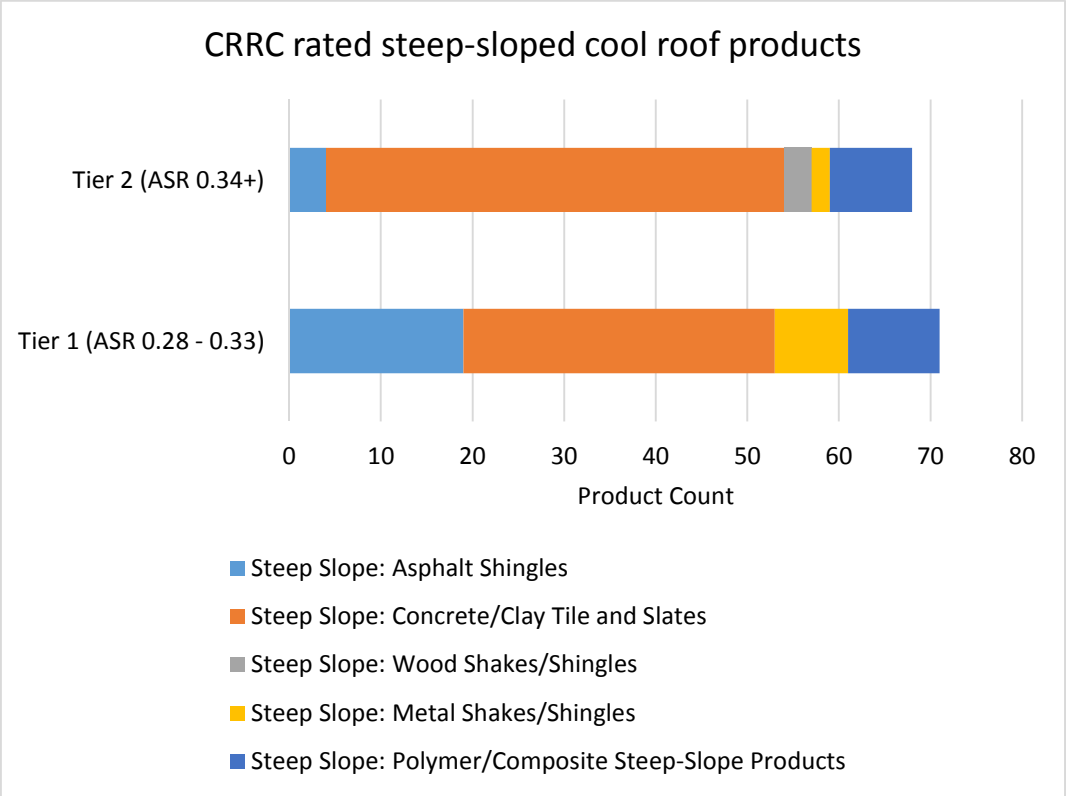

Figure 3: Steep-sloped roofing product availability according to CRRC product directory as of March 2014

According to a California roofer interviewed in March of 2014, the breakdown of asphalt shingles and tiles in residential new construction in California is 70:30. Another roofer specific to the inland Los Angeles area (representative of climate zone 9) notes that their company typically installs asphalt shingles on residential new construction, while tile is more common along the coast (climate zone 6).

Based on interviews with several roofers and roof supply distributors in the Los Angeles area, roofers are able to meet the Tier 1 and Tier 2 requirements at little or no additional cost when using asphalt shingles or clay tiles, depending on the product selected. Multiple roofers confirmed that there is no additional labor to install cool roof products.

The following prices were obtained from roofers, roof supply distributors and retail stores. When providing baseline costs, roofers and distributors were asked for the price of a basic quality asphalt or tile product. Therefore, the baseline costs do not incorporate the high costs associated with higher end non-cool roof products. The cost estimates for asphalt shingles and concrete and clay tiles are provided below in Table 8. The cost premium for cool roof products meeting the Tier 2 requirements varies greatly depending on the product selected; tile products exceeding the Tier 2 requirement can be found at about the same cost as a non-cool roof product, but our sample data found an average cost increase of \$0.35/ft^2.

Table 8: Cost data for steep-sloped cool roof products collected March 2014

Steep-sloped Cool Roof product prices	# of cost data points	Low Estimate ($/ft2)	High Estimate ($/ft2)	Average cost ($/ft2)	Average Incremental cost ($/ft2)
Baseline (2008 T24: ASR 0.15)	14	$0.60	$2.00	$1.02	-
Prescriptive (2013 T24: ASR 0.20)	7	$0.79	$1.84	$1.37	$0.34
Tier 1 (ASR 0.28)	16	$0.83	$2.58	$1.45	$0.43
Tier 2 (ASR 0.34)	11	$0.61	$2.14	$1.38	$0.35

Asphalt Shingles

Based on interviews with several roofers and roof supply distributors in the Los Angeles area, roofers are able to meet the Tier 1 and Tier 2 requirements at little additional cost when using asphalt shingles, depending on the product selected. Multiple roofers made the statement that there is no additional labor to install cool roof products.

