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Document Title:	County of Los Angeles Cool Roof Ordinance Board Approval 1016.18
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COUNTY OF LOS ANGELES
DEPARTMENT OF PUBLIC WORKS
"To Enrich Lives Through Effective and Caring Service"

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IN REPLY PLEASE
REFER TO FILE

ADOPTED
BOARD OF SUPERVISORS
COUNTY OF LOS ANGELES

30 October 16, 2018

CELIA ZAVALA
EXECUTIVE OFFICER

October 16, 2018

The Honorable Board of Supervisors
County of Los Angeles
383 Kenneth Hahn Hall of Administration
500 West Temple Street
Los Angeles, California 90012

Dear Supervisors:

DEVELOPMENT SERVICES CORE SERVICE AREA PROPOSED AMENDMENTS TO THE 2017 LOS ANGELES COUNTY GREEN BUILDING STANDARDS CODE (ALL SUPERVISORIAL DISTRICTS) (3 VOTES)

SUBJECT

Public Works is seeking Board approval for a proposed ordinance to amend the Los Angeles County Green Building Standards Code known as Title 31 of the Los Angeles County Code to add supplemental cool roof standards for reduction of the heat island effect on newly constructed or altered buildings.

IT IS RECOMMENDED THAT THE BOARD:

1. Find that the proposed ordinance is categorically exempt from the provisions of the California Environmental Quality Act for the reasons stated in this Board letter.

2. Approve the introduction of an ordinance to amend Title 31 - Los Angeles County Green Building Standards Code to add cool roof building standards.

3. Introduce, waive reading, and place the proposed ordinance on a subsequent agenda for adoption.

4. Find that the proposed changes and modifications to building standards contained in the 2016 California Green Building Standards Code, as adopted in Title 31 - Los Angeles County Green Building Standards Code, are necessary because of local climatic, geological, and/or topographical conditions, as detailed in the ordinance.

5. Approve the cost analysis and effectiveness study by the California Energy Commission regarding the proposed energy standards included in the ordinance and find that these proposed energy standards will require buildings to be designed to consume no more energy than permitted by the California Energy Code.

6. Approve and authorize the Director of Public Works or his designee to file the adopted ordinance containing the Board of Supervisors' findings with the California Building Standards Commission and the California Energy Commission.

PURPOSE/JUSTIFICATION OF RECOMMENDED ACTION

The enclosed proposed ordinance, when adopted, will amend Title 31 – Los Angeles County Green Building Standards Code to mandate the utilization of cool roofing materials for new building construction, building additions, and major roof replacements in the unincorporated areas of Los Angeles County.

Pursuant to provisions of the California Health and Safety Code, on November 22, 2016, the Board adopted an ordinance amending Title 31 – Green Building Standards Code to incorporate, by reference, the building standards contained in the 2016 California Green Building Standards Code together with certain changes and modifications.

The 2016 California Green Building Standards Code contains voluntary requirements for the use of cool roof materials, which were not adopted or made mandatory in November 2016. The recommended ordinance will adopt and make mandatory certain voluntary cool roof requirements from the 2016 Green Building Standards Code.

On July 31, 2017, the Board directed Public Works, in coordination with the Department of Regional Planning, the Chief Sustainability Officer, and the Department of Public Health, to draft an ordinance that would require utilization of cool roofing materials for new building construction, building additions, and major roof replacements in the unincorporated areas of Los Angeles County. The recommendation to mandate the use of cool roofing materials through this proposed ordinance is in alignment with this Board initiative to address the effects of climate change in the unincorporated County areas. These standards will help reduce the urban heat island effect, improve air quality, and decrease the energy consumption of buildings.

The ordinance also provides for exceptions for certain types of roof repairs, photovoltaic roofs, or roof replacements of less than some to-be-determined portion of roof area.

Implementation of Strategic Plan Goals

The Countywide Strategic Plan directs the provisions of Strategy II.1, Continually Pursue Development of our Workforce, and Strategy II.3.3, Make Environmental Sustainability our Daily Reality, as it provides services to the public that have a wide-reaching positive effect on the entire community. The adoption of the County's Green Building Standards Code amendments provides minimum green building design and construction standards and encourages sustainable construction practices that promote the health and welfare of the general public throughout the unincorporated areas of Los Angeles County. By mandating updated green building standards, the County will be able to ensure that its Strategic Goals are fully addressed.

FISCAL IMPACT/FINANCING

There will be minimal impact on expenditures for Public Works pertaining to training personnel. All associated costs including these training costs and the printing of the code amendments are included in the Public Works General Fund Fiscal Year 2018-19 Budget.

FACTS AND PROVISIONS/LEGAL REQUIREMENTS

Pursuant to provisions of the California Health and Safety Code, the County adopted the 2016 California Green Building Standards Code with modifications in Title 31 of the County Code. The California Green Building Standards Code had voluntary cool roof building standards, which through the proposed ordinance will become mandatory subject to exemptions identified in Sections 3 and 5, respectively. In accordance with Sections 17958.5 and 17958.7 of the Health and Safety Code, the Board must determine and expressly find that the amendments to the State standards are necessary because of local climatic, geological, and/or topographical conditions.

The applicable finding(s) for each proposed amendment to the State's building standards are clearly delineated in a chart, set forth in the proposed ordinance.

The proposed ordinance establishes additional energy conservation measures that require buildings to be more energy efficient than the standards contained in the California Energy Code. Accordingly, Section 25402.1 of the Public Resources Code requires that the Board find the proposed energy standards to be cost-effective and require buildings to be designed to consume no more energy than permitted by the California Energy Code. The enclosed Energy Cost-Effectiveness study contains supporting analysis of energy savings and a basis for cost-effectiveness for the proposed energy standards in Title 31.

Following the adoption of the ordinance by the Board, four copies of the enclosed application, the ordinance, and cost-effectiveness studies must be submitted to the Executive Director of the California Energy Commission for approval. The energy standards contained in the proposed ordinance cannot become operative until they have been approved by the California Energy Commission. Accordingly, upon approval by the Board, Public Works will seek approval from the California Energy Commission. The proposed amendments contained in the ordinance will then become operative when the Board's findings are filed with the State of California Building Standards Commission.

ENVIRONMENTAL DOCUMENTATION

Adoption of this proposed ordinance is exempt from the California Environmental Quality Act (CEQA) in that it can be seen with certainty that there is no possibility that the ordinance will have a significant effect on the environment pursuant to State CEQA Guidelines Section 15061(b)(3). Adoption of the proposed ordinance is covered by the general rule that CEQA applies only to projects that have the potential for causing a significant effect on the environment. Adoption of the proposed ordinance does not have such potential.

IMPACT ON CURRENT SERVICES (OR PROJECTS)

Other departments embarking on construction projects will be required to comply with the provisions of this proposed ordinance if construction permit applications are submitted on or after the operative date of the proposed ordinance.

Copies of the proposed code amendments were circulated to professional associations within the design and construction communities for review and comments. No comments regarding the ordinance language were received by Public Works.

CONCLUSION

Upon approval of the proposed ordinance, please return one adopted copy of this Board letter and one adopted copy of the proposed ordinance to the Department of Public Works, Building and Safety Division.

Respectfully submitted,

MARK PESTRELLA

Director

MP:RDA:sd

Enclosures

c: Chief Executive Office (Chia-Ann Yen)
County Counsel
Executive Office
Department of Public Health
Department of Regional Planning

COUNTY OF LOS ANGELES
OFFICE OF THE COUNTY COUNSEL

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August 7, 2018

Mark Pestrella, Director
Department of Public Works
900 South Fremont Avenue
Alhambra, California 91803

Attention: Hassan Alameddine, Assistant Deputy Director
Building & Safety Division

Re: Ordinance Amending Title 31 – Green Building Standards Code – of the Los Angeles County Code

Dear Mr. Pestrella:

As requested, we have prepared the proposed analysis and ordinance amending Title 31 – Green Building Standards Code – of the Los Angeles County Code, to add supplemental and administrative provisions that are not in the current Green Building Standards Code.

The ordinance and its analysis may be presented to the Board of Supervisors for its consideration after a duly-noticed public hearing.

Very truly yours,

MARY C. WICKHAM
County Counsel

By Carole Suzuki
CAROLE B. SUZUKI
Senior Deputy County Counsel
Public Works Division

APPROVED AND RELEASED:

LAWRENCE L. HAFETZ
Chief Deputy

CBS:ck
Enclosures

HOA.102267913.1

ANALYSIS

This ordinance amends Title 31 – Green Building Standards Code – of the Los Angeles County Code, to add supplemental green building standards for cool roofs to reduce the heat island effect for newly-constructed buildings and for alterations and additions to existing buildings, subject to specified exceptions. This ordinance also adds administrative provisions that are not in the current Green Building Standards Code.

MARY C. WICKHAM
County Counsel

By
CAROLE B. SUZUKI
Senior Deputy County Counsel
Public Works Division

CBS:ck

Requested: 04/25/18
Revised 07/25/18

ORDINANCE NO._____

An ordinance amending Title 31 – Green Building Standards Code – of the Los Angeles County Code, relating to building standards for cool roof construction to reduce the heat island effect.

The Board of Supervisors of the County of Los Angeles ordains as follows:

SECTION 1. Section 202 is hereby amended to read in alphabetical order as follows:

202 DEFINITIONS.

. . .

COOL ROOF RATING COUNCIL or CRRC. The entity recognized by the California Energy Commission to rate and certify the reflectance and emittance values of roofing products.

. . .

SECTION 2. Section 301.3.3 is hereby amended to read as follows:

301.3.3 Nonresidential buildings greater than or equal to 25,000 square feet.

In addition to the requirements of Section 301.3, any newly constructed nonresidential building greater than or equal to 25,000 square feet shall comply with all requirements of Section A5.601.2.4 Tier 1. Roofing materials shall comply with Tier 2 requirements of Table A5.106.11.2.3.[BSC].

Exceptions:

1. Compliance with Section A5.601.2.3 shall be voluntary.

2. High-rise residential buildings of seven stories or greater shall comply with Table A4.106.5.1(~~3~~4) in lieu of Table A5.106.11.2.~~2~~3.

SECTION 3. Section 4.106.6 of Title 31 is hereby added to read as follows:

4.106.6 Cool roof for reduction of heat island effect.

Roofing materials shall comply with the solar reflectance and thermal emittance requirements of this section.

Exceptions:

1. Roof repair.

2. Roof replacement when the roof area being replaced is equal to or less than 50 percent of the total roof area.

3. Installation of building-integrated photovoltaics.

4. Installation of a steep-sloped roof (roof slope > 2:12) in climate zone 16 on other than a low-rise multifamily building.

5. Additions resulting in less than 500 square feet of added roof area or less than 50 percent of the total roof area, whichever is greater.

6. Roof construction that has a thermal mass over the roof membrane, including areas of vegetated (green) roofs, weighing at least 25 pounds per square foot.

4.106.6.1 Solar reflectance.

Roofing materials shall have a minimum 3-year aged solar reflectance equal to or greater than the values specified in Table 4.106.6(1) and Table 4.106.6(2).

Solar reflectance values shall be based on the aged reflectance value of the roofing product or the equation in Section A4.106.5.1, if the CRRC testing for aged solar reflectance is not available.

4.106.6.2 Thermal emittance.

Roofing materials shall have a CRRC initial or aged thermal emittance equal to or greater than the values specified in Table 4.106.6(1) and Table 4.106.6(2).

4.106.6.3 Solar reflectance index alternative.

Roofing materials having a Solar Reflectance Index (SRI) equal to or greater than the values specified in Table 4.106.6(1) and Table 4.106.6(2) may be used as an alternative to compliance with the 3-year aged solar reflectance and thermal emittance values.

SRI values used to comply with this section shall be calculated using the SRI Calculation Worksheet (SRI-WS) developed by the California Energy Commission or in compliance with ASTM E1980-01, as specified in the current California Energy Code. Solar reflectance values used in the SRI-WS shall be based on the aged reflectance value of the roofing product or the equation in Section A4.106.5.1, if the CRRC certified aged solar reflectance is not available. Certified thermal emittance used in the SRI-WS may be either the initial value or the aged value listed by the CRRC.

SECTION 4. Tables 4.106.6(1) and 4.106.6(2) are hereby added to read as follows:

TABLE 4.106.6(1) – LOW-RISE RESIDENTIAL

ROOF SLOPE	MINIMUM 3-YEAR AGED SOLAR REFLECTANCE	THERMAL EMITTANCE	SRI
≤2:12	0.65	0.85	78
>2:12	0.25	0.85	20

TABLE 4.106.6(2) – HIGH RISE RESIDENTIAL BUILDINGS, HOTELS AND MOTELS

ROOF SLOPE	MINIMUM 3-YEAR AGED SOLAR REFLECTANCE	THERMAL EMITTANCE	SRI
≤2:12	0.65	0.75	78
>2:12	0.25	0.75	20

SECTION 5. Section 5.106.11 is hereby added to read as follows:

5.106.11 Cool roof for reduction of heat island effect.

Roofing materials shall comply with the solar reflectance and thermal emittance requirements of this section.

Exceptions:

1. Roof repair.
2. Roof replacement when the roof area being replaced is equal to or less than 50 percent of the total roof area.
3. Installation of building-integrated photovoltaics.
4. Additions resulting in less than 500 square feet of added roof area or less than 50 percent of the total roof area, whichever is greater.

5. Roof construction that has a thermal mass over the roof membrane, including areas of vegetated (green) roofs, weighing at least 25 pounds per square foot.

5.106.11.1 Solar reflectance.

Roofing materials shall have a minimum 3-year aged solar reflectance equal to or greater than values specified in Table 5.106.11.

Solar reflectance values shall be based on the aged reflectance value of the roofing product or the equation in Section A5.106.11.2.1, if the CRRC testing for aged solar reflectance is not available.

5.106.11.2 Thermal emittance.

Roofing material shall have a CRRC initial or aged thermal emittance equal to or greater than the values specified in Table 5.106.11.

5.106.11.3 Solar reflectance index alternative.

Roofing material having an SRI equal to or greater than the values specified in Table 5.106.11 may be used as an alternative to compliance with the 3-year aged solar reflectance and thermal emittance values.

SRI values used to comply with this section shall be calculated using the SRI-WS developed by the California Energy Commission or in compliance with ASTM E1980-01, as specified in the current California Energy Code. Solar reflectance values used in the SRI-WS shall be based on the aged reflectance value of the roofing product or the equation in Section A5.106.11.2.1, if the CRRC certified aged solar reflectance is not available. Certified thermal emittance used in the SRI-WS may be either the initial value or the aged value listed by the CRRC.

SECTION 6. Table 5.106.11 is hereby added to read as follows:

TABLE 5.106.11

ROOF SLOPE	MINIMUM 3-YEAR AGED SOLAR REFLECTANCE	THERMAL EMITTANCE	SRI
≤2:12	0.68	0.85	82
>2:12	0.28	0.85	27

SECTION 7. The provisions of this ordinance contain various changes or modifications to requirements contained in the building standards published in the California Green Building Standards Code.

Pursuant to California Health and Safety Code sections 17958.5, 17958.7, and 18941.5, the Board of Supervisors hereby expressly finds that all of the changes and modifications to requirements contained in the building standards published in the California Green Building Standards Code contained in this ordinance are reasonably necessary because of local climatic, geological, or topographical conditions in the County of Los Angeles, as more particularly described in the table set forth below:

GREEN BUILDING STANDARDS CODE AMENDMENTS		
CODE SECTION	**CONDITION**	**EXPLANATION**
4.106.6, 4.106.6.1, 4.106.6.2, 4.106.6.3, Table 4.106.6(1) and Table 4.106.6(2)	Climatic	Environmental resources in the County of Los Angeles are scarce due to varying and occasionally immoderate temperature and weather conditions. Adding mandatory requirements for cool roofs for residential occupancies will achieve a greater reduction in greenhouse gases, higher efficiencies of energy, and improved environmental air quality.

5.106.11, 5.106.11.1, 5.106.11.2, 5.106.11.3, and Table 5.106.11	Climatic	Environmental resources in the County of Los Angeles are scarce due to varying and occasionally immoderate temperature and weather conditions. Adding mandatory requirements for cool roofs for non-residential occupancies will achieve a greater reduction in greenhouse gases, higher efficiencies of energy, and improved environmental air quality.

[TITLE31SECT30133CSCC]

Title 24 Codes and Standards
Local Ordinances

Cost-Effectiveness Study for Cool Roofs
FINAL Report for All Climate Zones

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Last modified: March 30, 2016

This report was prepared by the California Statewide Utility Codes and Standards Program and funded by the California utility customers under the auspices of the California Public Utilities Commission.

Contents

Executive Summary

This Cost Effectiveness Study provides information on product cost, energy savings, cost-effectiveness and urban heat island mitigation to support minimum reach code requirements for residential and nonresidential cool roofs for jurisdictions in all California Climate Zones. The 2013 Building Energy Efficiency Standards, effective July 1, 2014, have been used as the baseline for calculating the energy performance of cool roofs. There are 162 steep-slope and 289 low-slope products available to meet the 2013 Title 24 Prescriptive reflectance requirements, including products that meet Reach Code.

Interviews with several roofers and roof supply distributors throughout California in March through December 2014 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. This study finds that there are only incremental costs associated with asphalt shingle cool roof products. Concrete and clay tile cool roof products do not have incremental costs over the base case roof. Most low-slope cool roof products also have no incremental costs of the base case, primarily because the roofing commonly used in the state is already a cool roof, though incremental cost data collected has been used in the cost effectiveness analysis to be conservative.

Several building prototypes were simulated in compliance simulation software to estimate the energy savings of cool roofs. The energy savings were compared against the cost data collected to determine the cost effectiveness of cool roofs. Reach Code recommendations are summarized in Table 1 below.

Table 1. Summary of Reach Code Recommendations

CZ	Should Jurisdictions Pursue the Reach Code?					
	teep- pe	Tier?	Building Types?	Low-Slo		Building Types?
1	No	-	-	No	-	
2	Yes	Tier 2	Low-Rise Multifamily	Yes	Tier 2	All
3	Yes, if costs decrease	Tier 2	Low-Rise Multifamily	Yes	Tier 2	All
4	Yes	Tier 2	Low-Rise Multifamily	Yes	Tier 2	All
5	Yes, if costs decrease	Tier 2	Low-Rise Multifamily	Yes	Minimum	All
6	Yes	Tier 2	Low-Rise Multifamily	Yes	Tier 2	All
7	Yes	Tier 2	Low-Rise Multifamily	Yes	Tier 2	All
8	Yes	Tier 2	All	Yes	Tier 2	All
9	Yes	Tier 2	All	Yes	Tier 2	All
10	Yes	Tier 2	All	Yes	Tier 2	All except High-Rise Multifamily
11	Yes	Tier 2	All	Yes	Tier 2	All
12	Yes	Tier 2	All	Yes	Tier 2	All
13	Yes	Tier 2	All	Yes	Tier 2	All except High-Rise Multifamily
14	Yes	Tier 2	All	Yes	Tier 2	All

CZ	Should Jurisdictions Pursue the Reach Code?					
	Steep-Slope	Tier?	Building Types?	Low-Slope	Tier?	Building Types?
15	Yes	Tier 2	All	Yes	Varies	Tier 2 for Low-Rise Multifamily and Nonresidential Tier 1 for High-Rise Multifamily
16	Yes	Tier 2	Low-Rise Multifamily	Yes	Tier 2	All

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.

1. Introduction

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.

As defined by the 2013 Building Energy Efficiency Standards (Title 24, Part 6), a Cool Roof is "a roofing material with high thermal emittance [TE] and high solar reflectance [SR]." With the intent of providing local governments with the bases for adopting cool roof Reach Code measures, TRC compares the energy savings of cool roofs using simulation software against the costs of installing them, determining the cost effectiveness of cool roofs in every California Climate Zone.

2. Methodology and Assumptions

2.1 CURRENT AND PROPOSED CODES

The Title 24 (T24) Standards have been used as the baseline in calculating the energy performance of cool roof measures summarized in this study. The default assumptions and prescriptive requirements in the 2013 Title 24 Standards are detailed below in Table 2. All solar reflectances described in this report are referencing 3-year aged solar reflectance.