The following prices were obtained from roofers, roof supply distributors and retail stores. When providing baseline costs, roofers and distributors were asked for the price of a basic quality asphalt or tile product. Therefore, the baseline costs do not incorporate the high costs that associated with higher end non-cool roof products. The cost estimates for asphalt shingles are provided below in Table 9.

Table 9: Asphalt shingle cost data collected March and April 2014

	# of cost data points	Low Estimate ($/ft^2)	High Estimate ($/ft^2)	Average cost ($/ft^2)	Average Incremental cost ($/ft^2)
Baseline[4] (2008 T24: ASR 0.15)	10	$0.77	$1.83	$0.97	-
Prescriptive (2013 T24: ASR 0.20)	7	$0.79	$1.84	$1.37	$0.40
Tier 1 (ASR 0.28)	9	$0.83	$1.87	$1.15	$0.18
Tier 2 (ASR 0.34)	3	$1.44	$1.78	$1.56	$0.59

To meet Tier 1, the cost premium can be as little as $0.05/sf compared to a basic asphalt shingle. However, there are products available from the same manufacturers which do not meet the cool roof requirements but exceed the cost of the highly reflective products due to other quality and durability characteristics. It is possible to install an asphalt shingle cool roof at no additional cost, or with cost savings, as compared to an equivalent quality product that is not cool roof rated.

For example, Owens Corning TruDefinition Duration products in a cool roof shade and a non-cool roof shade cost the same according to online comparison at a major retailer[5]. To meet Tier 2, there is the potential for increased cost compared to a "basic" asphalt shingle, as these Tier 2 asphalt shingles are generally higher quality products in addition to having higher reflectances. The available product pool is smaller, but remains cost competitive with high quality non-cool roof products.

A roofer in the Los Angeles area who commonly installs cool roofs noted that although the cool roof shingles might be 25 percent more costly, the quality is 25 percent better than the basic product. The

[4] Roofers and distributors were asked to provide the cost of a basic quality product. Therefore, these price points do not reflect higher quality products generally associated with higher costs.

[5] Lowes.com

price differential for some of these higher-scale cool roof shingles are based on factors other than cool roof characteristics, consistent with non-cool roof shingles.

Interviews and researching online retailers revealed the following:

- From several distributors: no additional price to special order cool roof products, just requires a few additional days.
- Multiple roofers: no increase in labor on residential buildings for tile or asphalt cool roofs.
- Roofer: costs for residential cool roof products will remain competitive, but not as low as industry normal prices.
- Roofer: sometimes certain shingles are minimum run quantities, meaning you need to buy a certain amount of product.

Concrete and Clay Tile

Multiple distributors noted that concrete and clay tile products typically already meet cool roof requirements. Similar to shingles, a tile product can come in several shades, some of which meet the Tier 1 and Tier 2 requirements and some that do not. The price for the product does not vary based on its solar reflectivity properties, rather, tile products vary simply based on the color. Although color also affects the solar reflectivity properties, there is not a direct correlation between the cool roof colors and the higher costing colors; cool roof products are available in the lower price categories.

The cost estimates for concrete and clay tile are provided below in Table 10.

Table 10: Concrete and Clay tile cost data collected March and April 2014

	# of cost data points	Low Estimate ($/ft^2)	High Estimate ($/ft^2)	Average cost ($/ft^2)	Average Incremental cost ($/ft^2)
Baseline[6] (2008 T24: ASR 0.15)	4	$0.60	$2.00	$1.18	-
Prescriptive (2013 T24: ASR 0.20)	0	-	-	-	-
Tier 1 (ASR 0.28)	7	$1.38	$2.58	$1.84	$0.67
Tier 2 (ASR 0.34)	8	$0.61	$2.14	$1.31	$0.14

Tile products are more likely to be used on higher end homes. One roofer mentioned that tile is mostly done on the coast (which generally consists of a larger proportion of higher end homes).

Interviews and researching online retailers revealed the following:

- Distributor: Prices are the same for the same tile product for colors that do and do not meet cool roof requirements.
- Distributor: being a cool roof has no effect on the cost.
- Distributor: Prices for tile vary by color, whether it is a solid color or a blend. Solid color is typically cheaper than a blend. (Note that there are cool roof colors that are solid, i.e. red).
- Distributor: Concrete tile prices do not vary by color, clay tile prices will vary by color.

[6] Roofers and distributors were asked to provide the cost of a basic quality product. Therefore, these price points do not reflect higher quality products generally associated with higher costs.

LOW-SLOPED COOL ROOFS FOR COMMERCIAL BUILDINGS

Figure 4: Examples of Commercial Cool Roofs (Rosenfeld 2012)

The base case solar reflectance of low-sloped roofs on commercial buildings is 0.55 per the 2008 Title 24 Building Energy Efficiency Standards. The new Reach Code requirements increase the required reflectance to 0.68 and 0.70 for Tier 1 and Tier 2, respectively. The 2013 Title 24 update recently increased the statewide prescriptively required reflectance for low-sloped roofs to 0.63.

There is no additional labor for installing a cool roof product, as it requires the same techniques and types of products as installing a standard roof. In fact, the cost of cool roof products meeting the 2013 Title 24 requirements or even the Reach Code, can be cheaper than their darker, non-cool roof counterparts, as evidenced by recent data collection and bolstered by the 2013 Case Report for Nonresidential Cool Roofs:

> *Looking first to the question of product availability, the research showed that there are a sufficient number of products on the market at or near the R_{aged} = 0.67 level to support the adoption of that standard for enforcement starting in 2014. There are over 200 products listed on the CRRC database that meet the proposed R_{aged} = 0.67 standard. More products are likely coming on the market before the proposed standard would take effect in 2014.*
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> …
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> *Within the cool roof market, many of the products with R_{aged} values close to 0.55 are actually tinted versions of the more conventional white versions of the same product. The products with the darker reflectance can, therefore, actually have a higher initial cost while also driving higher energy costs.*

The prediction of more products becoming available made by the CASE author is supported by recent data collection. As of March 2014, the CRRC products directory contains 403 field applied coatings, 97 built-up and modified bitumen, and 85 single ply thermoplastic roofing options. It appears that field applied coatings have a broader range of cool roof products available.

Based on interviews with several roofers and roof supply distributors in the Los Angeles area, roofers are able to meet the Tier 1 and Tier 2 requirements at little or no additional cost, depending on the product selected. Multiple roofers made the statement that there is no additional labor to install cool roof products.

Table 11: Low-slope roof product cost data collected March and April 2014

	# of data points	Low Estimate ($/ft²)	High Estimate ($/ft2)	Average cost ($/ft2)	Average Incremental cost ($/ft²)
Baseline (2008 T24: ASR 0.55)	3	$0.61	$1.37	$1.00	-
Prescriptive (2013 T24: ASR 0.63)	5	$0.21	$1.25	$0.67	-$0.33
Tier 1 (ASR 0.68)	1	$0.79	$0.79	$0.79	-$0.22
Tier 2 (ASR 0.70)	6	$0.78	$1.13	$1.04	$0.03

The response from roofing contractors and distributors contacted in March and April of 2014, found that the incremental cost of cool roof products is often negligible, which is consistent with the findings shown in Figure 5 and Figure **6** from the 2013 Nonresidential Cool Roofs CASE Report (IOU 2011). See the excerpts below, which break down the material costs by product type:

> *For field-applied coatings, costs are flat in relation to reflectance throughout the range from R_{aged} = 0.67 to R_{aged} = 0.80. Below the level of R_{aged} = 0.67 prices appear to actually increase.*