Table 2. Prescriptive 2013 Title 24 Cool Roof Requirements

Default Assumptions – Section 110.8(i)1			
Roof Type	**Climate Zone**	**3-year Aged Solar Reflectance**	**Thermal Emittance**
Asphalt	1-16	0.08	0.75
Other	1-16	0.10	0.75
Nonresidential Prescriptive – Section 140.3(a)1Ai			
Roof Slope	**Climate Zone**	**Minimum 3-year Aged Solar Reflectance**	**Thermal Emittance**
≤ 2 : 12	1-16	0.63	0.75
> 2 : 12	1-16	0.20	0.75
High-Rise Residential, Hotel, Motel Prescriptive - Section 140.3(a)1Aii			
Roof Slope	**Climate Zone**	**Minimum 3-year Aged Solar Reflectance**	**Thermal Emittance**
≤ 2 : 12	9-11, 13-15	0.55	0.75
> 2 : 12	2-15	0.20	0.75
Residential Prescriptive – Section 150.1(c)11			
Roof Slope	**Climate Zone**	**Minimum 3-year Aged Solar Reflectance**	**Thermal Emittance**
≤ 2 : 12	13, 15	0.63	0.75
> 2 : 12	10-15	0.20	0.75

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.[1] This discrepancy is discussed in greater detail in the Appendix (Page 31). According to Chapter 1, Section 101.6.3 of Title 24 Part 11: "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." The 2013 Title 24, Part 6 and Part 11 Cool Roof requirements collectively are less stringent than the proposed cool roof Reach Code requirements in this cost effectiveness study.

The proposed cool roof Reach Code requirements are in Table 3.

Table 3. Proposed Cool Roof Reach Code Requirements for All Buildings

All Building Types, All Climate Zones	≤ 2:12 (low-slope)		> 2:12 (steep-slope)	
	SR	TE	SR	TE
Minimum Reach Code	≥ 0.63	≥ 0.75	≥ 0.20	≥ 0.75
TIER 1	≥ 0.68	≥ 0.85	≥ 0.28	≥ 0.85
TIER 2	≥ 0.70	≥ 0.85	≥ 0.34	≥ 0.85

[1] CALGreen is available at:
http://www.ecodes.biz/ecodes_support/Free_Resources/2013California/13Green/13Green_main.html

2.2 PROTOTYPES FOR BUILDING SIMULATION

TRC used CEC-approved building prototypes and scenarios to model the energy savings of cool roofs, presented in Table 4 and Table 5. TRC developed the high-rise multifamily prototype using a previous model from the work done by ARUP on the CEC's Zero Net Energy Roadmap. All prototypes were iterated to be as close to exactly compliant as possible, and only cool roof characteristics were changed to isolate the effect of the cool roof.

Prototypes in Table 4 were simulated in CBECC-Res 2013 v4 software, and prototypes in Table 5 were simulated in CBECC-Com 2013 v3 software.[2] In climate zones where there are no baseline code requirements, TRC used the T24 default assumptions shown in Table 2 as the baseline roof construction.

Low-rise residential building prototypes are simulated with steep-slope roofs of both asphalt and tile construction, and energy savings results are averaged for these two construction types. TRC simulated low-rise multifamily residential building prototypes with steep-slope roofs (both asphalt and tile), and also with low-slope roofs.

Table 4. Low-Rise Residential Building Prototypes

Building Type	One-Story	Two-Story	Low-Rise Multifamily	
Area	2,100	2,700	6,960	
Roof Slope	Steep-slope (>2:12)		Steep-slope (>2:12)	Low-slope (≤ 2:12)
Roof Area	2,520	1,740	4,176	
# of floors	1	2	2	
Window-to-Wall Ratio	24%	18.2%	21.0%	
Cooling Plant	Direct Expansion			
Heating Plant	Gas Furnace			
Distribution System	Ducted			
Thermal Zones	1	2	8	
Default Roof	SR = 0.10, TE = 0.75			
Prescriptive Roof	SR = 0.20, TE=0.75 in CZs 10-15 (no requirements elsewhere)			SR = 0.63, TE=0.75 in CZs 13, 15 (no requirements elsewhere)
Minimum Reach Code	SR = 0.20, TE=0.75			SR = 0.63, TE=0.75
TIER 1 Requirements	SR = 0.28, TE = 0.85			SR = 0.68, TE=0.85
TIER 2 Requirements	SR = 0.34, TE = 0.85			SR = 0.70, TE=0.85

[2] More information available at http://bees.archenergy.com/software.html and http://www.bwilcox.com/BEES/BEES.html.

Nonresidential and high-rise multifamily building prototypes were simulated with low-slope roofs only.

Table 5. Nonresidential and High-Rise Building Prototypes

Building Type	Medium Office	Retail Standalone	Strip Mall	High-Rise Multifamily
Roof Slope	Low-slope (≤ 2:12)			
Floor Area	53,600	24,695	22,500	84,531
Net Roof Area (excluding skylights)	17,876	24,051	22,324	8,431
# of floors	3	1	1	11
Window-to-Wall Ratio	33%	7.1%	10.5%	15%
Cooling Plant	Direct Expansion			Chiller
Heating Plant	Boiler			
Distribution System	3 Packaged VAVs with Hot Water Reheat	1 Packaged VAV with Hot Water Reheat	1 Packaged VAV with Hot Water Reheat	Four-Pipe Fan Coil
Area Weighted Average Lighting Power Density (W/ft²)	0.75	1.1	1.2	0.5
Area Weighted Average Plug Loads (W/ft²)	1.5	0.9	1	0.5
Thermal Zones	18	5	10	80
Default Roof	SR = 0.10, TE = 0.75			
Prescriptive Roof	SR = 0.63, TE = 0.75			SR = 0.55, TE = 0.75 in CZs 9-11, 13-15 (no requirements elsewhere)
Minimum Reach Code	SR = 0.63, TE = 0.75			
TIER 1 Reach Code	SR = 0.68, TE = 0.85			
TIER 2 Reach Code	SR = 0.70, TE = 0.85			

2.3 TIME DEPENDENT VALUATION AND COST EFFECTIVENESS

TRC used the CEC Life Cycle Cost (LCC) Methodology to demonstrate cost effectiveness of the proposed Reach Code (CEC 2011a). The LCC methodology involves estimating and quantifying the energy savings associated with measures using a Time Dependent Valuation (TDV) of energy savings (CEC 2011b). TDV is a normalized format, developed by the CEC, for comparing electricity and natural gas savings that takes into account the cost of electricity and natural gas consumed during different times of the day and year. The TDV values are based on long term discounted costs (30 years for all residential measures and nonresidential envelope measures and 15 years for all other nonresidential measures). The simulation software outputs are in terms of TDV kBTUs. The present value of the energy cost savings

in dollars is calculated by multiplying the TDV kBTU savings by an NPV factor, also developed by the CEC. The NPV factor is 0.173 for residential and 0.154 for nonresidential buildings.

The energy cost savings of the cool roof Reach Code is the difference between energy cost of a building with default or prescriptive cool roof characteristics, and the energy cost of a building with the Reach Code cool roof characteristics. TRC then compares the TDV energy cost savings to the incremental costs of the cool roof Reach Code requirement to determine cost effectiveness. Incremental costs represent the incremental initial construction and maintenance costs of the cool roof Reach Code requirement relative to the 2013 Title 24 Standards default or prescriptive requirements. The Benefit to Cost (B/C) Ratio is the incremental TDV energy costs savings divided by the incremental cost. When the B/C ratio is greater than 1.0, the added cost of the measure is more than offset by the discounted energy cost savings and the measure is deemed to be cost effective.

3. Energy Savings

Cool roofs are designed to intentionally reflect a portion of infrared radiation from the sun striking the surface of the roof, thereby reduce cooling energy consumption. Generally, benefits decrease in proportion to the amount of roof insulation present, and they produce greater savings for low-sloped roofs due to more direct angles of incidence during the summer. Since cool roofs also reflect solar radiation in the winter, they generally do increase the heating energy required for a building, though in most California Climate Zones this is not as great as the reduction in cooling energy.

TRC simulated each of the seven prototypes in all California Climate Zones, with the results summarized in Table 6, Table 7, and Table 8 below. Energy impacts are presented in terms of present value of savings in 2014 dollars (PV$). A positive PV$ value, highlighted in green, indicates that the cool roof Reach Code results in energy cost savings for a prototype. Negative PV$ values highlighted in red indicate that a cool roof increased TDV energy usage.

Table 6 shows the following results:

- **Single family** prototypes in CZs 4, 6, 7, 8, 9, and 16 show energy savings from the minimum cool roof Reach Code requirement. (CZs 10-15 already have a Title 24, part 6 prescriptive requirement equivalent to the Reach Code).
- **Low-rise multifamily** prototypes show energy savings in all Climate Zones when modeled with steep and low-slope roofs, except CZ 1. (Where there are $0 savings, the CZs already have prescriptive requirements equivalent to the minimum cool roof Reach Code). Multifamily prototypes with low-slope roofs show much higher savings than with steep-slope roofs, because the change in cool roof from the default (SR = 0.10) to the Reach Code (SR = 0.63) is much larger than the steep-slope baseline (SR = 0.10) and Reach Code (SR = 0.20).
- **High-rise multifamily** prototypes in CZs 2-8, 12, and 14-16 show energy savings from the minimum cool roof Reach Code requirement. Even though Climate Zones 14 and 15 already have prescriptive cool roof requirements of SR = 0.55 and TE = 0.75, they can benefit from adopting the minimum Reach Code.
- All **nonresidential** prototypes have zero energy benefits, because the prescriptive requirement area equivalent to the minimum cool roof Reach Code.

The results in Table 7 and Table 8 can be interpreted in a similar way to Table 6. Prototypes in some CZs do not show any differences in energy savings when going between the Reach Code tiers. This is the case when the building simulations show fluctuations in heating and cooling energy, but they have an offsetting effect in terms of TDV energy usage.

Table 6. Minimum Reach Code Present Value of Energy Savings

		Residential				High-Rise and Nonresidential			
Reach Code	CZ	1-story Single Family	2-story Single Family	Low-rise Multifamily (steep slope)	Low-rise Multifamily (low slope)	High-rise Multifamily	Medium Office	Standalone Retail	Strip Mall
Minimum	1	-$449	-$255	-$343	-$2,480	-$3,905	$0	$0	$0
	2	-$73	$107	$897	$4,022	$3,905	$0	$0	$0
	3	-$218	-$82	$205	$578	$1,302	$0	$0	$0
	4	$85	$192	$885	$4,238	$3,905	$0	$0	$0
	5	-$291	-$135	$271	$506	$5,207	$0	$0	$0
	6	$0	$54	$771	$3,323	$5,207	$0	$0	$0
	7	$58	$86	$572	$2,709	$7,811	$0	$0	$0
	8	$567	$497	$1,385	$7,164	$6,509	$0	$0	$0
	9	$768	$726	$1,577	$8,188	$0	$0	$0	$0
	10	$0	$0	$0	$8,874	$0	$0	$0	$0
	11	$0	$0	$0	$8,826	$0	$0	$0	$0
	12	$0	$0	$0	$7,959	$3,905	$0	$0	$0
	13	$0	$0	$0	$0	$0	$0	$0	$0
	14	$0	$0	$0	$7,309	$2,604	$0	$0	$0
	15	$0	$0	$0	$0	$1,302	$0	$0	$0
	16	$25	$156	$662	$3,383	$3,905	$0	$0	$0

Table 7. Tier 1 Reach Code Present Value of Energy Savings

		Residential				High-Rise and Nonresidential			
Reach Code	CZ	1-story Single Family	2-story Single Family	Low-rise Multifamily (steep slope)	Low-rise Multifamily (low slope)	High-rise Multifamily	Medium Office	Standalone Retail	Strip Mall
Tier 1	1	-$1,117	-$626	-$975	-$3,119	-$3,905	-$826	-$6,607	-$1,733
	2	-$394	$119	$1,740	$4,238	$3,905	$3,303	$0	$3,119
	3	-$563	-$229	$313	$482	$1,302	$1,652	-$378	$1,040
	4	-$31	$273	$1,692	$4,600	$3,905	$2,478	$0	$2,772
	5	-$730	-$383	$385	$277	$3,905	$2,478	-$4,129	$693

Reach Code	CZ	Residential				High-Rise and Nonresidential			
		1-story Single Family	2-story Single Family	Low-rise Multifamily (steep slope)	Low-rise Multifamily (low slope)	High-rise Multifamily	Medium Office	Standalone Retail	Strip Mall
	6	-$125	$49	$1,523	$3,600	$6,509	$3,303	$826	$3,811
	7	-$16	$135	$1,162	$3,058	$6,509	$4,955	$4,129	$4,158
	8	$1,054	$953	$2,926	$8,188	$7,811	$4,955	$2,478	$4,158
	9	$1,448	$1,408	$3,215	$9,295	$1,302	$3,303	$4,955	$5,198
	10	$783	$780	$1,908	$10,162	$0	$1,652	$5,781	$4,158
	11	$906	$923	$1,770	$10,126	$1,302	$3,303	$4,955	$5,544
	12	$699	$710	$1,571	$9,055	$5,207	$2,478	$3,303	$4,851
	13	$1,055	$1,023	$1,951	$1,337	$0	$4,129	$4,955	$5,891
	14	$718	$752	$1,487	$8,332	$2,604	$4,129	$8,259	$6,930
	15	$1,780	$1,569	$3,113	$2,276	$1,302	$4,955	$11,562	$9,009
	16	-$151	$206	$1,337	$3,648	$3,905	$2,478	$7,433	$6,584

Table 8. Tier 2 Reach Code Present Value of Energy Savings

Reach Code	CZ	Residential				High-Rise and Nonresidential			
		1-story Single Family	2-story Single Family	Low-rise Multifamily (steep slope)	Low-rise Multifamily (low slope)	High-rise Multifamily	Medium Office	Standalone Retail	Strip Mall
Tier 2	1	-$1,393	-$773	-$1,240	-$3,251	-$5,207	-$826	-$8,259	-$2,079
	2	-$532	$140	$2,125	$4,311	$3,905	$4,955	$0	$4,158
	3	-$698	-$285	$373	$470	$1,302	$2,478	-$378	$1,040
	4	-$82	$327	$2,107	$4,696	$3,905	$3,303	$826	$3,465
	5	-$906	-$483	$427	$229	$3,905	$2,478	-$4,955	$1,039
	6	-$171	$49	$1,848	$3,648	$6,509	$4,955	$1,652	$4,504
	7	-$78	$149	$1,457	$3,143	$6,509	$5,781	$4,955	$5,544
	8	$1,262	$1,172	$3,636	$8,453	$6,509	$5,781	$2,478	$5,544
	9	$1,773	$1,742	$4,028	$9,597	$2,604	$4,955	$5,781	$6,237
	10	$1,144	$1,142	$2,769	$10,463	$0	$2,478	$7,433	$5,198
	11	$1,350	$1,392	$2,613	$10,451	$0	$4,129	$6,607	$7,277
	12	$1,028	$1,060	$2,354	$9,368	$5,207	$3,303	$4,955	$5,544
	13	$1,588	$1,544	$2,896	$1,686	$0	$5,781	$5,781	$6,930

		Residential				High-Rise and Nonresidential			
Reach Code	CZ	1-story Single Family	2-story Single Family	Low-rise Multifamily (steep slope)	Low-rise Multifamily (low slope)	High-rise Multifamily	Medium Office	Standalone Retail	Strip Mall
	14	$1,057	$1,130	$2,191	$8,597	$2,604	$4,955	$9,910	$8,663
	15	$2,536	$2,263	$4,539	$2,745	$1,302	$5,781	$14,866	$11,435
	16	-$233	$245	$1,650	$3,733	$3,905	$3,303	$8,259	$7,970

4. Cost Analysis

The 2013 CASE reports (AEC 2011b, 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 at the time of the CASE analysis (2011). The following cost analysis shows that, since that time, the number of products available to meet the 2013 Title 24 Prescriptive reflectance requirements has increased, including products that meet the proposed Tier 1 and Tier 2 levels of stringency.

TRC conducted interviews over six (6) months in 2014 with several roofers and roof supply distributors throughout California. For the complete set of collected data, please see *Appendix C: Complete Cost Data Collected.* Multiple roofers made the statement that there is no additional labor to install cool roof products. Additionally, several distributors reported that the product prices are relatively constant for a given region (i.e. the Bay Area in general will have consistent pricing for a particular product, same for the Central Coast and Southern California regions). Five regions were identified during cost collection:

- Northern California
- Bay Area
- Central Coast
- Central California
- Southern California

Specific Climate Zone costs were determined by combining the data points from these regions, as shown in Table 9. For a map of California Climate Zones, please see *Appendix A: Map of California Climate Zones.*

Table 9. Regions Used to Determine Climate Zone Specific Costs

Climate Zone	Region
1	Northern California
2	Northern California, Bay Area
3	Bay Area, Central Coast
4	Bay Area, Central Coast, Central California
5	Central Coast
6	Southern California
7	Southern California
8	Southern California
9	Southern California
10	Southern California
11	Northern California
12	Bay Area, Central California
13	Central Coast, Central California
14	Southern California
15	Southern California
16	Northern California, Central California, Southern California

4.1 STEEP-SLOPED ROOFS FOR RESIDENTIAL BUILDINGS

4.1.1 Cool Roofs Rating Council Data

The Cool Roofs Rating Council's (CRRC) product directory[3] contains 143 clay or concrete tile products with an aged solar reflectance exceeding 0.28, and 85 of which meet have an aged solar reflectance of 0.34 or higher. There are 19 asphalt shingle products found in the CRRC product directory with an aged solar reflectance greater than 0.28, three (3) of which meet Tier 2 with an initial solar reflectance of 0.34 or higher (compared to zero at a solar reflectance of 0.30 or higher in 2011).

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 several distributors have said that these products can be ordered upon request at no additional cost.

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

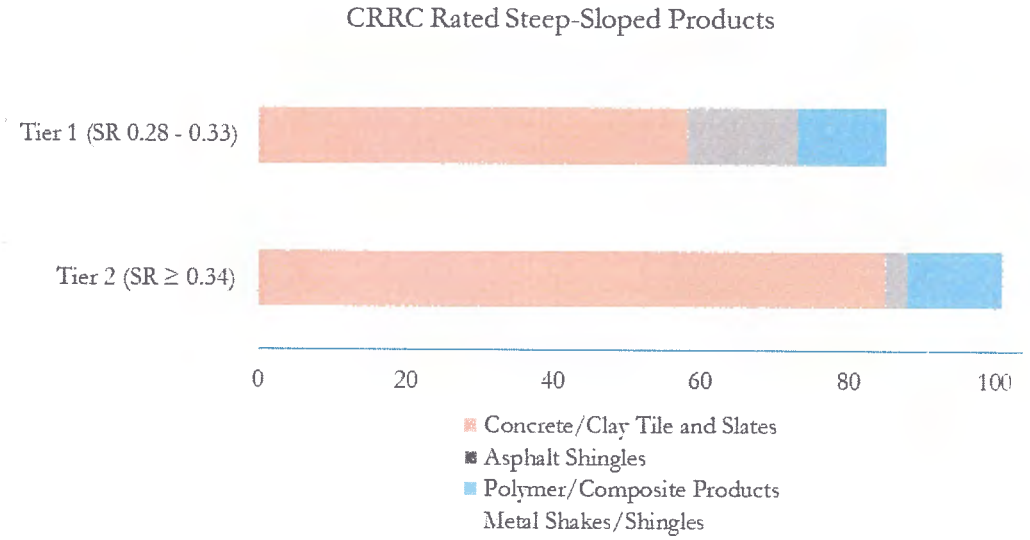

Figure 1. Steep-sloped Roof Product Availability in CRRC Product Directory as of March 2015

4.1.2 Summary of Interview Findings

Based on interviews with several roofers and roof supply distributors in the Fremont, San Mateo, Salinas, South San Francisco, Paso Robles, Tahoe, Sacramento, Santa Rosa, Fresno, San Jose, Los Angeles, and San Diego regions, 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.