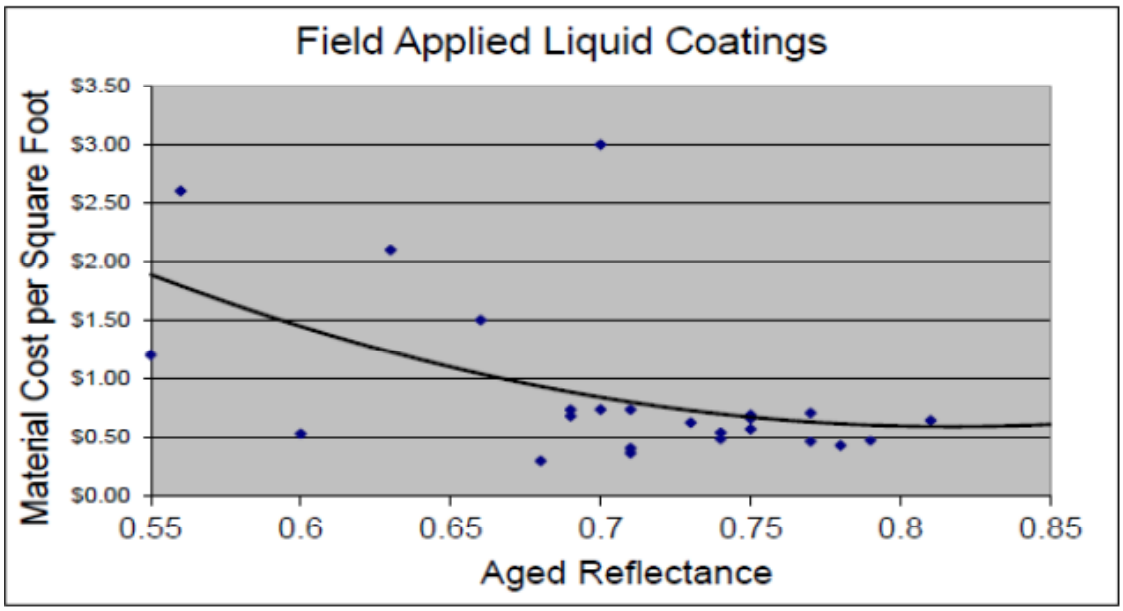

Figure 5: Cost of Field Applied Coatings

Source: 2013 Case Report for Nonresidential Cool Roofs (IOU 2011)

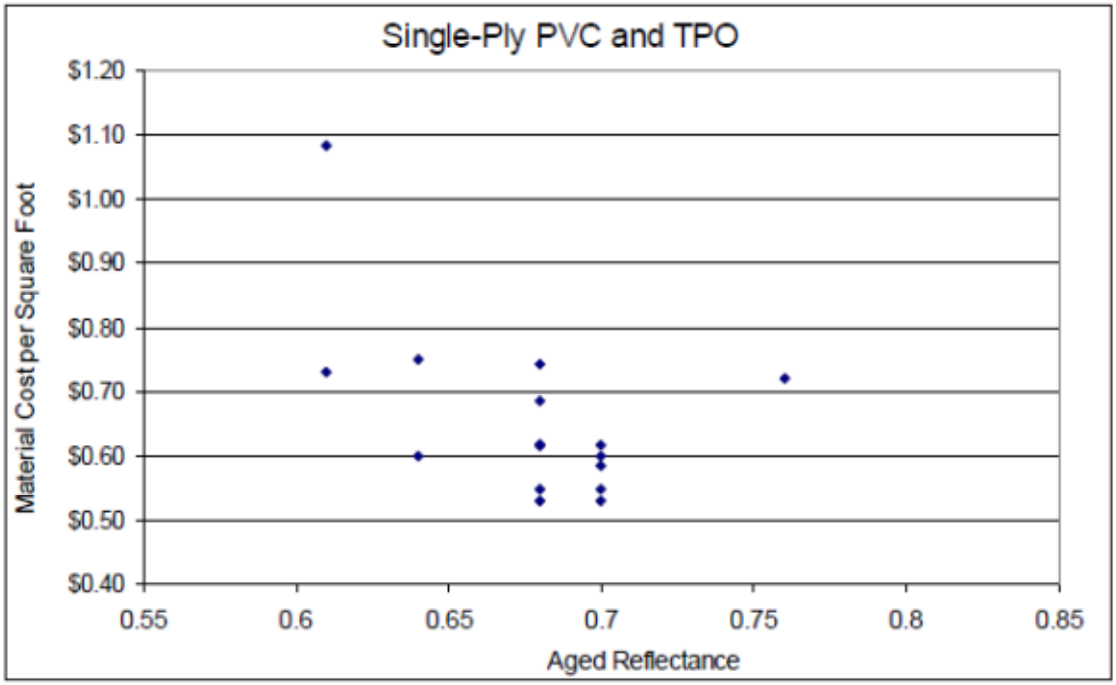

Figure 6: Material Cost of Single-Ply Membranes - Source: 2013 Case Report for Nonresidential Cool Roofs (IOU 2011)

> *For single-ply membranes, the lowest cost products appear to be in the R_{aged} = 0.67 range. An additional comparison is to compare the installed cost of a built-up roof with a cool cap sheet that meets the 2008 Title 24 cool roof requirements (ρ=0.55) with the installed cost of a single-ply roof that meets the new proposed requirement (ρ =0.67). This incremental installed costs, from cost surveys, is estimated at $0.30/ft^2. This number will be used as a conservative estimate for the incremental cost.*

As demonstrated by the 2013 CASE report, and bolstered by recent data collection in March and April of 2014, the incremental cost of a low-sloped cool roof for a nonresidential building is negligible, but was still proven cost-effective assuming a $0.30/ft^2 cost premium using the CEC's 2013 Life-Cycle Cost Methodology[7].