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

The incremental cost estimates for steep-slope roof products (asphalt shingles and concrete and clay tiles) are provided below in Table 10, with detailed findings in the following sections. TRC calculated costs by interviewing roofers and roof supply distributors and searching online retail stores for product pricing. Note the following from Table 10:

- The incremental costs are above the base case roof. When providing base case costs, roofers and distributors were asked for the price of a basic quality asphalt or tile product sold in their region. Therefore, the base case costs do not incorporate the high costs associated with higher end non-cool roof products.
- The cost premium for cool roof products meeting the Tier 1 and Tier 2 requirements varies greatly depending on the product selected. The data collected rarely shows a consistently higher price correlated with higher solar reflectances.
- Tile products exceeding the Tier 2 requirement can be found at the same cost as a non-cool roof tile product. Several roofing distributors, manufacturers, and roofers stated that a cool roof designation does not affect the price of the tile and most tile products meet cool roof standards. Thus, tile roofing products do not show any cost premium for cool roof products.
- According to a California roofer, 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 notes that their company typically installs asphalt shingles on residential new construction, while tile is more common along the coast. Because TRC could not locate a data source to verify the roofer assertions, a breakdown of 50:50 between asphalt shingles and tiles is assumed.
- The incremental costs shown in Table 10 are an average between the incremental cost for tile and asphalt. Essentially, because the incremental cost of tile is $0, the total incremental cost is half of the incremental costs for asphalt shingles.
- The Minimum Reach Code has $0 incremental cost in CZs 10-15 because it is equivalent to the prescriptive requirement in these CZs. The Base Case cost in these CZs has been grayed out, and the Tier 1 and Tier 2 costs are incremental from the Minimum Reach Code.

Table 10. Summary of Steep-Slope Roof Incremental Costs above Base Case ($/ft²)

CZ	# Price Points	Avg Cost - Base Case	Avg Cost - Minimum (SR = 0.20, TE = 0.75)	Min +/-	Avg Cost - Tier 1 (SR = 0.28, TE = 0.85)	Tier 1 +/-	Avg Cost - Tier 2 (SR = 0.34, TE = 0.85)	ier +/-
1	19	$1.13	$1.25	$0.12	$1.27	$0.15	$1.69	$0.56
2	47	$1.11	$1.31	$0.20	$1.23	$0.12	$1.60	$0.50
3	40	$1.07	$1.42	$0.35	$1.31	$0.25	$1.54	$0.47
4	48	$1.15	$1.28	$0.13	$1.22	$0.08	$1.52	$0.38
5	12	$1.04	$1.46	$0.42	$1.44	$0.40	$1.56	$0.52
6	53	$1.09	$1.33	$0.25	$1.15	$0.07	$1.35	$0.26
7	53	$1.09	$1.33	$0.25	$1.15	$0.07	$1.35	$0.26
8	53	$1.09	$1.33	$0.25	$1.15	$0.07	$1.35	$0.26
9	53	$1.09	$1.33	$0.25	$1.15	$0.07	$1.35	$0.26
10	53	$1.09	$1.33	$0.00	$1.15	-$0.18	$1.35	$0.01
11	19	$1.13	$1.25	$0.00	$1.27	$0.03	$1.69	$0.44
12	36	$1.20	$1.19	$0.00	$1.11	-$0.07	$1.51	$0.32

13	20	$1.18	$1.23	$0.00	$1.24	$0.01	$1.53	$0.29
14	53	$1.09	$1.33	$0.00	$1.15	-$0.18	$1.35	$0.01
15	53	$1.09	$1.33	$0.00	$1.15	-$0.18	$1.35	$0.01
16	80	$1.18	$1.19	$0.02	$1.15	-$0.02	$1.51	$0.32

4.1.3 Detailed Findings - Concrete and Clay Tile

Multiple distributors noted that concrete and clay tile products typically 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 (see Figure 2). Interviews and online research of retailers revealed the following:

- Distributor: Prices are the same for a tile product in colors that do and do not meet cool roof requirements.
- Distributor: A cool roof has no effect on the cost.
- Multiple distributors: 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.

Thus, 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, as in Figure 2. Thus, cool roof products are available in the lower price categories.

Figure 2. Conventional and Cool Colored Tiles (EPA 2011)

4.1.4 Detailed Findings - Asphalt Shingles

Based on interviews with several roofers and roof supply distributors throughout California, roofers are able to meet the Tier 1 and Tier 2 requirements at some 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 prices per square foot in Table 11 were obtained from roofers, roof supply distributors and retail stores. As stated in the cost summary, the base case costs do not incorporate the high costs of higher end non-cool roof products.

Table 11. Asphalt Shingle Cost Data for California Regions ($/ft²)

Region	Price Points	Base Case	each Code		
			Minimum		Tier 2
Northern California	19	$1.03	$1.27	$1.32	$2.15
Bay Area	28	$0.95	$1.51	$1.15	$1.81
Central Coast	12	$0.86	$1.70	$1.66	$1.90
Central California	8	$1.40	$0.78	$0.85	$1.76
Southern California	53	$0.93	$1.42	$1.06	$1.45

The costs in Table 11 generally indicate an incremental cost premium for installing cool roofs, as the Minimum, Tier 1, and Tier 2 prices are higher than the Base Case costs in most regions. However, products are available from the same manufacturers which do not meet any of the cool roof requirements but exceed the cost of the highly reflective products due to other quality and durability characteristics. As shown in Figure 3, the lowest cost estimates for all three cool roof levels are lower than the highest estimate for a base case product.

Tier 1 products show a large range of costs due to the number of asphalt products available to meet these requirements. The lower costing products are typically base case shingles in light or white shades; the higher costing products are typically designated "cool roof" products that come in various shades and carry a cost premium. Some Tier 1 products are even more expensive than Tier 2 products due to other quality performance characteristics.

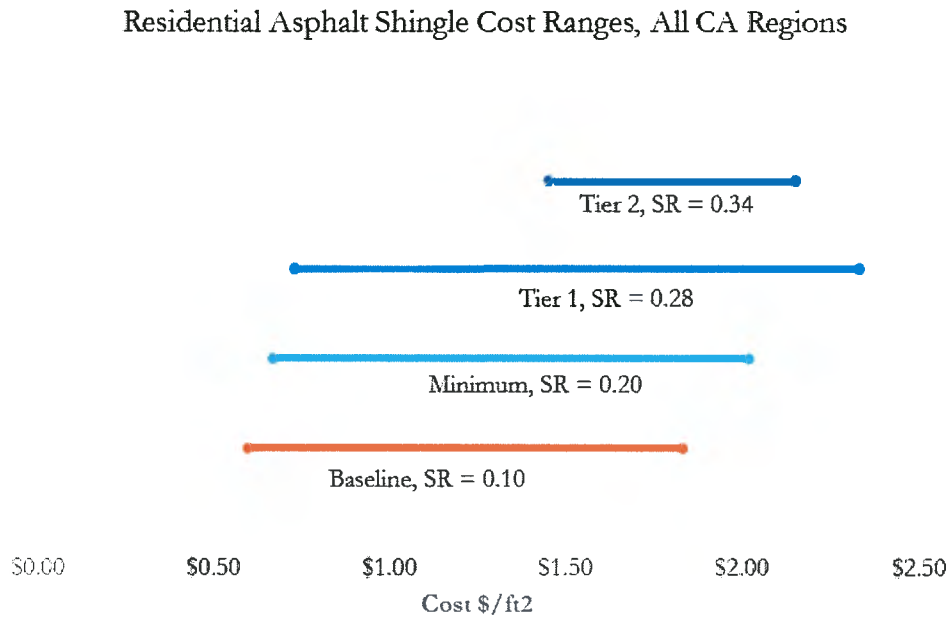

Figure 3. Asphalt Shingles Cost Ranges at Different SR Levels

This range of costs show that it is possible to install an asphalt shingle cool roof at no additional cost, as compared to an equivalent quality product that has a lower CRRC cool roof rating. 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[4]. 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 more costly than a base case product, the quality is also better. The price differential for some of these higher-scale cool roof shingles are based on other factors in addition to cool roof characteristics. Interviews and researching online retailers revealed the following:

- Multiple 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 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.
- Distributor: Purchasing asphalt shingles in large volumes can result in significant savings over base case prices.
- Distributor: There are manufacturers that deliver to the west coast, but do not ship their cool roof products because there is no demand for them. This distributor believes this dynamic will change if cool roofs are mandated.

As shown in Table 11, in CZs without a cool roof requirement, the cost premium of a Tier 1 cool roof can range between -$0.60/ft² to $0.80/ft², compared to a basic asphalt shingle. Tier 1 can be met with basic asphalt shingles in white shades, which are lower cost than some of the manufacturer-specified cool roof products.

Table 12 and Table 13 show the differences in costs between white asphalt shingle products and manufacturer-specified cool roof products throughout California. Table 12 shows that white shades of basic asphalt shingles can achieve Tier 1 with lower incremental cost (-$0.20/ft²) than base case shingles (all colors). The availability and popularity of white asphalt shingle products is unknown, but they bring the overall cost of Tier 1 asphalt shingle products downwards.

[4] Lowes.com

Table 12. Cost of White Asphalt Shingle Products

	Low Estimate ($/ft²)	High Estimate ($/ft²)	Average cost ($/ft²)	Average Incremental cost ($/ft²)
Base case[5]	$0.60	$1.83	$0.96	-
Minimum	$0.67	$0.82	$0.76	-$0.20
Tier 1	$0.72	$1.31	$0.87	-$0.09
Tier 2	none	none	none	-

Table 13. Cost of Cool Roof Designated Asphalt Shingle Products

	Low Estimate ($/ft²)	High Estimate ($/ft²)	Average cost ($/ft²)	Average Incremental cost ($/ft²)
Base case[5]	$0.60	$1.83	$0.96	-
Minimum	$1.34	$2.02	$1.63	$0.67
Tier 1	$1.21	$2.33	$1.60	$0.63
Tier 2	$1.45	$2.15	$1.80	$0.84

4.2 LOW-SLOPED COOL ROOFS

Interviews found that roofers may be 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 are cost savings associated with choosing a low-slope cool roof meeting the Prescriptive or Tier 1 levels of reflectance.

The 2013 Title 24 update increased the statewide prescriptively required reflectance for nonresidential low-sloped roofs to 0.63. In this report, this reflectance serves as the base case solar reflectance of low-sloped roofs on all nonresidential buildings. The proposed Reach Code requirements make the prescriptive value the minimum required, and increase the required reflectance to 0.68 and 0.70 for Tier 1 and Tier 2, respectively.

High-rise residential low-slope buildings in CZs 9-11 and 13-15 have prescriptive requirements for a solar reflectance of 0.55. No other CZs have low-slope requirements for high-rise residential buildings. There are prescriptive requirements for nonresidential and high-rise residential steep-slope roofs that have not been analyzed in this report because they are considered to be constructed very rarely, and the results of this analysis would not apply to a large number of buildings.

According to industry interviews, there is no additional labor for installing a cool roof product, as it requires the same techniques and types of products as installing a base case 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 data collection below, and supported 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.*

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

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 December 2014, the CRRC products directory contains 258 field applied coatings, 7 built-up and modified bitumen sheet roofing, and 24 single ply thermoplastic roofing options that meet the Tier 1 requirements (SR = 0.68, TE = 0.85).

Based on interviews with several roofers and roof supply distributors contacted in March through December of 2014 in the Petaluma, Daly City, Fremont, Sacramento, Lake Tahoe, Fresno, San Jose, Los Angeles, and San Diego areas, roofers are able to meet the Tier 1 and Tier 2 requirements at little or no additional cost, depending on the product selected. This finding is consistent with the findings from the 2013 Nonresidential Cool Roofs CASE Report (IOU 2011). A few roofers noted that there are certain product categories that would add about 10-15% more to the material cost to meet cool roof requirements, but that there are alternative methods that have no additional cost. Multiple roofers made the statement that there is no additional labor to install cool roof products. Two roofers in the Bay Area noted that their base case commercial low-sloped roofing application is cool roof; one of which noted that their base case is white reflective roofing at a solar reflectance of 0.70. This second roofer also mentioned that this is base case practice for commercial roofers in the area.

Table 14 below displays the low, high, and average costs for products to meet the cool roof requirements. Roofers and distributors were asked to provide the cost for a base case product for the various applications, such as a standard field applied coating or cap sheet. The following table includes cost estimates for field applied coatings, single-ply TPO/PVC, and cap sheets.

Table 14. Low-Sloped Products Cost Data ($/ft²) Collected March – December 2014

	# of cost data points	Low Estimate	High Estimate	Average cost	Averag Incremental cost for NonRes	Averag Incremental cost for High-Rise Res
Base Case[6]	8	$0.21	$1.37	$0.74	–	–
Minimum	25	$0.28	$1.43	$0.69	–	-$0.05
Tier 1	9	$0.39	$1.05	$0.57	-$0.12	-$0.17
Tier 2	20	$0.33	$1.26	$0.61	-$0.08	-$0.13

Cost figures for all Climate Zones, shown in Table 16 and Table 16, are the prices used in the cost effectiveness analysis. Base case costs are only relevant to the low-rise and high-rise multifamily models because the Title 24 default or prescriptive requirement is lower than the minimum Reach Code requirement for these building types. Thus, the Reach Code incremental cost is compared to the base case cost in Table 15. As described earlier, Title 24 Part 6 prescriptive requirements for nonresidential buildings serve as the 'base case' for cost effectiveness, and these are the same as the minimum Reach Code requirements. Thus, in Table 16 the Reach Code costs are compared to the Minimum Reach Code.

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

These prices represent a limited sample, and a small difference in cost (e.g., $0.03 difference for a Tier 2 product in CZ 3) in cost may be considered within a margin of error.

Table 15. Low-sloped Multifamily Residential Roof Average and Incremental Costs

CZ	# Points	Avg Cost – Base Case	Avg Cost – Minimum (SR = 0.63, TE = 0.75)	Min +/-	Avg Cost – Tier 1 (SR = 0.68, TE = 0.85)	Tier 1 +	Avg Cost – Tier 2 (SR = 0.70, TE = 0.85)	Tier 2 +/-
1	7	$0.66	$0.76	$0.10	$0.46	-$0.20	$0.40	-$0.26
2	23	$0.66	$0.76	$0.10	$0.46	-$0.20	$0.40	-$0.26
3	25	$0.67	$0.39	-$0.28	$0.46	-$0.22	$0.42	-$0.25
4	25	$0.67	$0.39	-$0.28	$0.46	-$0.22	$0.42	-$0.25
5	9	$0.67	$0.43	-$0.24	$0.46	-$0.22	$0.42	-$0.26
6	21	$0.81	$0.97	$0.17	$0.56	-$0.25	$0.97	$0.17
7	21	$0.81	$0.97	$0.17	$0.56	-$0.25	$0.97	$0.17
8	21	$0.81	$0.97	$0.17	$0.56	-$0.25	$0.97	$0.17
9	21	$0.81	$0.97	$0.17	$0.56	-$0.25	$0.97	$0.17
10	21	$0.81	$0.97	$0.17	$0.56	-$0.25	$0.97	$0.17
11	7	$0.67	$0.56	-$0.11	$0.46	-$0.21	$0.41	-$0.25
12	16	$0.67	$0.36	-$0.32	$0.46	-$0.22	$0.43	-$0.25
13	9	$0.67	$0.39	-$0.28	$0.46	-$0.22	$0.42	-$0.25
14	21	$0.81	$0.97	$0.17	$0.56	-$0.25	$0.97	$0.17
15	21	$0.81	$0.97	$0.17	$0.56	-$0.25	$0.97	$0.17
16	28	$0.71	$0.70	-$0.02	$0.49	-$0.22	$0.60	-$0.11

Table 16. Low-sloped Nonresidential Roof Average and Incremental Costs

CZ	# Price Points	Avg Cost – Minimum (SR = 0.63, TE = 0.75)	Min +/-	Avg Cost – Tier 1 (SR = 0.68, TE = 0.85)	Tier 1 +/-	Avg Cost – Tier 2 (SR = 0.70, TE = 0.85)	Tier 2 +/-
1	7	$0.76	$0.00	$0.46	-$0.30	$0.40	-$0.36
2	23	$0.76	$0.00	$0.46	-$0.30	$0.40	-$0.36
3	25	$0.39	$0.00	$0.46	$0.06	$0.42	$0.03
4	25	$0.39	$0.00	$0.46	$0.06	$0.42	$0.03
5	9	$0.43	$0.00	$0.46	$0.03	$0.42	-$0.01
6	21	$0.97	$0.00	$0.56	-$0.41	$0.97	$0.00
7	21	$0.97	$0.00	$0.56	-$0.41	$0.97	$0.00
8	21	$0.97	$0.00	$0.56	-$0.41	$0.97	$0.00
9	21	$0.97	$0.00	$0.56	-$0.41	$0.97	$0.00
10	21	$0.97	$0.00	$0.56	-$0.41	$0.97	$0.00
11	7	$0.56	$0.00	$0.46	-$0.10	$0.41	-$0.14
12	16	$0.36	$0.00	$0.46	$0.10	$0.43	$0.07
13	9	$0.39	$0.00	$0.46	$0.06	$0.42	$0.03

CZ	# Price Points	Avg Cost – Minimum (SR = 0.63, TE = 0.75)	Min +/-	Avg Cost – Tier 1 (SR = 0.68, TE = 0 85)	Tier 1 +/-	Avg Cost – Tier 2 (SR = 0.70, TE = 0.85)	Tier 2
14	21	$0.97	$0.00	$0.56	-$0.41	$0.97	$0.00
15	21	$0.97	$0.00	$0.56	-$0.41	$0.97	$0.00
16	28	$0.70	$0.00	$0.49	-$0.20	$0.60	-$0.10

5. Cost-Effectiveness Analysis

The cost-effectiveness results using the energy savings and the Reach Code costs described in the preceding sections are provided below. A positive PV$ indicates that there are energy savings associated with the cool roof. The PV$ is divided by the incremental price of the cool roof to determine the Benefit-to-Cost (B/C) ratio of the cool roof. Thus, a B/C ratio over 1 indicates the cool roof is cost effective over its lifetime.

Because of the extensive data collected, only summary findings are provided in this section. Detailed cost effectiveness results and recommendations for each Climate Zone are located in *Appendix C: Complete Cost Data Collected*, and a summary of the cost effectiveness for all prototypes and climate zones is provided below in Table 17, Table 18, and Table 19. Cells highlighted in green indicate that the proposed cool roof reach code is cost effective in those Climate Zones. Dashed lines in Table 17 indicate that the Title 24 Prescriptive requirement is the same as the Minimum Reach Code requirement.

When viewing the cost effectiveness results, note the following:

Single Family Residential

- Prototypes in Climate Zones 1-7 have relatively low or negative energy savings associated with the cool roofs Reach Code. This results in mostly cost ineffective Reach Code.
- Prototypes in Climate Zones 8 and 9 show that adopting the Minimum Reach Code is moderately cost effective, but adopting Tier 1 and Tier 2 Reach Codes is significantly cost effective.
- Prototypes in Climate Zones 10-15 generally show that adopting Tier 1 and Tier 2 Reach Codes cost effective, despite already having prescriptive requirements equivalent to the Minimum Reach Code.

Low-Rise Multifamily

- Prototypes show energy savings for both low-slope and steep-slope cool roof Reach Codes in Climate Zones 2-16. Low-slope roof types provide much higher energy savings because there is a larger difference between the Minimum Reach Code of SR = 0.63 from the default value of SR = 0.10. (The minimum steep-slope Reach Code is SR = 0.28).
- Prototypes in Climate Zones 2, 4, and 6-16 show that adopting the steep-slope Reach Code Tiers 1 and 2 is cost effective.
- Prototypes in Climate Zones 2-16 show that adopting the low-slope cool roof Reach Code is cost effective.