As the cost for low-sloped roofing products remain relatively flat as the reflectances increase, the higher-reflectance products meeting Tiers 1 and 2 provide even greater energy benefits for comparable costs, increasing the cost-effectiveness of such products.

Urban Heat Island Mitigation

A great deal of research has been done to identify and quantify the energy savings and GHG reduction potential of cool roofs. Below are citations from studies that summarize the benefits.

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[7] 2013 Life-Cycle Cost Methodology available from the California Energy Commission at: http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/general_cec_documents/2011-01-14_LCC_Methodology_2013.pdf

Additional detailed information to support the initiative is available in the references contained in these studies.

According to the study *Global Cooling: Increasing World-wide Urban Albedos to Offset CO_2* (Akbari 2008), improving the solar reflectance of roofing materials provides two significant benefits:

- More reflective roof material allows less solar radiation through the building envelope into the conditioned space, reducing the HVAC equipment load which reduces GHG emissions associated with energy generation.
- The solar reflective, cooler roof helps reject solar radiation out of the atmosphere and creates a "global" cooling effect on its urban surroundings. This indirectly reduces the HVAC load again by minimizing the temperature difference between the surrounding ambient and the conditioned space. This reduction in "global" temperature (or the reversal of the urban heat island effect) also creates a negative impact (in radiative forcing) on GHG concentration in the atmosphere.

Cool roofs, cool pavements, and shade trees, save energy and improve air quality. Additionally, higher albedo surfaces (roofs and pavements) directly reduce outdoor temperatures, cool the globe, independent of reduced energy use and avoided CO_2. Both the direct and indirect mechanisms for cool roof impact on GHG are depicted below in Figure 7.

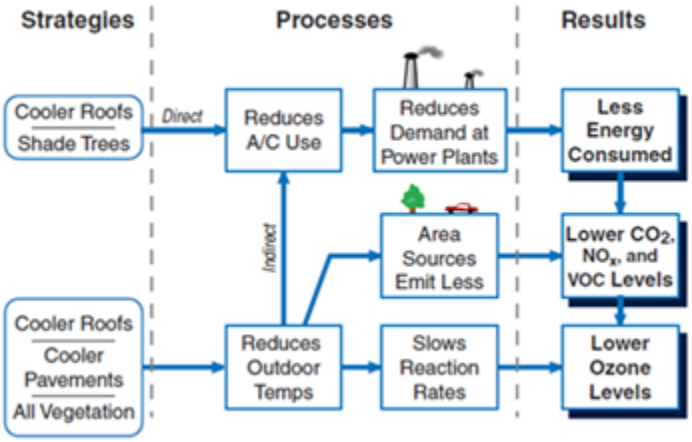

Figure 7: Mechanism: "Cool Roofs, Cool Pavements and Shade Trees Save Energy and Improve Air Quality". [8]

The cool roof's indirect effect of radiative forcing on atmospheric CO_2 concentration is in addition to the avoided CO_2 emission associated with lower HVAC loads. Based on an IPCC estimate, a 0.01 increase in reflectance of an urban surface results in the emitted CO_2 equivalent offset of -2.5 kg CO_2 per m^2 (or -26.8 kg CO_2 per square foot). The negative sign here denotes an increase in roof reflectance decreases the associated emitted GHGs.

According to the climate change advocacy group C-Change LA[9], UCLA research suggests that by midcentury local temperatures will increase between 3.7°F and 5.4°F. Rising temperatures will be most notable during the summer and fall, with the number of "extreme heat" days above 95°F

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[8] Citation for image: Global Cooling: Increasing World-wide Urban Albedos to Offset CO2, Hashem Akbari, Heat Island Group, Ernest Orlando Lawrence Berkeley National Laboratory Fifth Annual California Climate Change Conference, Sacramento, CA, September 9, 2008

[9] http://climateresolve.org/la-becomes-first-major-city-to-mandate-cool-roofs-on-all-new-residences/

tripling in downtown Los Angeles and nearly quadrupling in the San Fernando and San Gabriel valleys. "The changes our region will face are significant, and we will have to adapt," said UCLA Professor Alex Hall, lead author of "Mid-Century Warming in the Los Angeles Region." Cool roofs were recommended as an effective measure to mitigate the projected temperature increases and provide the following benefits to the greater Los Angeles region:

1. become more resilient and healthier on hot days
2. reduce heat related hospitalizations
3. improve air quality by reducing the formation of ozone
4. inoculate against power outages
5. reduce homeowners electricity bills
6. reduce greenhouse gas emissions
7. provide a more pleasant home environment

According to the findings contained in the study *Reducing Urban Heat Islands: Compendium of Strategies* (EPA 2011), 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. The use of cool roofs as a mitigation strategy brings many benefits, including reduced energy use, reduced air pollution and greenhouse gas emissions, and improved human health and comfort.