High-Rise Multifamily

- Prototypes in Climate Zones 9-11, 13, and 15 do not show energy savings at various Reach Code levels. These are Climate Zones with prescriptive cool roof requirements.

- Climate Zone 14 also has prescriptive cool roof requirements, but shows that adopting cool roofs leads to energy savings cost effectively.
- Climate Zones 2-8, 12, and 16 would see energy reductions from high-rise multifamily cool roofs.

Nonresidential

- Nonresidential low-slope roofs are prescriptively required by the 2013 Standards to have a cool roof (SR = 0.63). Thus the minimum reach code proposal does not result in an incremental cost in any of the Climate Zones for these prototypes.
- Standalone Retail new construction prototypes in Climate Zones 1-5 show low or negative energy savings as a result of the Reach Code.
- Although simulations show low or negative energy savings for new construction, the Standalone Retail prototype shows energy savings in Climate Zone 3 and 4 when considering a retrofit situation with higher internal lighting loads.
- Medium Office and Strip Mall prototypes in Climate Zones 2-5 show that adopting the cool roof Reach Code is cost effective.
- All nonresidential prototypes in Climate Zones 6-16 demonstrate that the cool roofs Reach Code is cost effective.

To help policymakers in each Climate Zone make decisions for their jurisdiction, Climate-Zone-specific result summaries are provided in *Appendix D: Full Cost Effectiveness Results*.

Table 17. Benefit to Cost Ratios for the Minimum Reach Code in All CZs

		Residential				High-Rise and Nonresidential			
Reach Code	CZ	1-story Single Family	2-story Single Family	Low-rise Multifamily (steep slope)	Low-rise Multifamily (low slope)	High-rise Multifamily	Medium Office	Standalone Retail	Strip Mall
Minimum	1	No Savings	No Savings	No Savings	No Savings	No Savings	-	-	-
	2	No Savings	0.3	1.1	9.7	4.7	-	-	-
	3	No Savings	No Savings	0.1	No Costs	No Costs	-	-	-
	4	0.3	0.8	1.6	No Costs	No Costs	-	-	-
	5	No Savings	No Savings	0.2	No Costs	No Costs	-	-	-
	6	No Savings	0.1	0.7	4.8	3.7	-	-	-
	7	0.1	0.2	0.6	3.9	5.6	-	-	-
	8	0.9	1.2	1.3	10.3	4.6	-	-	-
	9	1.2	1.7	1.5	11.8	No Savings	-	-	-
	10	-	-	-	12.7	No Savings	-	-	-
	11	-	-	-	No Costs	No Savings	-	-	-
	12	-	-	-	No Costs	No Costs	-	-	-
	13	-	-	-	-	No Savings	-	-	-
	14	-	-	-	10.5	1.9	-	-	-
	15	-	-	-	-	0.9	-	-	-
	16	0.5	4.8	8.5	No Costs	No Costs	-	-	-

Table 18. Benefit to Cost Ratios for Tier 1 Reach Code in All CZs

Reach Code	CZ	Residential				High-Rise and Nonresidential			
		1-story Single Family	2-story Single Family	Low-rise Multifamily (steep slope)	Low-rise Multifamily (low slope)	High-rise Multifamily	Medium Office	Standalone Retail	Strip Mall
Tier 1	1	No Savings	No Savings	No Savings	No Savings	No Savings	No Savings	No Savings	No Savings
	2	No Savings	0.6	3.4	No Costs	No Costs	No Costs	No Savings	No Costs
	3	No Savings	No Savings	0.3	No Costs	No Costs	1.4	No Savings	0.7
	4	No Savings	2.1	5.4	No Costs	No Costs	2.2	No Savings	1.9
	5	No Savings	No Savings	0.2	No Costs	No Costs	5.0	No Savings	1.1
	6	No Savings	0.4	5.6	No Costs	No Costs	No Costs	No Costs	No Costs
	7	No Savings	1.2	4.3	No Costs	No Costs	No Costs	No Costs	No Costs
	8	6.4	8.4	10.7	No Costs	No Costs	No Costs	No Costs	No Costs
	9	8.8	12.4	11.8	No Costs	No Costs	No Costs	No Costs	No Costs
	10	No Costs	No Costs	No Costs	No Costs	No Savings	No Costs	No Costs	No Costs
	11	13.9	20.5	16.4	No Costs	No Costs	No Costs	No Costs	No Costs
	12	No Costs	No Costs	No Costs	No Costs	No Costs	1.4	1.4	2.2
	13	50.6	71.0	56.4	No Costs	No Savings	3.6	3.2	4.1
	14	No Costs	No Costs	No Costs	No Costs	No Costs	No Costs	No Costs	No Costs
	15	No Costs	No Costs	No Costs	No Costs	No Costs	No Costs	No Costs	No Costs
	16	No Savings	No Costs	No Costs	No Costs	No Costs	No Costs	No Costs	No Costs

Table 19. Benefit to Cost Ratios for Tier 2 Reach Code in All CZs

		Residential				High-Rise and Nonresidential			
Reach Code	CZ	1-story Single Family	2-story Single Family	Low-rise Multifamily (steep slope)	Low-rise Multifamily (low slope)	High-rise Multifamily	Medium Office	Standalone Retail	Strip Mall
Tier 2	1	No Savings	No Savings	No Savings	No Savings	No Savings	No Savings	No Savings	No Savings
	2	No Savings	0.2	1.0	No Costs	No Costs	No Costs	No Savings	No Costs
	3	No Savings	No Savings	0.2	No Costs	No Costs	4.5	No Savings	1.5
	4	No Savings	0.5	1.3	No Costs	No Costs	6.1	1.1	5.1
	5	No Savings	No Savings	0.2	No Costs	No Costs	No Costs	No Savings	No Costs
	6	No Savings	0.1	1.7	5.2	4.6	256.8	63.6	186.9
	7	No Savings	0.3	1.3	4.5	4.6	299.6	190.9	230.1
	8	1.9	2.6	3.4	12.1	4.6	299.6	95.4	230.1
	9	2.7	3.9	3.7	13.7	1.8	256.8	222.7	258.8
	10	34.2	49.4	49.9	14.9	No Savings	128.4	286.3	215.7
	11	1.2	1.8	1.4	No Costs	No Savings	No Costs	No Costs	No Costs
	12	1.3	1.9	1.8	No Costs	No Costs	2.6	2.9	3.5
	13	2.1	3.0	2.4	No Costs	No Savings	10.6	7.9	10.2
	14	31.6	48.9	39.5	12.3	1.8	256.8	381.8	359.5
	15	75.8	97.9	81.8	3.9	0.9	299.6	572.6	474.5
	16	No Savings	0.4	1.2	No Costs	No Costs	No Costs	No Costs	No Costs

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

6.1 GLOBAL COOLING: INCREASING WORLD-WIDE URBAN ALBEDOS TO OFFSET CO2

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 and thereby reducing GHG emissions associated with energy generation.
- The solar reflective 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. Both the direct and indirect mechanisms for cool roof impact on GHG are depicted below in Figure 4.

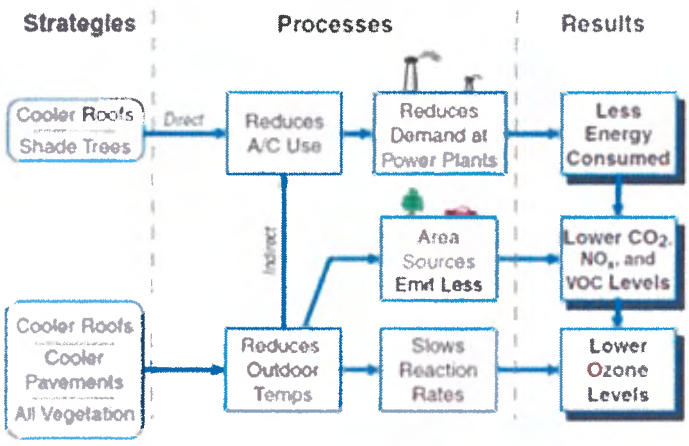

Figure 4. Mechanism: "Cool Roofs, Cool Pavements and Shade Trees Save Energy and Improve Air Quality". [7]

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 decreasing emitted CO_2 equivalent by -2.5 kg CO_2 per m^2 (or -0.23 kg CO_2 per square foot).

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[7] 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

6.2 MID-CENTURY WARMING IN THE LOS ANGELES REGION

According to the climate change advocacy group C-Change LA[8], 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 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* (Hall, 2012). 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

6.3 REDUCING URBAN HEAT ISLANDS: COMPENDIUM OF STRATEGIES

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.

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

7. Documents Relied Upon

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17. 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

18. 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

8. Appendices

8.1 APPENDIX A: MAP OF CALIFORNIA CLIMATE ZONES

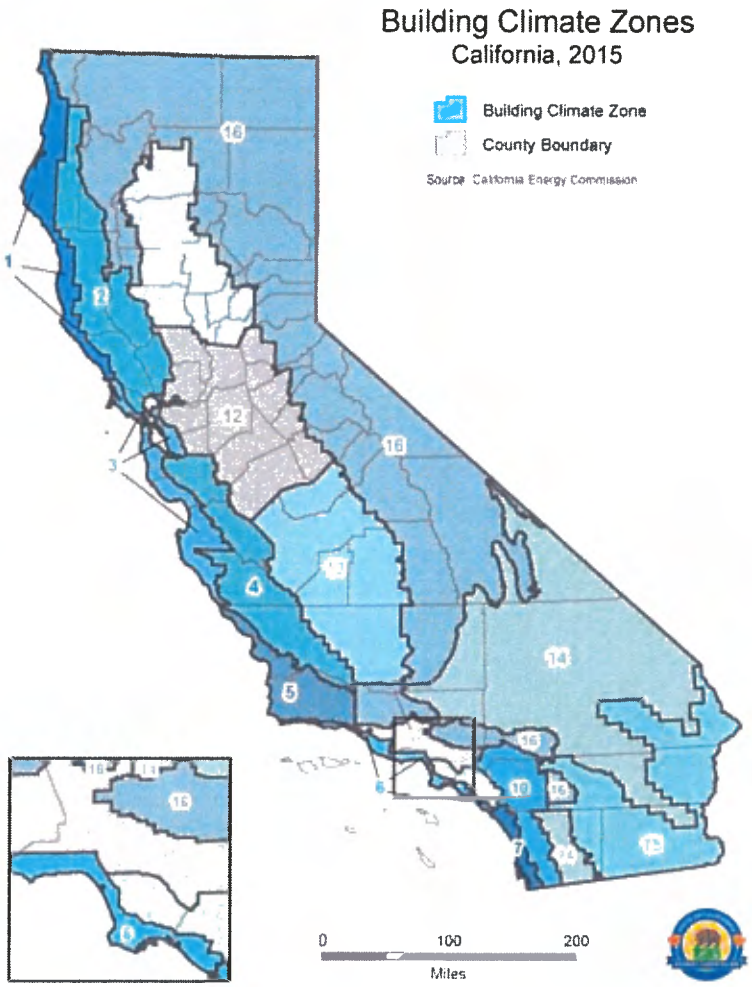


Figure 5. California Climate Zones Map (courtesy of CEC)

For a list of jurisdictions and zip codes in each climate zone, please reference the Title 24 Standards Joint Appendices JA2.

8.2 APPENDIX B: COOL ROOF REQUIREMENTS IN TITLE 24 PART 6 AND PART 11 (CALGREEN)

The Building Energy Efficiency Standards (Title 24, Part 6 of the California Code of Regulations) establish a minimum level of building energy efficiency. The California Energy Commission has adopted and periodically updates the Standards to ensure that building construction, system design and installation achieve energy efficiency and preserve outdoor and indoor environmental quality. A building can be designed to a higher efficiency level, resulting in additional energy savings. The Standard updates 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.

Local governmental agencies may adopt and enforce other energy standards, such as Reach Codes, 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.

CalGreen has both mandatory and voluntary (CALGreen Tier 1 and Tier 2) measures. As shown below in Table 20, the most recently adopted versions (2013) of Title 24 Parts 6 and 11 have different requirements. CALGreen set Tier 1 levels for low-sloped cool roofs below the prescriptive requirements contained in Title 24 Part 6. (The CALGreen Tier 1 steep-slope roofs requirements are equivalent to Title 24 Part 6).

According to Chapter 1, Section 101.6.3 of Title 24 Part 11[9]: "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 the 2013 version Title 24 Part 6 are the minimum requirements, and the justification of energy savings and costs are compared to these requirements.

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

Table 20. Cool Roof Requirements in Title 24 Part 6 and Part 11

Climate Zone	Code	Requirement Type	Slope	Minimum 3-yr Aged Solar Reflectance	Thermal Emittan	Minimum RI
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
ıg 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 Resi ential						
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

8.3 APPENDIX C: COMPLETE COST DATA COLLECTED

8.3.1 Tile Costs

Data was collected over the months of March – December 2014. Cost estimates for concrete and clay tile are not distinguished by the aged solar reflectance (ASR) values because, based on feedback from interviews, pricing for tile is independent of its ASR value; therefore, these values are omitted in the table below. Note that while prices were attained for specific products, the prices are assumed to be applicable to all tile products within the same tile category from that manufacturer. Thus, these prices are assumed for both the base case and Reach code because the tile products offered within each category span across the requirements.

Distribution Area	Location	Retailer/ Distributor	ile Produc	Reach Code Tier	Price ($/ft²)	Notes from Interview
ALL		Eagle Roofing	All Tile	ALL		There is no cost increase for just reflective tile. For tile, the highly reflective products are in the same price matrix as the rest of our products.
Bay Area/ Central Coast	San Jose	ABC Supply Co.	Eagle Roofing "Builder/Re-roof"	ALL	$1.19	For Eagle Tile, color doesn't matter. All profiles and colors are the same for the selected "category" or tile.
Bay Area/ Central Coast	San Jose	ABC Supply Co.	Eagle Roofing "Designer Select"	ALL	$1.26	For Eagle Tile, color doesn't matter. All profiles and colors are the same for the selected "category" or tile.
Bay Area/ Central Coast	Paso Robles	ABC Supply Co.	All Tile	ALL		Tile cost based on blends, the more extreme blends you have in the mix the more you charge. That is for cool roof or standard. Cool roofs usually have 2 mixes, so more blends.
Northern California	Santa Rosa	ABC Supply Co.	All Tile	ALL		Tile is pretty much tile, they just change the glaze, not the mold so the prices don't change.
Southern California	El Monte	Ford Wholesale	Tile	ALL	$1.10	
Southern California	Pasadena	JB Wholesale Roofing	Tile	ALL		Most tile are cool roof; no effect on cost
Southern California	Commerce	Structural Materials Co	Eagle Roofing BelAir Builder/re-roof (red)	ALL	$0.68	

Distribution Area	Location	Retailer/ Distributor	Tile Product	Reach Code Tier	Price ($/ft²)	Notes from Interview
Southern California	Commerce	Structural Materials Co	Eagle Roofing Capistrano red (Builder/Re-roof)	ALL	$0.61	
Southern California	Santa Fe Springs	Pacific Coast Supply	Boral/US Tile Monterey Slate	ALL	$1.94	
Southern California	Santa Fe Springs	Pacific Coast Supply	US Tile Modera 1-piece	ALL	$1.38	
Southern California	Santa Fe Springs	Pacific Coast Supply	US Tile Modera 2-piece	ALL	$2.58	
Southern California	Los Angeles	United Roofing Supply	Boral/US Tile Barcelona	ALL	$1.00	Price can vary based on color, but mostly in this price range
Southern California	Los Angeles	United Roofing Supply	US Tile/Boral Clay 1-piece S (red)	ALL	$1.45	
Southern California	Los Angeles	United Roofing Supply	US Tile/Boral Clay 1-piece S (blend)	ALL	$1.78	
Southern California	Los Angeles	United Roofing Supply	US Tile/Boral Clay 1-piece light (red)	ALL	$1.66	
Southern California	Los Angeles	United Roofing Supply	US Tile/Boral Clay 1-piece light (blend)	ALL	$1.76	
Southern California	Los Angeles	Allied Roofing Products	All Tile	ALL		Concrete tile prices do not vary based on color, clay tile do vary by color
Southern California	San Diego	Ford Wholesale	All Tile	ALL		Concrete/clay tile cost depends on the color blend. Could have a cool roof tile that is the same cost as a non-cool roof color
Southern California	Vista	Structural Materials Co	All Tile	ALL		Pretty much all tile is cool roof rated. For pricing, it depends on the brand, color, and profile.
Southern California	San Diego	Roofing Supply Group	All Tile	ALL		Blends are more expensive, slurry finish is the standard/base cost, color through is more expensive. No difference in application of tile (labor).
Southern California	Los Angeles	Structural Materials Co	All Tile - low range basic	ALL	$0.60	

Distribution ea	Location	Retailer/ Distributor	Tile Product	Reach Code Tier	Price ($/ft²)	Notes from Interview
Southern California	Los Angeles	Structural Materials Co	All Tile - High range basic	ALL	$1.00	

8.3.2 Asphalt Shingle Costs

Data was collected over the months of March – December 2014. Products where the 3-yr SR is notated with an N/A are base case roof materials obtained when roofers and roof material distributors were asked for the price of a "standard" product in their area.

Distribution Area	Location	Retailer/Distri utor	sphalt S e Product	-yr	each Code ier	Price ($/ft²)
Bay Area	Santa Rosa	Home Depot	GAF Lifetime Timberline Natural Shadow	N/A	N/A	$0.92
Bay Area	Santa Rosa	Home Depot	GAF Royal Sovereign	N/A	N/A	$0.80
Bay Area	Cotati	Lowes	Owens Corning Oakridge	N/A	N/A	$0.92
Bay Area	Cotati	Lowes	Owens Corning TruDefinition	N/A	N/A	$1.27
Bay Area	Burlingame	ABC Supply Co.	GAF Timberline Cool	0.26	Mandatory	$1.75
Bay Area	Burlingame	ABC Supply Co.	CT Landmark Solaris (GOLD)	0.24 - 0.25	Mandatory	$1.60
Bay Area	Martinez	Roofing Supply Group	CT Landmark Solaris (GOLD)	0.24 - 0.25	Mandatory	$1.39
Bay Area	Martinez	Roofing Supply Group	Owens Corning Supreme	0.25 (unknown)	Mandatory	$0.82
Bay Area	Martinez	Roofing Supply Group	GAF Timberline Cool	0.26	Mandatory	$1.35
Bay Area	Martinez	Roofing Supply Group	GAF Royal Sovereign	0.27	Mandatory	$0.82
Bay Area	Santa Rosa	ABC Supply Co.	CT Landmark Solaris (GOLD)	0.24-0.25	Mandatory	$1.93
Bay Area	Burlingame	ABC Supply Co.	GAF Timberline Natural Shadow	0.29	Tier 1	$0.80
Bay Area	Burlingame	ABC Supply Co.	Malarkey Dura Seal (20)	0.28	Tier 1	$0.78
Bay Area	Martinez	Roofing Supply Group	Owens Corning Duration Premium Cool	0.28 - 0.30	Tier 1	$1.47
Bay Area	Martinez	Roofing Supply Group	Owens Corning Oakridge	0.28	Tier 1	$0.82

Distribution Area	Location	Retailer/Distributor	Asphalt Shingle Produc	3-yr SR	Reach Code	Price (
Bay Area	Martinez	Roofing Supply Group	GAF Timberline HD	0.29	Tier 1	$0.84
Bay Area	Martinez	Roofing Supply Group	GAF Timberline UltraHD	0.29	Tier 1	$1.14
Bay Area	Burlingame	ABC Supply Co.	CT Landmark Solaris (PLATINUM)	(0.41) pending	Tier 2	$1.90
Bay Area	Martinez	Roofing Supply Group	CT Landmark Solaris (PLATINUM)	(0.41) pending	Tier 2	$1.63
Bay Area/ Central Coast	Martinez/ Burlingame/ Castroville/ Paso Robles	ABC Supply Co.	Entry level composition	N/A	N/A	$0.85
Bay Area/ Central Coast	Martinez/ Burlingame/ Castroville/ Paso Robles	ABC Supply Co.	CT Landmark Solaris (GOLD)	0.24	Mandatory	$1.93
Bay Area/ Central Coast	Martinez/ Burlingame/ Castroville/ Paso Robles	ABC Supply Co.	GAF Timberline Cool	0.26	Mandatory	$2.02
Bay Area/ Central Coast	Martinez/ Burlingame/ Castroville/ Paso Robles	ABC Supply Co.	Low-end estimate		Mandatory	$1.60
Bay Area/ Central Coast	Martinez/ Burlingame/ Castroville/ Paso Robles	ABC Supply Co.	Owens Corning Duration Premium Cool	0.28 - 0.30	Tier 1	$1.82
Bay Area/ Central Coast	Martinez/ Burlingame/ Castroville/ Paso Robles	ABC Supply Co.	High-end estimate		Tier 2	$1.90
Central California	Fresno	R&S Supply Inc	CT Presidential	N/A	N/A	$1.40
Central California	Clovis	Home Depot	GAF Royal Sovereign	0.27	Mandatory	$0.78
Central California	Clovis	Home Depot	GAF Timberline Natural Shadow	0.29	Tier 1	$0.86
Central California	Fresno	Pacific Supply	GAF Timberline Natural Shadow	0.29	Tier 1	$0.74

Distribution Area	Location	Retailer/Distributor	Asphalt Shingle Product	3-yr SR	Reach Code Tier	Price ($/ft²)
Central California	Fresno	Pacific Supply	Owens Corning Oakridge	0.28	Tier 1	$0.74
Central California	Fresno	Pacific Supply	Owens Corning Duration Premium Cool	0.3	Tier 1	$1.21
Central California	Fresno	R&S Supply Inc	Malarkey Dura Seal (20)	0.28	Tier 1	$0.72
Central California	Fresno	R&S Supply Inc	CT Landmark Solaris (PLATINUM)	0.41	Tier 2	$1.76
Central Coast	Salinas	Home Depot	GAF Lifetime Timberline Natural Shadow	N/A	N/A	$0.92
Central Coast	Atascadero	Home Depot	GAF Lifetime Timberline Natural Shadow	N/A	N/A	$0.88
Central Coast	Paso Robles	ABC Supply Co.	GAF Lifetime Timberline Natural Shadow	N/A	N/A	$0.80
Central Coast	San Leandro/ San Jose/ Fresno	Roofing Supply Group	CT Landmark Solaris (GOLD)	0.24 - 0.25	Mandatory	$1.47
Central Coast	San Leandro/ San Jose/ Fresno	Roofing Supply Group	GAF Timberline Cool	0.26	Mandatory	$1.50
Central Coast	San Leandro/ San Jose/ Fresno	Roofing Supply Group	Owens Corning Duration Premium Cool	0.28 - 0.30	Tier 1	$1.50
Northern California	Reno, NV	Sierra Roofing Supply	Low-end estimate	N/A	N/A	$0.78
Northern California	Reno, NV	Sierra Roofing Supply	High-end estimate	N/A	N/A	$1.20
Northern California	Minden, NV	Washoe Building Supply	CT Landmark Premium	N/A	N/A	$1.33
Northern California	Garnerville, NV	Silver State Roofing Materials Inc	PABCO standard asphalt	N/A	N/A	$0.94
Northern California	Grass Valley	Diamond Pacific	Owens Corning Duration	N/A	N/A	$1.05
Northern California	Turlock	Home Depot	GAF Lifetime Timberline Natural Shadow	N/A	N/A	$0.86

Distribution Area	Location	Retailer/Distributor	Asphalt Shingle Product	3-yr SR	Reach Code Tier	Price ($/ft²)
Northern California	Placerville	Home Depot	GAF Royal Sovereign	0.27	Mandatory	$0.78
Northern California	Grass Valley	Diamond Pacific	GAF Timberline Cool	0.26	Mandatory	$1.85
Northern California	Garnerville, NV	Silver State Roofing Materials, Inc	PABCO Premier Radiance Elite	0.25	Mandatory	$1.35
Northern California	Fresno	Pacific Supply	GAF Timberline Cool	0.26	Mandatory	$1.34
Northern California	Fresno	Pacific Supply	GAF Royal Sovereign	0.27	Mandatory	$0.67
Northern California	Minden, NV	Washoe Builidng Supply	CT Presidential Solaris	0.25	Mandatory	$1.60
Northern California	Placerville	Home Depot	GAF Timberline Natural Shadow	0.29	Tier 1	$0.86
Northern California	Sparks, NV	Lowes	Owens Corning Oakridge	0.28	Tier 1	$0.93
Northern California	Minden, NV	Washoe Builidng Supply	Owens Corning Oakridge	0.28	Tier 1	$1.03
Northern California	Grass Valley	Diamond Pacific	Owens Corning Duration Premium Cool	0.3	Tier 1	$1.60
Northern California	Sparks, NV	Lowes	Owens Corning Duration Premium Cool	0.3	Tier 1	$2.33
Northern California	Garnerville, NV	Silver State Roofing Materials, Inc	PABCO Premier Radiance	0.28	Tier 1	$1.15
Northern California	Minden, NV	Washoe Builidng Supply	CT Landmark Solaris (PLATINUM)	0.41	Tier 2	$2.15
Southern California	Glendale	Home Depot	GAF Lifetime Timberline Natural Shadow	N/A	N/A	$0.88
Southern California	Glendale	Home Depot	GAF Royal Sovereign	N/A	N/A	$0.77
Southern California	Burbank	Lowes	Owens Corning Oakridge	N/A	N/A	$0.88
Southern California	Burbank	Lowes	Owens Corning TruDefinition	N/A	N/A	$1.31
Southern California	Burbank	Lowes	Owens Corning Limited Lifetime Berkshire	N/A	N/A	$1.83
Southern California	Monrovia	ABC Supply Co.	Low-end estimate	N/A	N/A	$0.87
Southern California	Monrovia	ABC Supply Co.	High-end estimate	N/A	N/A	$0.95

Distribution Area	Location	Retailer/Distributor	Asphalt Shingle Product	3-yr SR	each Code ier	Price
Southern California	Burbank	Burbank Roofline Supply	Average	N/A	N/A	$0.77
Southern California	El Monte	Ford Wholesale	Low-end estimate	N/A	N/A	$0.79
Southern California	Los Angeles	Allied Roofing	Average	N/A	N/A	$0.81
Southern California	National City	ABC Supply Co.	Low-end estimate	N/A	N/A	$0.60
Southern California	Encinitas	Home Depot	GAF Lifetime Timberline Natural Shadow	N/A	N/A	$0.86
Southern California	Encinitas	Home Depot	GAF Royal Sovereign	N/A	N/A	$0.72
Southern California	Encinitas	Home Depot	Owens Corning Oakridge	N/A	N/A	$0.86
Southern California	Encinitas	Home Depot	Owens Corning TruDefinition	N/A	N/A	$1.06
Southern California	El Monte	Ford Wholesale	CT Landmark Silver Birch	0.27	Mandatory	$0.79
Southern California	Monrovia	ABC Supply Co.	CT Landmark Solaris (GOLD)	0.24	Mandatory	$1.50
Southern California	Burbank	Burbank Roofline Supply	CT Landmark Solaris (GOLD)	0.24	Mandatory	$1.75
Southern California	El Monte	Ford Wholesale	CT Landmark Solaris (GOLD)	0.24	Mandatory	$1.44
Southern California	Pasadena	JB Wholesale Roofing	CT Landmark Solaris (GOLD)	0.24	Mandatory	$1.47
Southern California	Monrovia	ABC Supply Co.	GAF Timberline Cool	0.26	Mandatory	$1.84
Southern California	Glendale	Home Depot	GAF: Royal Soverign	0.27	Mandatory	$0.77
Southern California	San Diego	Ford Wholesale	CT Landmark Solaris (GOLD)	0.24	Mandatory	$1.45
Southern California	Vista	Structural Materials	CT Landmark Solaris (GOLD)	0.24	Mandatory	$1.56
Southern California	Spring Valley	SG Whole Sale	Malarkey Ecoasis	0.25	Mandatory	$1.58
Southern California	Vista	Structural Materials	Malarkey Ecoasis	0.25	Mandatory	$1.80
Southern California	Spring Valley	SG Whole Sale	GAF Timberline Cool	0.26	Mandatory	$1.76
Southern California	Vista	Structural Materials	GAF Timberline Cool	0.26	Mandatory	$1.92
Southern California	San Marcos	ABC Supply Co.	GAF Timberline Cool	0.26	Mandatory	$1.72
Southern California	Encinitas	Home Depot	GAF Royal Sovereign	0.27	Mandatory	$0.72
Southern California	Lemon Grove	Home Depot	GAF Royal Sovereign	0.27	Mandatory	$0.72

Distribution Area	Location	Retailer/Distributor	Asphalt Shingle Product	3-yr SR	Reach Code Tier	Price ([2]
Southern California	Glendale	Home Depot	GAF: Timberline Natural Shadow	0.29	Tier 1	$0.88
Southern California	Burbank	Lowes	Owens Corning TruDefinition	0.28	Tier 1	$1.31
Southern California	Burbank	Lowes	Owens Corning Oakridge	0.28	Tier 1	$0.88
Southern California	Burbank	Lowes	Owens Corning Duration Premium Cool	0.3	Tier 1	$1.87
Southern California	Los Angeles	Allied Roofing	Owens Corning TruDefinition	0.28	Tier 1	$0.87
Southern California	Los Angeles	Allied Roofing	Owens Corning Oakridge	0.28	Tier 1	$0.82
Southern California	Los Angeles	Allied Roofing	Owens Corning Duration Premium Cool	0.3	Tier 1	$1.51
Southern California	Commerce	Structural Materials	Owens Corning TruDefinition	0.28	Tier 1	$0.83
Southern California	Commerce	Structural Materials	Owens Corning Duration Premium Cool	0.3	Tier 1	$1.37
Southern California	Encinitas	Home Depot	GAF Timberline Natural Shadow	0.29	Tier 1	$0.86
Southern California	Lemon Grove	Home Depot	GAF Timberline Natural Shadow	0.29	Tier 1	$0.86
Southern California	Vista	Structural Materials	GAF Timberline Natural Shadow	0.29	Tier 1	$0.84
Southern California	Oceanside	Lowes	Owens Corning Oakridge	0.28	Tier 1	$0.86
Southern California	Mission Valley	Lowes	Owens Corning Oakridge	0.28	Tier 1	$0.86
Southern California	Vista	Structural Materials	Owens Corning Oakridge	0.28	Tier 1	$0.84
Southern California	Spring Valley	SG Whole Sale	Owens Corning Duration Premium Cool	0.3	Tier 1	$1.45
Southern California	Vista	Structural Materials	Owens Corning Duration Premium Cool	0.3	Tier 1	$1.41
Southern California	El Cajon	ABC Supply Co.	Owens Corning Duration Premium Cool	0.3	Tier 1	$1.60
Southern California	Spring Valley	SG Whole Sale	Malarkey Dura Seal (20)	0.28	Tier 1	$0.73
Southern California	San Diego	Ford Wholesale	Malarkey Dura Seal (20)	0.28	Tier 1	$0.73

Distribution Area	Location	Retailer/Distributor	Asphalt Shingle Product	3-yr SR	Reach Code Tier	Price ($/ft²)
Southern California	Vista	Structural Materials	Malarkey Dura Seal (20)	0.28	Tier 1	$0.92
Southern California	Commerce	Structural Materials	CT Landmark Solaris (PLATINUM)	0.41	Tier 2	$1.45

8.3.3 Low-slope Roof Costs

Data was collected over the months of March – December 2014. Products where the 3-yr SR is notated with an N/A are base case roof materials obtained when roofers and roof material distributors were asked for the price of a "standard" product in their area.

Distribution Area	Location	Retailer/Distributor	Low-Slope Product	3-yr SR	Reach Code Tier	Price ($/ft²)
Bay Area	Daly City	Advantage Roofing Inc	Cap Sheet	N/A	N/A	$0.80
Bay Area	Daly City	Advantage Roofing Inc	CT: CoolStar	0.59	N/A	$1.00
Bay Area	San Jose (serve all of Bay Area)	Elite Roofing Supply	Standard cap sheet product	0	N/A	$0.22
Bay Area	Fremont	Lowes	Black Jack Roof-Gard 700	0.65	Mandatory	$0.29
Bay Area	Fremont	Lowes	Henry Co: 287 Solar-FLex	0.72	Mandatory	$0.28
Bay Area	San Mateo	Home Depot	Henry Co: 287 Solar-FLex	0.72	Mandatory	$0.28
Bay Area	San Mateo	Home Depot	Gardner Sta-Kool 770	0.65	Mandatory	$0.58
Bay Area	San Jose (serve all of Bay Area)	Elite Roofing Supply	GAF Evergaurd TPO White	0.68	TIER 1	$0.58
Bay Area	San Jose (serve all of Bay Area)	Elite Roofing Supply	Tropical Roofing: Asphalt 911 Eternalastic	0.69	TIER 1	$0.53
Bay Area	Fremont	Lowes	Black Jack Ultra Roof 1000	0.72	TIER 2	$0.37
Bay Area	Daly City	Precisions Roofing Inc	APOC 272/252	0.77	TIER 2	N/A
Bay Area	Petaluma	Wedge Roofing	Silicone coating	0.7	TIER 2	$0.39
Bay Area	San Jose (serve all of Bay Area)	Elite Roofing Supply	Tropical Roofing: Asphalt 921 Re-Flex	0.74	TIER 2	$0.53
Bay Area	Hayward	CentiMark	GAF	ANY	Mandatory/ TIER 1/TIER 2	$0.39

Distribution Area	Location	Retailer/Distributor	Low-Slope Product	3-yr SR	Reach Code Tier	Price ($/ft²)
Bay Area	Hayward	CentiMark	ANY	ANY	Mandatory/ TIER 1/TIER 2	$0.39
Bay Area	Hayward	CentiMark	ANY	ANY	Mandatory/ TIER 1/TIER 2	$0.39
Central California	Fresno	Roofing Supply Group	Cool Cap	?	Mandatory	$0.35
Central California	Fresno	Roofing Supply Group	Cool Cap	0.69	TIER 1	$0.70
Central Coast	Salinas	Home Depot	Henry Co: 287 Solar-FLex	0.72	Mandatory	$0.28
Central Coast	Salinas	Home Depot	Henry Co: 587 Dura-Brite	0.72	Mandatory	$0.40
Central Coast	Salinas	Home Depot	Gardner Sta-Kool 770	0.65	Mandatory	$0.61
Central Coast	Salinas	Home Depot	Henry Co: 287 Solar-FLex	0.72	Mandatory	$0.28
Central Coast	Salinas	Home Depot	Gardner Sta-Kool 770	0.65	Mandatory	$0.58
Central Coast	Salinas	Home Depot	Henro Co: 687 Enviro-White	0.8	TIER 2	$0.51
Central Coast	Salinas	Home Depot	Henry Co: 587 Dura-Brite	0.73	TIER 2	$0.40
Central Coast	Gilroy	Lowes	Black Jack Ultra Roof 1000	0.72	TIER 2	$0.37
Central Coast	Salinas	Lowes	Henry Co: 587 Dura-Brite	0.73	TIER 2	$0.40
Northern California	Reno	Lowes	Gaco: Gacoflex S1000	0.56	N/A	$0.66
Northern California	Placerville	Home Depot	Henry Co: 287 Solar-FLex	0.72	Mandatory	$0.28
Northern California		Sierra Roofing Supply	CT: CoolStar Flintastic GTA	0.63	Mandatory	$1.42
Northern California	Placerville	Home Depot	Gardner Sta-Kool 770	0.65	Mandatory	$0.58
Northern California	Placerville	Home Depot	Henry Co: 587 Dura-Brite	0.73	TIER 2	$0.40
Northern California	Placerville	Home Depot	Henro Co: 687 Enviro-White	0.8	TIER 2	$0.48
Northern California	Reno	Lowes	Black Jack Ultra Roof 1000	0.72	TIER 2	$0.33
Southern California		Roofing Supply Group	Field Applied Coating	N/A	N/A	$1.03
Southern California		ABC Supply Co	Cap Sheet	N/A	N/A	$1.37
Southern California		Structural Materials	TPO/PVC	N/A	N/A	$0.61
Southern California		Structural Materials	GAF: GAFGLAS	0.29	N/A	$0.21
Southern California		Structural Materials	GAF: Ruberoid EnergyCap Mop FR	-0.74	Mandatory	$1.25
Southern California	Glendale	Home Depot	Henry Co: 287 Solar-FLex	0.72	Mandatory	$0.28
Southern California		United Roofing Supply	GenFlex: EZ Fleece Backed TPO	0.7	Mandatory	$0.65

Distribution Area	Location	Retailer/Distributor	Low-Slope Product	3-yr SR	Reach Code Tier	Price (ft²)
Southern California		ABC Supply Co	APOC 274	0.64	Mandatory	$0.85
Southern California	San Marcos	ABC Supply Co	GAF: Ruberoid EnergyCap Torch Granule FR	0.7	Mandatory	$1.26
Southern California	San Marcos	ABC Supply Co	GAF: Ruberoid EnergyCap FR SBS Membrane	-0.8	Mandatory	$1.26
Southern California	El Cajon	ABC Supply Co	JM: JM TPO .45, .60	0.62	Mandatory	$0.67
Southern California		Structural Materials	CT: CoolStar Flintastic GTA	0.63	Mandatory	$1.10
Southern California	National City	ABC Supply Co	CT: CoolStar Flintastic GTA	0.63	Mandatory	$1.43
Southern California	Vista	Pacific Supply	JM: JM TPO .45, .60	0.68	TIER 1	$0.49
Southern California	San Marcos	ABC Supply Co	GAF: EverGuard TPO	0.68	TIER 1	$0.63
Southern California		Pacific Supply	Henry Co: Permax 110	0.73	TIER 2	$0.79
Southern California	San Marcos	ABC Supply Co	GAF: Ruberoid Energy Cap Torch Plus FR	-0.74	TIER 2	$1.26
Southern California		ABC Supply Co	APOC: APOC 252 FR	-0.9	TIER 2	$0.78
Southern California		Pacific Supply	APOC: APOC 248	0.74	TIER 2	$1.13
Southern California		Structural Materials	Duro-Last Roofing: Duro-Tuff	-0.85	TIER 2	$1.11
Southern California		ABC Supply Co	Verisco Inc: Versiweld TPO	0.7	TIER 2	$0.69
Southern California		Pacific Supply	GAF: Topcoat EnergyCote	0.78	TIER 2	$1.05

8.4 APPENDIX D: FULL COST EFFECTIVENESS RESULTS

This section provides detailed results for each Climate Zone. Charts show the Present Value (PV$) of energy savings, benefit to cost ratio, and Life Cycle Costs (LCC) for each prototype and cool roof Reach Code level. LCC is another representation of cost effectiveness, based on the CEC's Life Cycle Cost Methodology. In this report, life cycle costs (a negative number) indicate that the cool roof reach code is not cost effective. Life cycle cost savings (a positive number) indicate that the cool roof reach code is cost effective.