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. Cool roofing 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.

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_X), as well as greenhouse gases, primarily carbon dioxide (CO_2). 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. Reductions in air pollutant emissions such as NO_X generally provide benefits in terms of improved air quality, particularly ground-level ozone. The CO_2 reductions can be substantial. For example, one study estimated potential CO_2 reductions of 6 to 7 percent in Baton Rouge and Houston from reduced building energy use (Konopacki et. Al 2002).

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.

Documents Relied Upon

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3. Architectural Energy Corporation, 2012b. Revised LCC for NR Cool Roofs, http://www.energy.ca.gov/title24/2013standards/rulemaking/documents/public_comments/45-day/2012-05-15_Revised_LCC_for_NR_Cool_Roofs_TN-65227.pdf, May 15, 2012.

4. Architectural Energy Corporation, 2012c. Architectural Energy Corporation Response to ARMA Comments TN-65233, May 11, 2012.

5. Akbari, H., 2003. "Measured energy savings from the application of reflective roofs in two small non-residential buildings." Energy. 2003; 28:953-967. Available online at: http://dx.doi.org/10.1016/S0360-5442(03)00032-X

6. Akbari et al. (2008) Global Cooling: Increasing World-wide Urban Albedos to Offset CO2, Climate Change Vol. 95, Joint Issue 3-4 (May-June 2009)

7. [IOU] California Utilities Statewide Code and Standards Team 2011. Residential Roof Envelope Measures, October, 2011. Available online at: http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/current/Reports/Residential/Envelope/2013_CASE_R_Roof_Measures_Oct_2011.pdf

8. [CEC] 2012a. Order Adopting Proposed Regulations and Negative Declaration. June 8, 2012.

   Available online at http://www.energy.ca.gov/title24/2013standards/rulemaking/notices/2012-05-31_Adoption_Order_No_2-0531-5_TN-65677.pdf

9. [CEC] 2012b. CEC Response E-mail to ARMA Comments and Supporting Data on Proposed 2013 Building Standards TN-65234, May 15, 2012. Available online at: http://www.energy.ca.gov/title24/2013standards/rulemaking/documents/public_comments/45-day/2012-05-15_CEC_Response_E-mail_to_ARMA_Comments_and_Supporting_Data_on_Proposed_2013_Building_Standards_TN-65234.pdf

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13. IPCC (2007) Climate change 2007—the physical science basis, contribution of working group I to the fourth assessment report of the IPCC. Chapter 7, Figure 7.4 and Section 7.3.2.1 (516–517)

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.

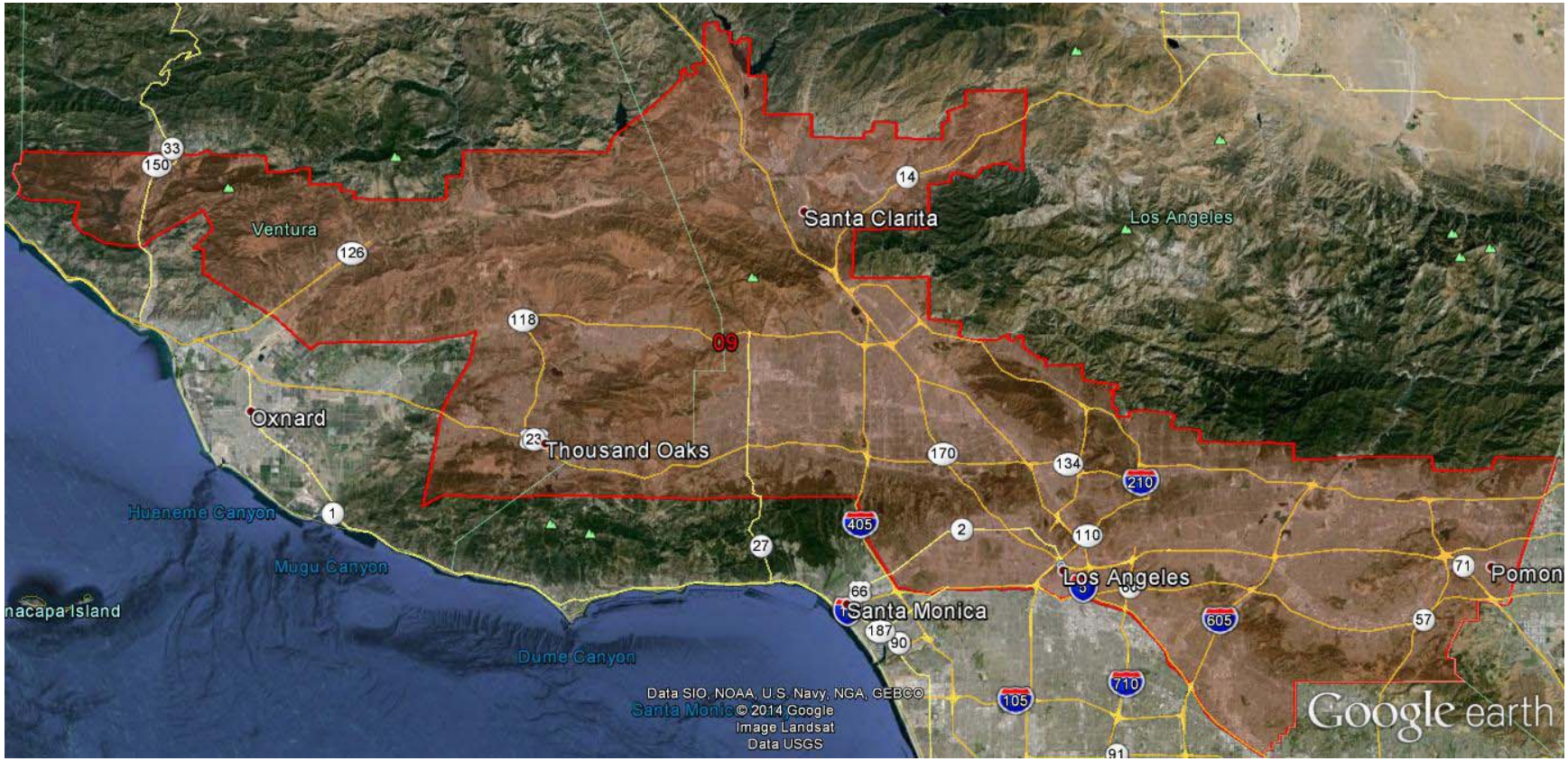
15. Levinson R, Akbari H, Konopacki S, Bretz SE. 2005. "Inclusion of cool roofs in nonresidential Title 24 prescriptive requirements." Energy Policy. 2005;33:151-170

16. Rose LS, Akbari H, Taha H (2003) Characterizing the fabric of the urban environment: a case study of Greater Houston, Texas. Lawrence Berkeley National Laboratory Report LBNL-51448, Berkeley, CA. A presentation of the same title was given at the Fifth Annual California Climate Change Conference, Sacramento, CA on September 9, 2008

17. Rosenfeld, Arthur (2012) ACEEE Talk: An Economic Comparison of White, "Green," & Black Flat Roofs in the U.S. and Globally. Asilomar/Pacific Grove, CA. August 13, 2012. Available online at: https://sites.google.com/a/lbl.gov/cool-white-planet/presentations

Appendix

MAP OF CLIMATE ZONE 9



LIST OF JURISDICTIONS IN CLIMATE ZONE 9

Jurisdictions within Climate Zone 9			
Agoura Hills	Granada Hills	Panorama City	Stevenson Ranch
Alhambra	Hacienda Heights	Pasadena	Studio City
Arcadia	La Crescenta	Pico Rivera	Sun Valley
Azusa	La Mirada	Pomona	Sylmar
Baldwin Park	La Puente	Porter Ranch	Tarzana
Beverly Hills	La Verne	Reseda	Temple City
Burbank	Los Angeles	Rosemead	Thousand Oaks
Calabasas	Mission Hills	Rowland Heights	Universal City
Canoga Park	Monrovia	San Dimas	Valencia
Canyon Country	Montebello	San Fernando	Valley Village
Castaic	Monterey Park	San Gabriel	Van Nuys
Chatsworth	Montrose	San Marino	Walnut
Claremont	Moorpark	Santa Clarita	West Covina
Covina	Newbury Park	Santa Fe Springs	West Hills
Diamond Bar	Newhall	Santa Paula	West Hollywood
Duarte	North Hills	Sherman Oaks	Westlake Village
El Monte	North Hollywood	Sierra Madre	Whittier
Encino	Northridge	Simi Valley	Winnetka
Fillmore	Oak Park	Somis	Woodland Hills
Glendale	Oak View	South El Monte	
Glendora	Pacoima	South Pasadena	

COOL ROOF REQUIREMENTS IN TITLE 24 PART 6 AND PART 11 (CALGREEN)

The Building Energy Efficiency Standards must be cost effective based on the life cycle of the building, must include performance and prescriptive compliance approaches, and must be periodically updated to account for technological improvements in efficiency technology. Accordingly, the California Energy Commission has adopted and periodically updated the Standards (codified in Title 24, Part 6 of the California Code of Regulations) to ensure that building construction, system design and installation achieve energy efficiency and preserve outdoor and indoor environmental quality. The Standards establish a minimum level of building energy efficiency. A building can be designed to a higher efficiency level, resulting in additional energy savings.