A sample calculation is provided below for how the findings for each result were calculated. Please note that figures may be slightly different due to the number significant figures used in the spreadsheet analysis:

Low-rise Multifamily, Tier 2, Steep-Slope, in Climate Zone 8

- Base Case Price: 4,176 ft^2 roof area (Table 4) × \$1.09/ft^2 (Table 10) = \$4,542
- Reach Code Price: 4,176 ft^2 roof area × \$0.26/ft^2 (Table 10) = \$5,627
- Incremental Price: \$5,627 - \$4,542 = \$1,085
- PV$ Energy Savings: \$3,636 (Table 8)
- B/C Ratio: \$3,636 ÷ \$1,085 = 3.4
- LCC Savings: \$3,636 - \$1,085 = \$2,551

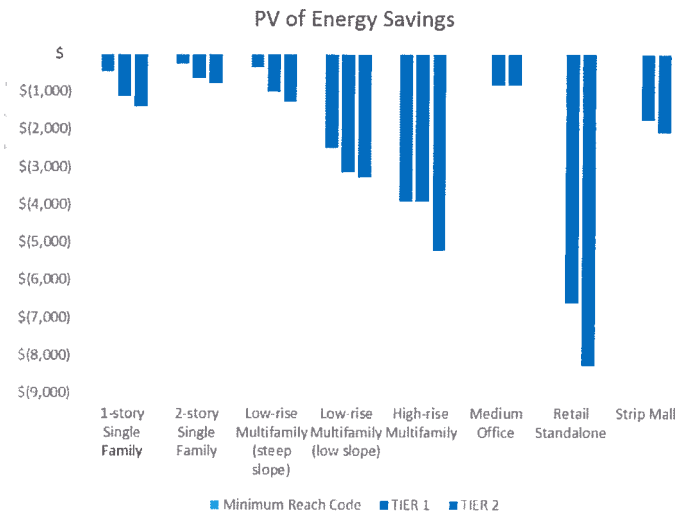
Recommendations are provided for jurisdictions in each Climate Zone regarding what Reach Code level to pursue, summarized in Table 21. Jurisdictions should consider the following when reviewing recommendations:

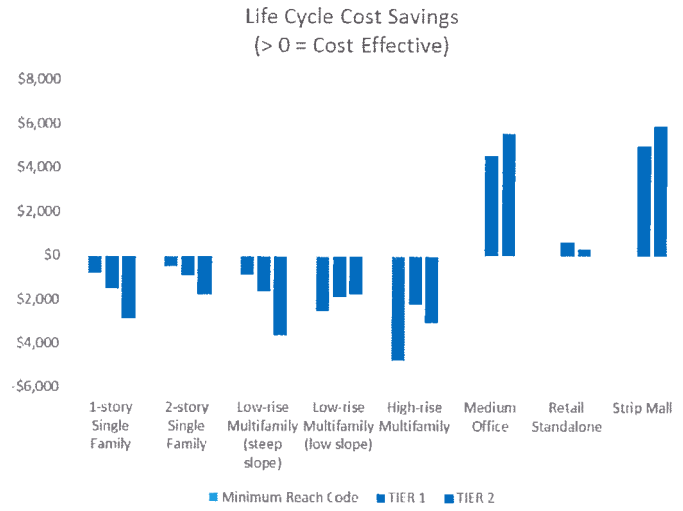
- Sensitivity of results – For prototypes that show no costs or B/C ratios that are close to 1.0, jurisdictions should consider the impact of a fluctuation of cool roof incremental prices and future climatic shifts.
- Other building types – Jurisdictions will need to consider applying the Reach Code to other building types than the prototypes simulated, particularly those with low internal cooling loads such as warehouses. When buildings have especially low occupancy or low lighting levels, the internal cooling loads can be low and a cool roof may not have a significant energy impact.
- Other construction scenarios – The majority of the simulations were conducted under new construction scenarios with the 2013 Title 24 as the baseline. Jurisidictions will need to consider how to apply results to alterations and additions.
    - The prescriptive baseline for nonresidential additions and residential additions larger than 700 ft^2 is the prescriptive T24 Standards. Thus the new construction findings are relevant to these additions, and Reach Code can be applied where cost effective for new construction.
    - Where cool roofs are shown to be cost effective, the benefits will likely be even greater in alterations scenarios where buildings have lower performance envelopes and higher lighting power density than the 2013 T24 prescriptive building. Thus, the cool roofs Reach Code should be applied to re-roofing alterations where results show cost effectiveness.

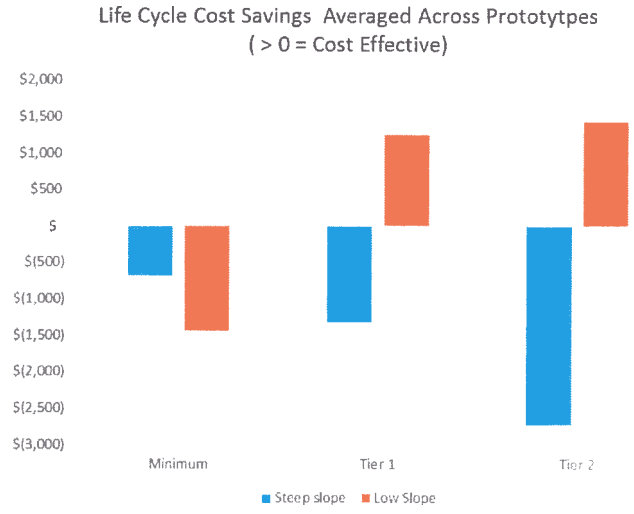
Table 21. Summary of Reach Code Recommendations

Jurisdictions in CZ	Should Pursue the Reach Code?					
	Steep-Slope	Tier?	Building Types?	Low-Slope	Tier?	Building Types?
1	No	-	-	No	-	
2	Yes	Tier 2	Low-Rise Multifamily	Yes	Tier 2	All
3	Yes, if costs decrease	Tier 2	Low-Rise Multifamily	Yes	Tier 2	All
4	Yes	Tier 2	Low-Rise Multifamily	Yes	Tier 2	All
5	Yes, if costs decrease	Tier 2	Low-Rise Multifamily	Yes	Minimum	All
6	Yes	Tier 2	Low-Rise Multifamily	Yes	Tier 2	All
7	Yes	Tier 2	Low-Rise Multifamily	Yes	Tier 2	All
8	Yes	Tier 2	All	Yes	Tier 2	All
9	Yes	Tier 2	All	Yes	Tier 2	All
10	Yes	Tier 2	All	Yes	Tier 2	All except High-Rise Multifamily
11	Yes	Tier 2	All	Yes	Tier 2	All
12	Yes	Tier 2	All	Yes	Tier 2	All
13	Yes	Tier 2	All	Yes	Tier 2	All except High-Rise Multifamily
14	Yes	Tier 2	All	Yes	Tier 2	All
15	Yes	Tier 2	All	Yes	Varies	Tier 2 for Low-Rise Multifamily and Nonresidential Tier 1 for High-Rise Multifamily
16	Yes	Tier 2	Low-Rise Multifamily	Yes	Tier 2	All

8.4.1 Climate Zone 1







<u>Recommendations</u>

Steep-Slope Reach Code: NO

Because of the relatively mild climate in Climate Zone 1, the simulations show no energy savings and no life cycle cost savings. Therefore, the steep-slope Reach Code should not be pursued by jurisdictions in Climate Zone 1.

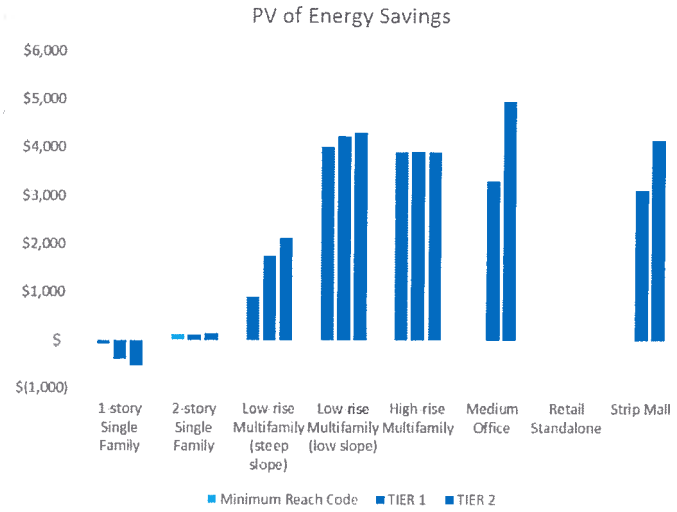
Low-Slope Reach Code: NO

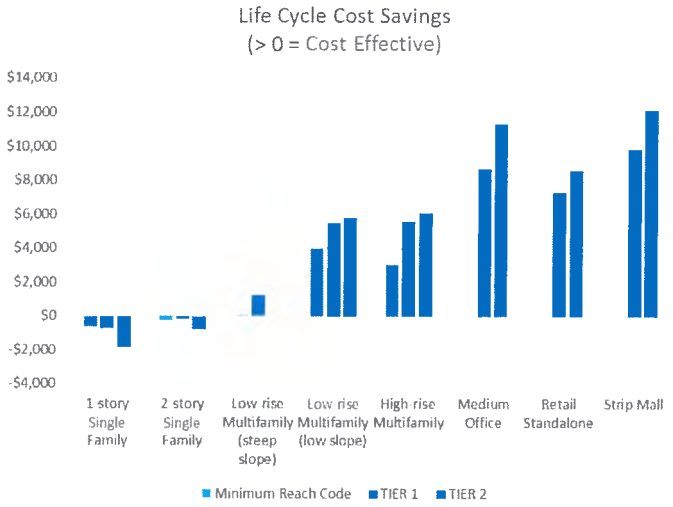
The simulations show no energy savings. Yet there are life cycle cost savings for some prototypes because low-slope cool roofs are less expensive than non-cool roofs. Low-slope cool roofs should not be pursued by jurisdictions in Climate Zone 1 because they do not produce energy savings.

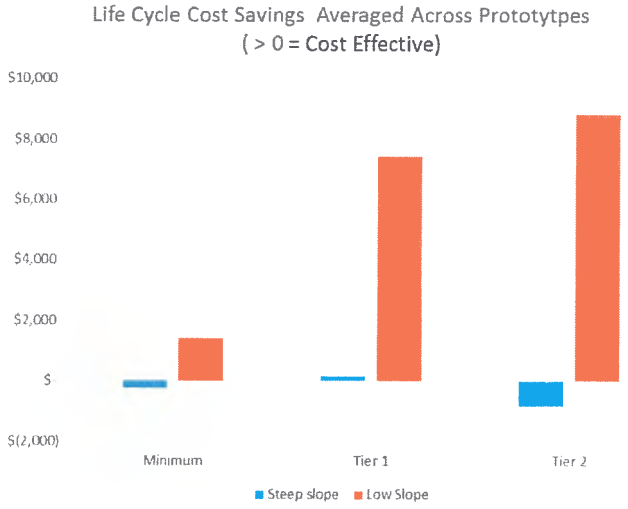
Cost-Effectiveness Study for Cool Roofs – Climate Zone 1 Results
Prepared for Pacific Gas & Electric Company by TRC Solutions

Prototype	Climate Zone 1 (Results, Bldg.)	Minimum Reach Code		TIER 1		TIER 2	
		≤ 2:12	> 2:12	≤ 2:12	> 2:12	≤ 2:12	> 2:12
1-story Single Family	Base Case Price		$2,836		$2,836		$2,836
	Reach Code Price		$3,137		$3,203		$4,253
	Incremental Price		$301		$366		$1,416
	PVS Energy Savings		($449)		($1,117)		($1,393)
	B/C Ratio		No Savings		No Savings		No Savings
	LCC Savings		($750)		($1,484)		($2,810)
2-story Single Family	Base Case Price		$1,958		$1,958		$1,958
	Reach Code Price		$2,166		$2,211		$2,936
	Incremental Price		$208		$253		$978
	PVS Energy Savings		($255)		($626)		($773)
	B/C Ratio		No Savings		No Savings		No Savings
	LCC Savings		($463)		($879)		($1,751)
Low-rise Multifamily	Base Case Price	$2,756	$4,700	$2,756	$4,700	$2,756	$4,700
	Reach Code Price	$3,170	$5,199	$1,906	$5,307	$1,672	$7,047
	Incremental Price	$413	$499	($850)	$607	($1,084)	$2,347
	PVS Energy Savings	($2,480)	($343)	($3,119)	($975)	($3,251)	($1,240)
	B/C Ratio	No Savings	No Savings	No Savings	No Savings	No Savings	No Savings
	LCC Savings	($2,894)	($843)	($2,268)	($1,583)	($2,167)	($3,587)
High-rise Multifamily	Base Case Price	$5,564		$5,564		$5,564	
	Reach Code Price	$6,399		$3,848		$3,375	
	Incremental Price	$835		($1,717)		($2,189)	
	PVS Energy Savings	($3,905)		($3,905)		($5,207)	
	B/C Ratio	No Savings		No Savings		No Savings	
	LCC Savings	($4,740)		($2,189)		($3,018)	
Medium Office	Base Case Price	$13,568		$13,568		$13,568	
	Reach Code Price	$13,568		$8,158		$7,157	
	Incremental Price	$0		($5,410)		($6,412)	
	PVS Energy Savings	-		($826)		($826)	
	B/C Ratio	-		No Savings		No Savings	
	LCC Savings	$0		$4,584		$5,586	
Retail Standalone	Base Case Price	$18,255		$18,255		$18,255	
	Reach Code Price	$18,255		$10,976		$9,629	
	Incremental Price	$0		($7,279)		($8,626)	
	PVS Energy Savings	-		($6,607)		($8,259)	
	B/C Ratio	-		No Savings		No Savings	
	LCC Savings	$0		$672		$368	
Strip Mall	Base Case Price	$16,944		$16,944		$16,944	
	Reach Code Price	$16,944		$10,188		$8,937	
	Incremental Price	$0		($6,756)		($8,007)	
	PVS Energy Savings	-		($1,733)		($2,079)	
	B/C Ratio	-		No Savings		No Savings	
	LCC Savings	$0		$5,024		$5,928	

8.4.2 Climate Zone 2







Recommendations

Steep-Slope Reach Code: YES, FOR LOW-RISE MULTIFAMILY BUILDINGS

The simulations show positive energy savings for the 2-story and Low-Rise Multifamily prototypes. Only the Low-Rise Multifamily prototype shows life cycle cost savings. Therefore, the steep-slope Reach Code should be pursued for low-rise multifamily buildings by jurisdictions in Climate Zone 2.

For Low-Rise Multifamily buildings, the Tier 1 Reach Code is the most cost effective, on average, while Tier 2 yields the most energy savings. Tier 2 is recommended to maximize energy savings.

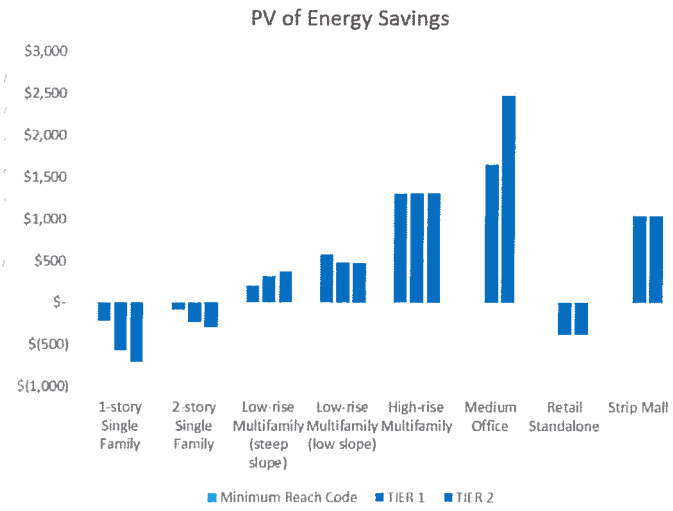
Low-Slope Reach Code: YES

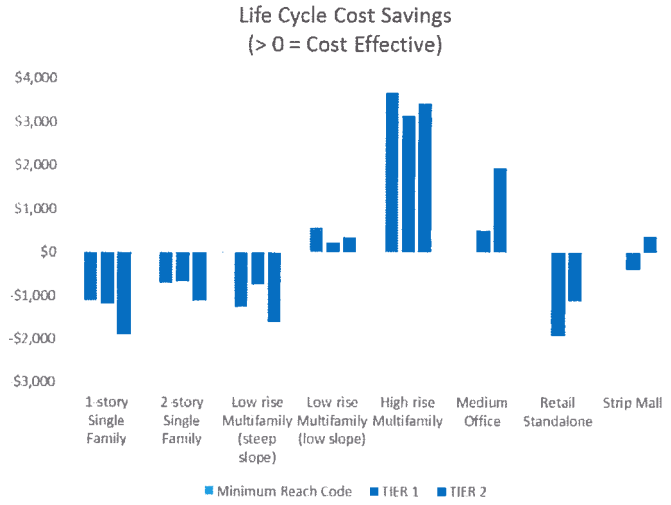
The simulations show energy savings and life cycle costs savings for all prototypes except Retail Standalone, which does not show an energy penalty. Low-slope cool roofs should be pursued by jurisdictions in Climate Zone 2.

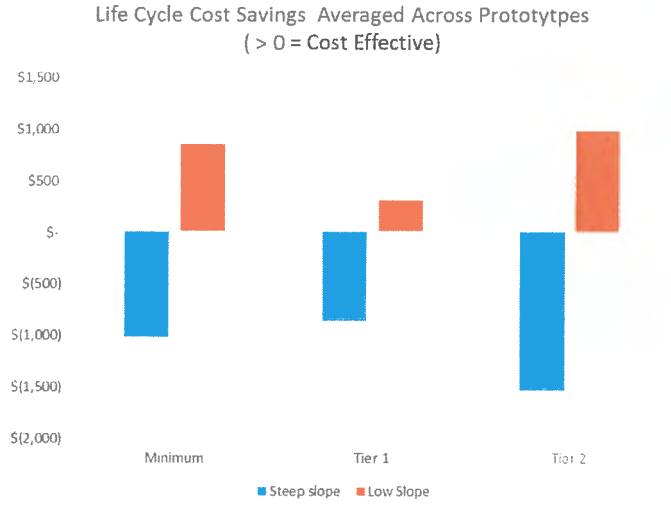
The Tier 2 Reach Code is the most cost effective, on average, and yields the most energy savings. Tier 2 is recommended to maximize energy savings.

Prototype	Climate Zone 2 (Results/Bldg.)	Minimum Reach Code		TIER 1		TIER 2	
		≤ 2:12	> 2:12	≤ 2:12	> 2:12	≤ 2:12	> 2:12
1-story Single Family	Base Case Price		$2,788		$2,788		$2,788
	Reach Code Price		$3,294		$3,095		$4,038
	Incremental Price		$507		$308		$1,251
	PVS Energy Savings		($73)		($394)		($532)
	B/C Ratio		No Savings		No Savings		No Savings
	LCC Savings		($579)		($702)		($1,783)
2-story Single Family	Base Case Price		$1,925		$1,925		$1,925
	Reach Code Price		$2,275		$2,137		$2,788
	Incremental Price		$350		$213		$864
	PVS Energy Savings		$107		$119		$140
	B/C Ratio		0.3		0.6		0.2
	LCC Savings		($242)		($93)		($723)
Low-rise Multifamily	Base Case Price	$2,756	$4,620	$2,756	$4,620	$2,756	$4,620
	Reach Code Price	$3,170	$5,459	$1,906	$5,130	$1,672	$6,692
	Incremental Price	$413	$840	($850)	$510	($1,084)	$2,072
	PVS Energy Savings	$4,022	$897	$4,238	$1,740	$4,311	$2,125
	B/C Ratio	9.7	1.1	No Costs	3.4	No Costs	1.0
	LCC Savings	$3,608	$57	$5,089	$1,230	$5,395	$53
High-rise Multifamily	Base Case Price	$5,564		$5,564		$5,564	
	Reach Code Price	$6,399		$3,848		$3,375	
	Incremental Price	$835		($1,717)		($2,189)	
	PVS Energy Savings	$3,905		$3,905		$3,905	
	B/C Ratio	4.7		No Costs		No Costs	
	LCC Savings	$3,071		$5,622		$6,094	
Medium Office	Base Case Price	$13,568		$13,568		$13,568	
	Reach Code Price	$13,568		$8,158		$7,157	
	Incremental Price	$0		($5,410)		($6,412)	
	PVS Energy Savings	-		$3,303		$4,955	
	B/C Ratio	-		No Costs		No Costs	
	LCC Savings	$0		$8,714		$11,367	
Retail Standalone	Base Case Price	$18,255		$18,255		$18,255	
	Reach Code Price	$18,255		$10,976		$9,629	
	Incremental Price	$0		($7,279)		($8,626)	
	PVS Energy Savings	-		$0		$0	
	B/C Ratio	-		No Savings		No Savings	
	LCC Savings	$0		$7,279		$8,626	
Strip Mall	Base Case Price	$16,944		$16,944		$16,944	
	Reach Code Price	$16,944		$10,188		$8,937	
	Incremental Price	$0		($6,756)		($8,007)	
	PVS Energy Savings	-		$3,119		$4,158	
	B/C Ratio	-		No Costs		No Costs	
	LCC Savings	$0		$9,875		$12,165	

8.4.3 Climate Zone 3







Recommendations

Steep-Slope Reach Code: YES, IF COSTS DECREASE

Because of the relatively mild climate in Climate Zone 3, The simulations show increased energy usage for the single family prototypes. Therefore, the steep-slope Reach Code should not be pursued by jurisdictions in Climate Zone 3 for single family prototypes. Multifamily prototypes showed energy savings, but increased life cycle costs. A multifamily steep-slope reach code may become cost effective if cool roof costs decrease.

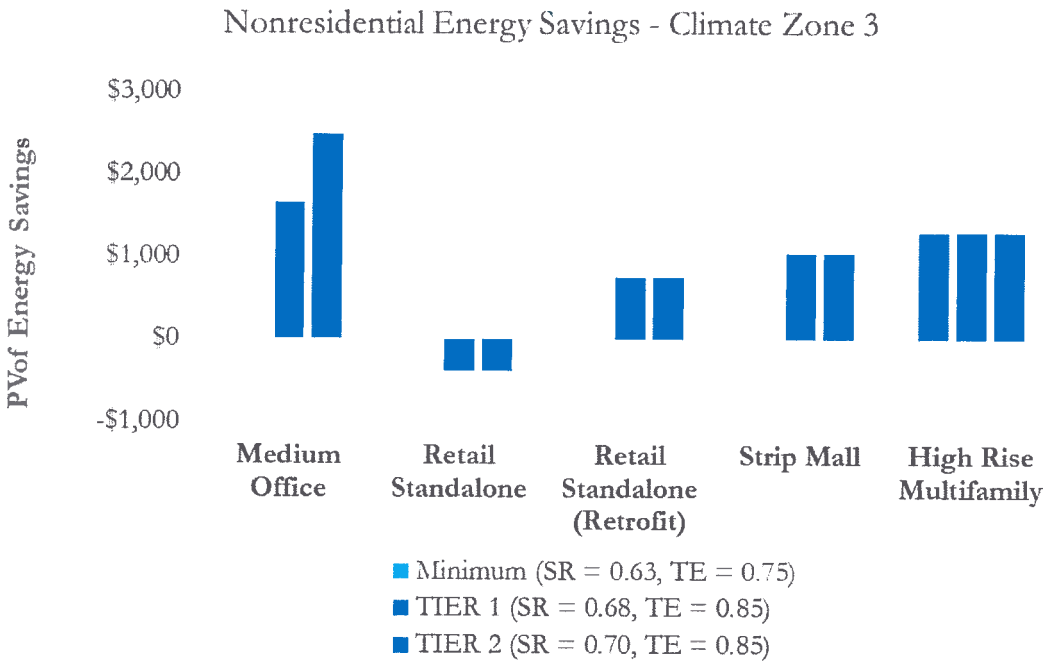
Low-Slope Reach Code: YES

Simulations show energy savings and life cycle cost savings for the high-rise multifamily, medium office, and strip mall prototypes. The retail standalone prototype does not shows a slight increase in energy usage with new construction characteristics, but shows energy savings in retrofit situations (see the figure on the following page). Furthermore, considering that in the long term cool roof prices are likely drop as they become more prevalent, and would provide further benefit as climate change becomes more severe, jurisdictions in Climate Zone 3 should pursue the cool roofs Reach Code.

The Tier 2 Reach Code is most cost effective, on average, and yields the most energy savings. Tier 2 is recommended to maximize energy savings.

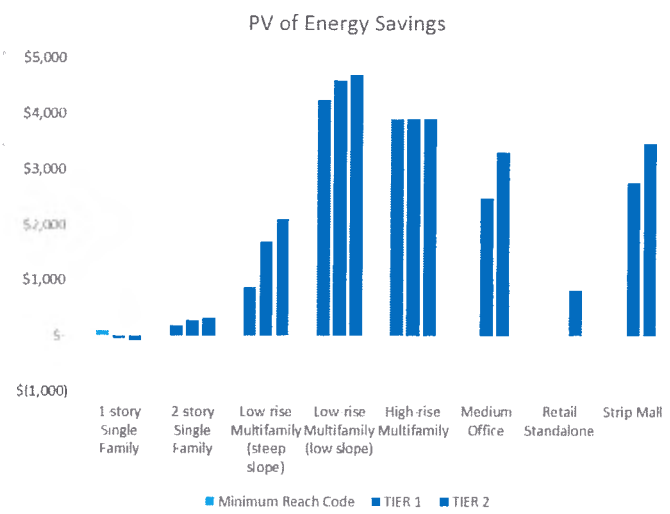
The retail standalone prototype shows negative savings for new construction. This is largely due to the relatively low internal heat loads (such as lighting) of this prototype compared to the other nonresidential prototypes. In retrofit situations, the lighting power density (LPD) will likely be higher, than the 2013 T24 prescriptive requirements, resulting in higher internal gains, thereby reducing the heating penalty associated with cool roofs.

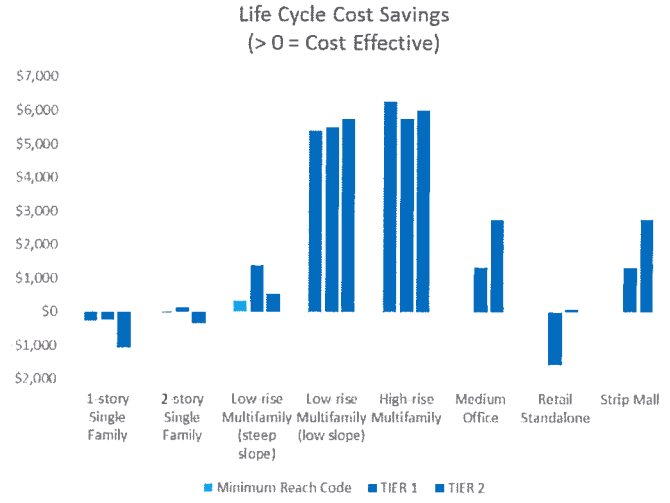
Simulations with a high LPD result in positive PV$ of savings for the retail standalone prototype in Climate Zones 3, as shown below. The retail standalone retrofit prototype used the 1992 prescriptive code as the baseline, which required the lighting power density to be at most 2.2 W/ft2 in the retail space, compared to 1.2 W/ft2 under the 2013 Standards. Simulations were also run with the 2001 prescriptive code baseline of 2.0 W/ft2, which did not show energy savings nor energy penalty due to the cool roof.

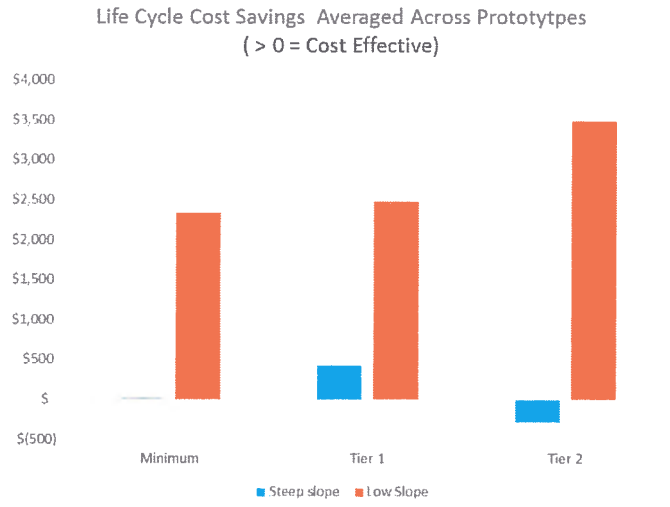


Prototype	Climate Zone 3 (Results/Bldg)	Minimum Reach Code		TIER 1		TIER 2	
		≤ 2:12	> 2:12	≤ 2:12	> 2:12	≤ 2:12	> 2:12
1-story Single Family	Base Case Price		$2,684		$2,684		$2,684
	Reach Code Price		$3,570		$3,313		$3,881
	Incremental Price		$886		$629		$1,197
	PVS Energy Savings		($218)		($563)		($698)
	B/C Ratio		No Savings		No Savings		No Savings
	LCC Savings		($1,104)		($1,192)		($1,895)
2-story Single Family	Base Case Price		$1,853		$1,853		$1,853
	Reach Code Price		$2,465		$2,288		$2,680
	Incremental Price		$612		$434		$826
	PVS Energy Savings		($82)		($229)		($285)
	B/C Ratio		No Savings		No Savings		No Savings
	LCC Savings		($694)		($663)		($1,111)
Low-rise Multifamily	Base Case Price	$2,812	$4,447	$2,812	$4,447	$2,812	$4,447
	Reach Code Price	$1,638	$5,916	$1,906	$5,490	$1,766	$6,431
	Incremental Price	($1,174)	$1,469	($906)	$1,043	($1,046)	$1,984
	PVS Energy Savings	$578	$205	$482	$313	$470	$373
	B/C Ratio	No Costs	0.1	No Costs	0.3	No Costs	0.2
	LCC Savings	$1,752	($1,264)	$1,388	($730)	$1,516	($1,610)
High-rise Multifamily	Base Case Price	$5,677		$5,677		$5,677	
	Reach Code Price	$3,307		$3,848		$3,565	
	Incremental Price	($2,370)		($1,829)		($2,112)	
	PVS Energy Savings	$1,302		$1,302		$1,302	
	B/C Ratio	No Costs		No Costs		No Costs	
	LCC Savings	$3,671		$3,131		$3,414	
Medium Office	Base Case Price	$7,012		$7,012		$7,012	
	Reach Code Price	$7,012		$8,158		$7,558	
	Incremental Price	$0		$1,146		$546	
	PVS Energy Savings	-		$1,652		$2,478	
	B/C Ratio	-		1.4		4.5	
	LCC Savings	$0		$506		$1,932	
Retail Standalone	Base Case Price	$9,435		$9,435		$9,435	
	Reach Code Price	$9,435		$10,976		$10,169	
	Incremental Price	$0		$1,541		$735	
	PVS Energy Savings	-		($378)		($378)	
	B/C Ratio	-		No Savings		No Savings	
	LCC Savings	$0		($1,920)		($1,113)	
Strip Mall	Base Case Price	$8,757		$8,757		$8,757	
	Reach Code Price	$8,757		$10,188		$9,439	
	Incremental Price	$0		$1,431		$682	
	PVS Energy Savings	-		$1,040		$1,040	
	B/C Ratio	-		0.7		1.5	
	LCC Savings	$0		($391)		$358	

8.4.4 Climate Zone 4







Recommendations

Steep-Slope Reach Code: YES, FOR LOW-RISE MULTIFAMILY BUILDINGS

The simulations show low or negative energy savings, as well as life cycle costs for single family prototypes. However, Low-Rise Multifamily simulations show significant energy savings, and LCC cost savings. Therefore, the steep-slope Reach Code should be pursued for low-rise multifamily buildings by jurisdictions in Climate Zone 4.

For Low-Rise Multifamily buildings, the Tier 1 Reach Code is the most cost effective, on average, while Tier 2 yields the most energy savings. Tier 2 is recommended to maximize energy savings.

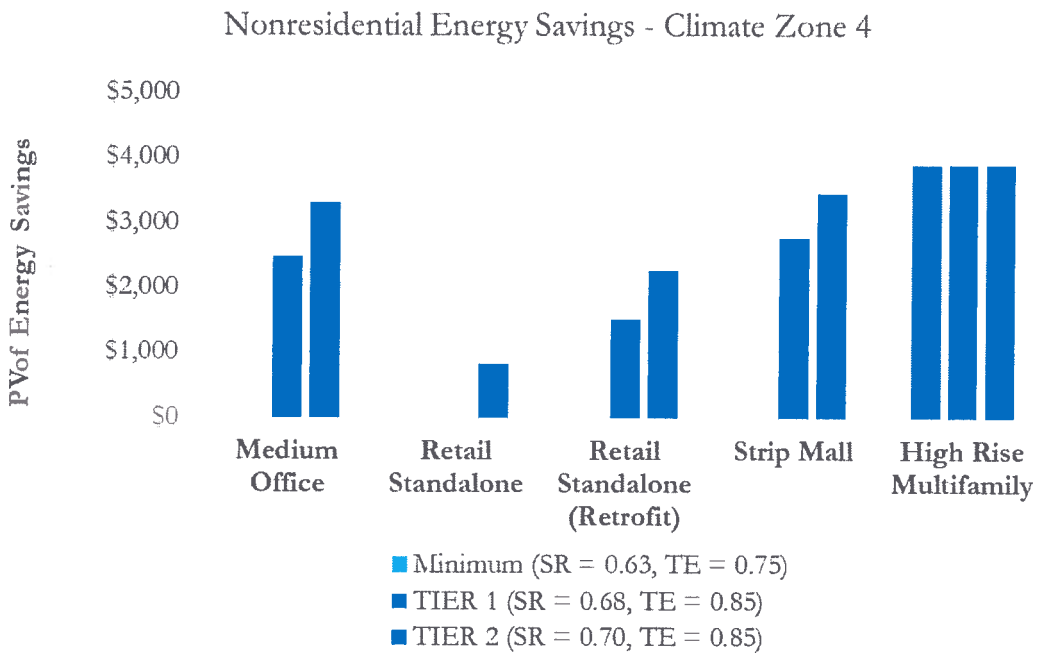
Low-Slope Reach Code: YES

All prototypes show energy savings and life cycle cost savings except the Retail Standalone prototype at a Tier 1 Reach Code level. (Retail standalone is cost effective at the Tier 2 level). However, as shown in the figure on the next page, standalone retail buildings in a retrofit scenario show $1,500 in energy savings at the Tier 1 Reach Code, which is roughly equivalent to the $1,500 in incremental costs estimated for the cool roof. Because the cool roof Reach Code is cost effective in nearly all scenarios, and considering that in the long term cool roof prices are likely drop as they become more prevalent, and would provide further benefit as climate change becomes more severe, jurisdictions in Climate Zone 4 should pursue the cool roof Reach Code.

The Tier 2 Reach Code is most cost effective, on average, and yields the most energy savings. Tier 2 is recommended to maximize energy savings.

The retail standalone prototype shows negative savings for new construction. This is largely due to the relatively low internal heat loads (such as lighting) of this prototype compared to the other nonresidential prototypes. In retrofit situations, the lighting power density (LPD) will likely be higher, than the 2013 T24 prescriptive requirements, resulting in higher internal gains, thereby reducing the cool roof heating penalty.

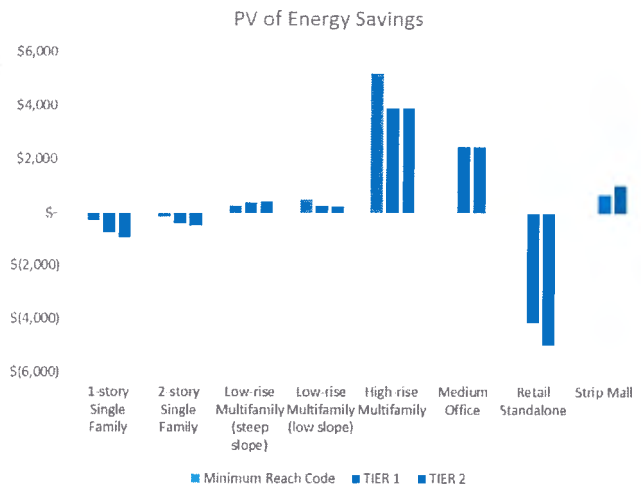
Simulations with a high LPD result in positive PV$ of savings for the retail standalone prototype in Climate Zone 4, as shown below. The retail standalone retrofit prototype used the 1992 prescriptive code as the baseline, which required the lighting power density to be at most 2.2 W/ft2 in the retail space, compared to 1.2 W/ft2 under the 2013 Standards.

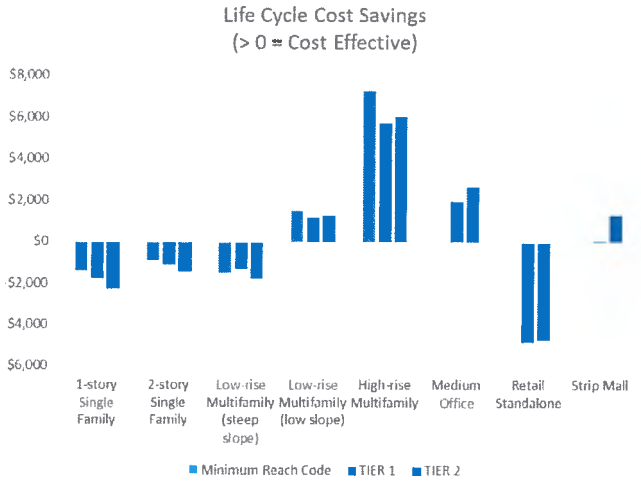


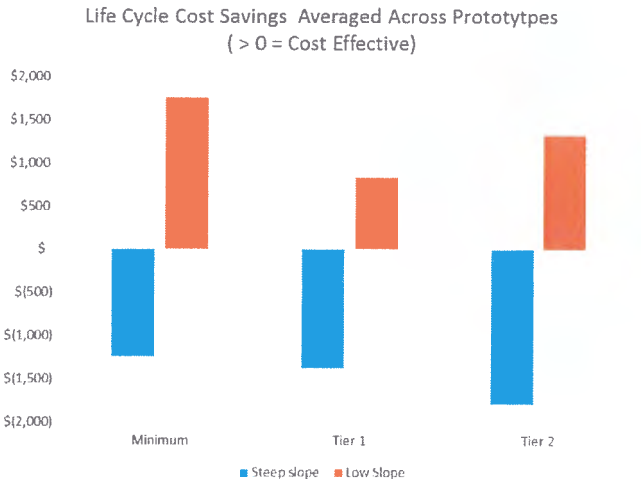
Cost-Effectiveness Study for Cool Roofs – Climate Zone 4 Results
Prepared for Pacific Gas & Electric Company by TRC Solutions

Prototype	Climate Zone 4 (Results Bldg)	Minimum Reach Code		TIER 1		TIER 2	
		≤ 2:12	> 2:12	≤ 2:12	> 2:12	≤ 2:12	> 2:12
1-story Single Family	Base Case Price		$2,892		$2,892		$2,892
	Reach Code Price		$3,222		$3,082		$3,841
	Incremental Price		$331		$190		$949
	PVS Energy Savings		$85		($31)		($82)
	B/C Ratio		0.3		No Savings		No Savings
	LCC Savings		($245)		($221)		($1,031)
2-story Single Family	Base Case Price		$1,997		$1,997		$1,997
	Reach Code Price		$2,225		$2,128		$2,652
	Incremental Price		$228		$131		$655
	PVS Energy Savings		$192		$273		$327
	B/C Ratio		0.8		2.1		0.5
	LCC Savings		($37)		$142		($328)
Low-rise Multifamily	Base Case Price	$2,812	$4,792	$2,812	$4,792	$2,812	$4,792
	Reach Code Price	$1,638	$5,340	$1,906	$5,107	$1,766	$6,365
	Incremental Price	($1,174)	$548	($906)	$315	($1,046)	$1,573
	PVS Energy Savings	$4,238	$885	$4,600	$1,692	$4,696	$2,107
	B/C Ratio	No Costs	1.6	No Costs	5.4	No Costs	1.3
	LCC Savings	$5,412	$337	$5,506	$1,377	$5,742	$534
High-rise Multifamily	Base Case Price	$5,677		$5,677		$5,677	
	Reach Code Price	$3,307		$3,848		$3,565	
	Incremental Price	($2,370)		($1,829)		($2,112)	
	PVS Energy Savings	$3,905		$3,905		$3,905	
	B/C Ratio	No Costs		No Costs		No Costs	
	LCC Savings	$6,275		$5,735		$6,017	
Medium Office	Base Case Price	$7,012		$7,012		$7,012	
	Reach Code Price	$7,012		$8,158		$7,558	
	Incremental Price	$0		$1,146		$546	
	PVS Energy Savings	-		$2,478		$3,303	
	B/C Ratio	-		2.2		6.1	
	LCC Savings	$0		$1,332		$2,757	
Retail Standalone	Base Case Price	$9,435		$9,435		$9,435	
	Reach Code Price	$9,435		$10,976		$10,169	
	Incremental Price	$0		$1,541		$735	
	PVS Energy Savings	-		$0		$826	
	B/C Ratio	-		No Savings		1.1	
	LCC Savings	$0		($1,541)		$91	
Strip Mall	Base Case Price	$8,757		$8,757		$8,757	
	Reach Code Price	$8,757		$10,188		$9,439	
	Incremental Price	$0		$1,431		$682	
	PVS Energy Savings	-		$2,772		$3,465	
	B/C Ratio	-		1.9		5.1	
	LCC Savings	$0		$1,341		$2,783	

8.4.5 Climate Zone 5







Recommendations

Steep-Slope Reach Code: YES, IF COSTS DECREASE

Because of the relatively mild climate in Climate Zone 5, the simulations show increased energy usage for the single family prototypes. Therefore, the steep-slope Reach Code should not be pursued by jurisdictions in Climate Zone 3 for single family prototypes. Multifamily prototypes showed energy savings, but increased life cycle costs. A multifamily steep-slope reach code may become cost effective if cool roof costs decrease.