Local governmental agencies may adopt and enforce energy standards for newly constructed buildings, additions, alterations, and repairs to existing buildings provided the Energy Commission finds that the standards will require buildings to be designed to consume no more energy than permitted by Title 24, Part 6.

The provisions of Part 6 apply to the building envelope, space-conditioning systems, water-heating systems, pool and spas, solar ready buildings, indoor lighting systems of buildings, outdoor lighting systems, and signs located either indoors or outdoors, in buildings that are of Occupancy Group A, B, E, F, H, M, R, S, or U.

The California Green Building Standards Code (aka "CALGreen", codified in Title 24, Part 11 of the California Code of Regulations) is intended to improve public health, safety and general welfare by enhancing the design and construction of buildings through the use of building concepts having a reduced negative impact or positive environmental impact and encouraging sustainable construction practices in the following categories:

- Planning and design.
- Energy efficiency.
- Water efficiency and conservation.
- Material conservations and resource efficiency.
- Environmental quality.

As shown below in Table 12, the most recently adopted versions (2013) of Title 24 Parts 6 and 11 have conflicting requirements; CALGreen set Tier 1 levels for low-sloped cool roofs below the prescriptive requirements contained in Title 24 Part 6. According to Chapter 1, Section 101.6.3 of Title 24 Part 11[10]: "When the requirements of CALGreen conflict with the requirements of any other part of the *California Building Standards Code*, Title 24, the most restrictive requirement shall prevail." Therefore the prescriptive requirements from Title 24 Part 6 are the minimum requirements.

The discrepancy between these requirements has no real impact on the reach code tiers proposed in this document, which are more stringent than any of these requirements. The justification of energy savings and costs are compared to the 2008 version of Title 24 Part 6, which contained less stringent requirements (and in some cases no requirements at all) for cool roofs in all scenarios.

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10 http://www.ecodes.biz/ecodes_support/free_resources/2013California/13Green/PDFs/Chapter%201%20-%20Administration.pdf

Table 12: Cool Roof Requirements in Title 24 Part 6 and Part 11

CZ	Code	Requirement Type	Slope	Minimum 3-yr Aged Solar Reflectance	Thermal Emittance	Minimum SRI
Nonresidential						
ALL	**2013 T24 Part 6**	**Prescriptive**	**Low (<2:12)**	**0.63**	**0.75**	**75**
ALL	**2013 T24 Part 6**	**Prescriptive**	**Steep (>2:12)**	**0.20**	**0.75**	**16**
ALL	2013 T24 Part 11	Voluntary TIER 1	Low (<2:12)	0.55	0.75	64
ALL	2013 T24 Part 11	Voluntary TIER 1	Steep (>2:12)	0.20	0.75	16
ALL	2013 T24 Part 11	Voluntary TIER 2	Low (<2:12)	0.65	0.85	78
ALL	2013 T24 Part 11	Voluntary TIER 2	Steep (>2:12)	0.30	0.85	30
High-Rise Residential						
9-11, 13-15	**2013 T24 Part 6**	**Prescriptive**	**Low (<2:12)**	**0.55**	**0.75**	**64**
2-15	**2013 T24 Part 6**	**Prescriptive**	**Steep (>2:12)**	**0.2**	**0.75**	**16**
10, 11, 13-15	2013 T24 Part 11	Voluntary TIER 1	Low (<2:12)	0.55	0.75	64
10-15	2013 T24 Part 11	Voluntary TIER 1	Steep (>2:12)	0.20	0.75	16
2-15	2013 T24 Part 11	Voluntary TIER 2	Low (<2:12)	0.65	0.75	78
2-15	2013 T24 Part 11	Voluntary TIER 2	Steep (>2:12)	0.23	0.75	20
Low-Rise Residential						
13,15	**2013 T24 Part 6**	**Prescriptive**	**Low (<2:12)**	**0.63**	**0.75**	**75**
10-15	**2013 T24 Part 6**	**Prescriptive**	**Steep (>2:12)**	**0.20**	**0.75**	**16**
13,15	2013 T24 Part 11	Voluntary TIER 1	Low (<2:12)	0.55	0.75	64
10-15	2013 T24 Part 11	Voluntary TIER 1	Steep (>2:12)	0.20	0.75	16
2,4,6-15	2013 T24 Part 11	Voluntary TIER 2	Low (<2:12)	0.65	0.85	78
2,4,6-15	2013 T24 Part 11	Voluntary TIER 2	Steep (>2:12)	0.23	0.85	20