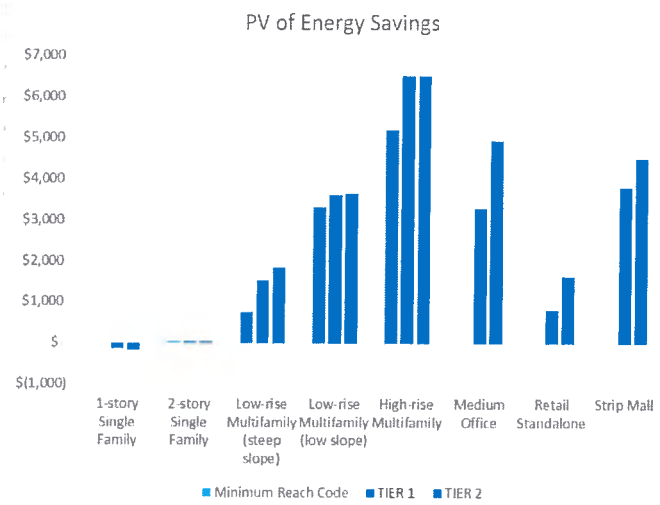
Low-Slope Reach Code: YES

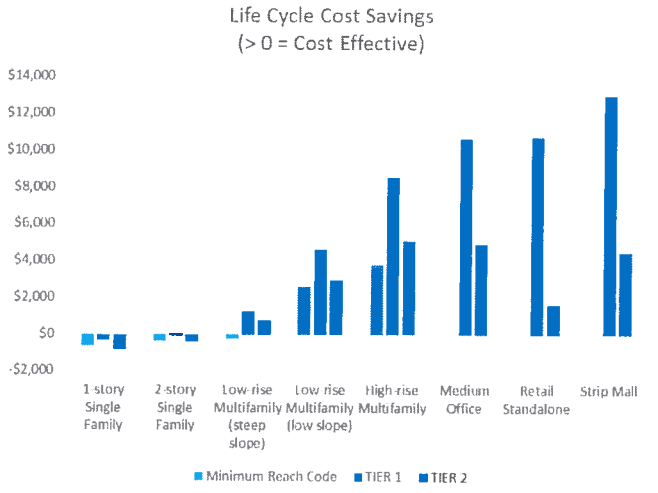
The simulations show energy savings and life cycle cost savings for all prototypes except the Retail Standalone. Even though the stand alone retail has large negative savings, averaging all of the nonresidential prototype results still shows life cycle cost savings. Considering that in the long term cool roof prices are likely drop as they become more prevalent, and would provide further benefit as climate change becomes more severe, jurisdictions in Climate Zone 5 should pursue the cool roof Reach Code.

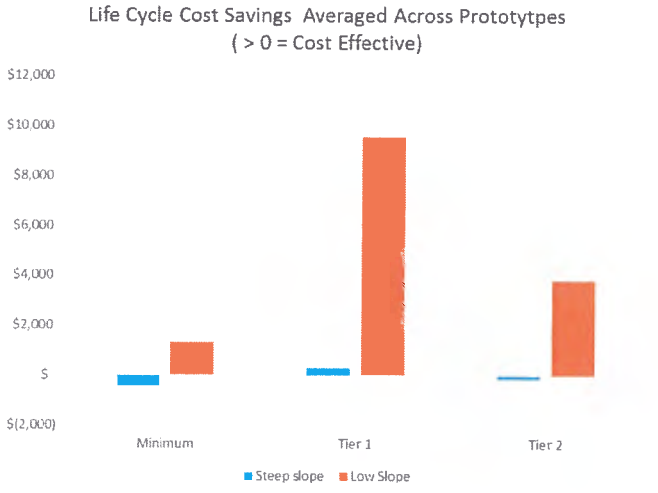
The Minimum Reach Code is the most cost effective, on average, and yields the most energy savings.

Prototype	Climate Zone 5 (Results/Bldg.)	Minimum Reach Code		TIER 1		TIER 2	
		≤ 2:12	> 2:12	≤ 2:12	> 2:12	≤ 2:12	> 2:12
1-story Single Family	Base Case Price		$2,628		$2,628		$2,628
	Reach Code Price		$3,689		$3,638		$3,938
	Incremental Price		$1,061		$1,009		$1,309
	PVS Energy Savings		($291)		($730)		($906)
	B/C Ratio		No Savings		No Savings		No Savings
	LCC Savings		($1,351)		($1,739)		($2,216)
2-story Single Family	Base Case Price		$1,815		$1,815		$1,815
	Reach Code Price		$2,547		$2,512		$2,719
	Incremental Price		$732		$697		$904
	PVS Energy Savings		($135)		($383)		($483)
	B/C Ratio		No Savings		No Savings		No Savings
	LCC Savings		($868)		($1,080)		($1,387)
Low-rise Multifamily	Base Case Price	$2,812	$4,356	$2,812	$4,356	$2,812	$4,356
	Reach Code Price	$1,790	$6,113	$1,906	$6,028	$1,745	$6,525
	Incremental Price	($1,022)	$1,758	($906)	$1,672	($1,067)	$2,169
	PVS Energy Savings	$506	$271	$277	$385	$229	$427
	B/C Ratio	No Costs	0.2	No Costs	0.2	No Costs	0.2
	LCC Savings	$1,527	($1,487)	$1,183	($1,287)	$1,296	($1,742)
High-rise Multifamily	Base Case Price	$5,677		$5,677		$5,677	
	Reach Code Price	$3,614		$3,848		$3,522	
	Incremental Price	($2,063)		($1,829)		($2,154)	
	PVS Energy Savings	$5,207		$3,905		$3,905	
	B/C Ratio	No Costs		No Costs		No Costs	
	LCC Savings	$7,270		$5,735		$6,060	
Medium Office	Base Case Price	$7,663		$7,663		$7,663	
	Reach Code Price	$7,663		$8,158		$7,468	
	Incremental Price	$0		$495		($195)	
	PVS Energy Savings	-		$2,478		$2,478	
	B/C Ratio	-		5.0		No Costs	
	LCC Savings	$0		$1,983		$2,672	
Retail Standalone	Base Case Price	$10,310		$10,310		$10,310	
	Reach Code Price	$10,310		$10,976		$10,048	
	Incremental Price	$0		$666		($262)	
	PVS Energy Savings	-		($4,129)		($4,955)	
	B/C Ratio	-		No Savings		No Savings	
	LCC Savings	$0		($4,795)		($4,693)	
Strip Mall	Base Case Price	$9,570		$9,570		$9,570	
	Reach Code Price	$9,570		$10,188		$9,327	
	Incremental Price	$0		$618		($243)	
	PVS Energy Savings	-		$693		$1,039	
	B/C Ratio	-		1.1		No Costs	
	LCC Savings	$0		$75		$1,282	

8.4.6 Climate Zone 6







Recommendations

Steep-Slope Reach Code: YES, FOR LOW-RISE MULTIFAMILY BUILDINGS

The simulations show low or negative energy savings and positive life cycle costs for the single family prototypes. However, the Low-Rise Multifamily prototype shows energy savings and life cycle cost savings for the Tier 1 and Tier 2 Reach Code. Therefore, the steep-slope Reach Code should be pursued for Low-Rise Multifamily buildings by jurisdictions in Climate Zone 6.

For Low-Rise Multifamily buildings, the Tier 1 Reach Code is the most cost effective, on average, while Tier 2 yields the most energy savings. Tier 2 is recommended to maximize energy savings.

Low-Slope Reach Code: YES

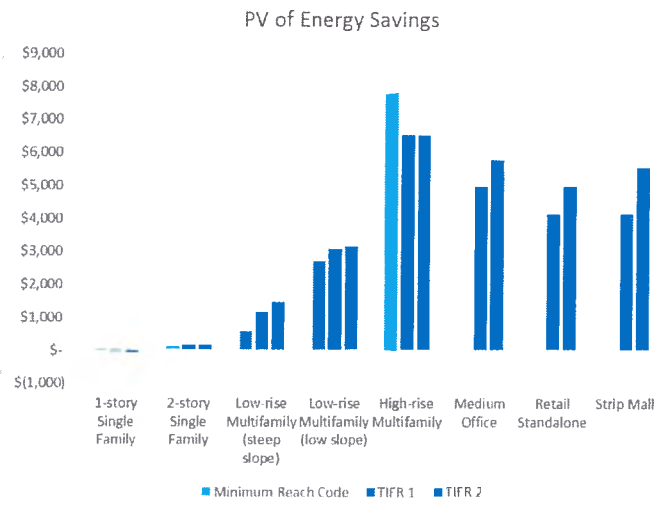
The simulations show energy savings and life cycle cost savings for all prototypes. Therefore, low-slope cool roofs should be pursued by jurisdictions in Climate Zone 6.

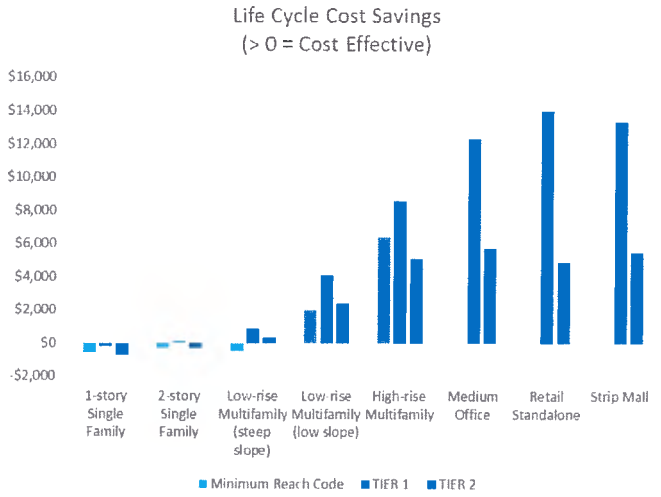
The Tier 1 Reach Code is the most cost effective, on average, while Tier 2 yields the most energy savings. Tier 2 is recommended to maximize energy savings.

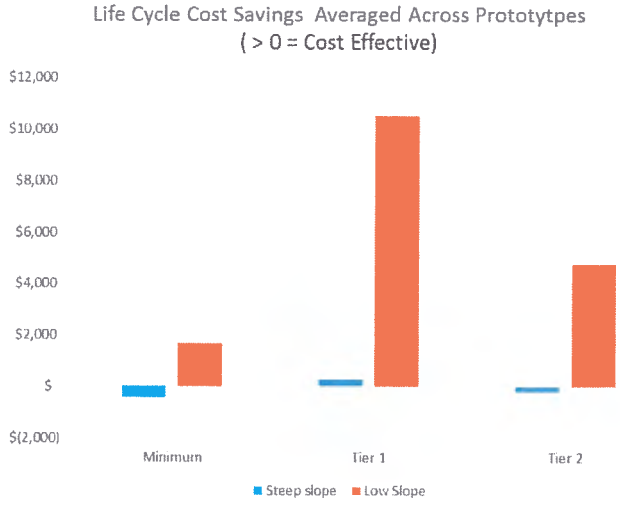
Cost-Effectiveness Study for Cool Roofs – Climate Zone 6 Results
Prepared for Pacific Gas & Electric Company by TRC Solutions

Prototype	Climate Zone 6 (Results/Bldg.)	Minimum Reach Code		TIER 1		TIER 2	
		≤ 2:12	> 2:12	≤ 2:12	> 2:12	≤ 2:12	> 2:12
1-story Single Family	Base Case Price		$2,741		$2,741		$2,741
	Reach Code Price		$3,362		$2,905		$3,396
	Incremental Price		$621		$164		$655
	PVS Energy Savings		$0		($125)		($171)
	B/C Ratio		No Savings		No Savings		No Savings
	LCC Savings		($621)		($290)		($826)
2-story Single Family	Base Case Price		$1,892		$1,892		$1,892
	Reach Code Price		$2,321		$2,006		$2,345
	Incremental Price		$429		$114		$452
	PVS Energy Savings		$54		$49		$49
	B/C Ratio		0.1		0.4		0.1
	LCC Savings		($375)		($64)		($403)
Low-rise Multifamily	Base Case Price	$3,362	$4,542	$3,362	$4,542	$3,362	$4,542
	Reach Code Price	$4,058	$5,571	$2,339	$4,814	$4,063	$5,627
	Incremental Price	$696	$1,030	($1,023)	$272	$701	$1,085
	PVS Energy Savings	$3,323	$771	$3,600	$1,523	$3,648	$1,848
	B/C Ratio	4.8	0.7	No Costs	5.6	5.2	1.7
	LCC Savings	$2,627	($259)	$4,623	$1,251	$2,947	$763
High-rise Multifamily	Base Case Price	$6,787		$6,787		$6,787	
	Reach Code Price	$8,193		$4,721		$8,202	
	Incremental Price	$1,406		($2,066)		$1,415	
	PVS Energy Savings	$5,207		$6,509		$6,509	
	B/C Ratio	3.7		No Costs		4.6	
	LCC Savings	$3,801		$8,574		$5,094	
Medium Office	Base Case Price	$17,371		$17,371		$17,371	
	Reach Code Price	$17,371		$10,011		$17,391	
	Incremental Price	$0		($7,361)		$19	
	PVS Energy Savings	-		$3,303		$4,955	
	B/C Ratio	-		No Costs		256.8	
	LCC Savings	$0		$10,664		$4,936	
Retail Standalone	Base Case Price	$23,372		$23,372		$23,372	
	Reach Code Price	$23,372		$13,469		$23,398	
	Incremental Price	$0		($9,904)		$26	
	PVS Energy Savings	-		$826		$1,652	
	B/C Ratio	-		No Costs		63.6	
	LCC Savings	$0		$10,730		$1,626	
Strip Mall	Base Case Price	$21,694		$21,694		$21,694	
	Reach Code Price	$21,694		$12,501		$21,718	
	Incremental Price	$0		($9,193)		$24	
	PVS Energy Savings	-		$3,811		$4,504	
	B/C Ratio	-		No Costs		186.9	
	LCC Savings	$0		$13,004		$4,480	

8.4.7 Climate Zone 7







Recommendations

Steep-Slope Reach Code: YES, FOR LOW-RISE MULTIFAMILY BUILDINGS

The simulations show low or no energy savings, and mostly life cycle costs for the single family prototypes. However, the Low-Rise Multifamily prototype shows energy savings and life cycle cost savings for the Tier 1 and Tier 2 Reach Code. Therefore, the steep-slope Reach Code should be pursued for low-rise multifamily buildings by jurisdictions Climate Zone 7.

For Low-Rise Multifamily buildings, the Tier 1 Reach Code is most cost effective, on average, while Tier 2 yields the most energy savings. Tier 2 is recommended to maximize energy savings.

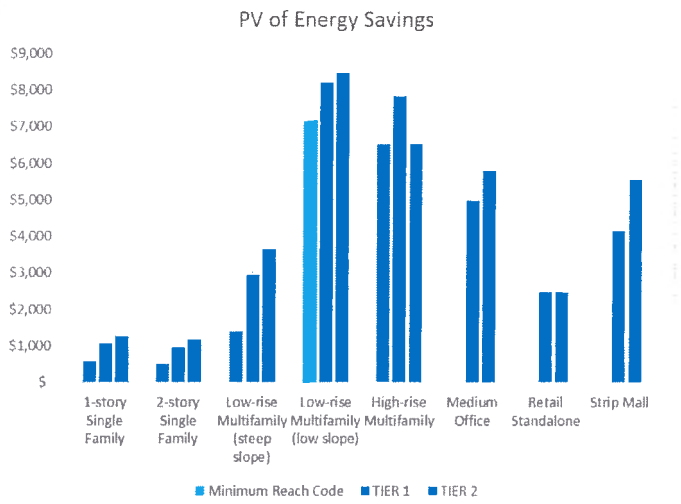
Low-Slope Reach Code: YES

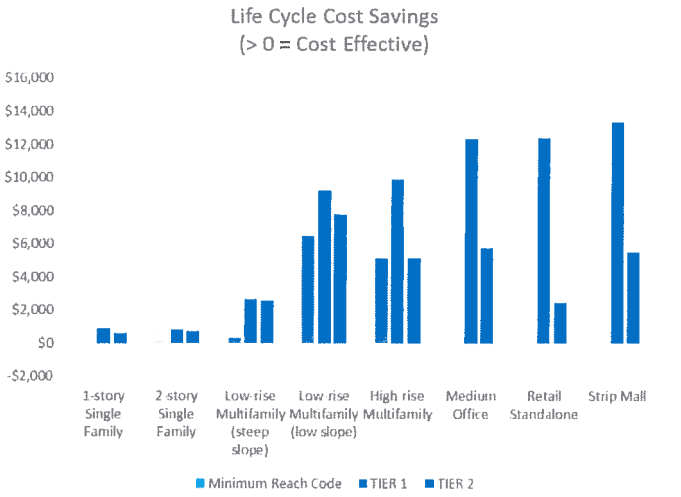
The simulations show energy savings and life cycle cost savings for all prototypes. Therefore, low-slope cool roofs should be pursued by jurisdictions in Climate Zone 7.

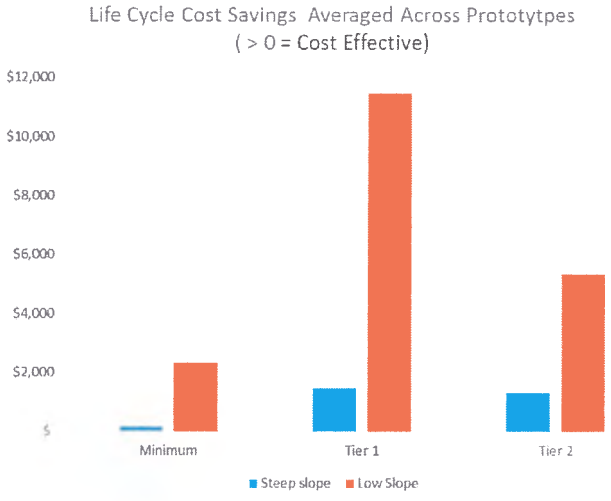
The Tier 1 Reach Code is the most cost effective, on average, while Tier 2 yields the most energy savings. Tier 2 is recommended to maximize energy savings.

Prototype	Climate Zone 7 (Results/Bldg.)	Minimum Reach Code		TIER 1		TIER 2	
		≤ 2:12	> 2:12	≤ 2:12	> 2:12	≤ 2:12	> 2 12
1-story Single Family	Base Case Price		$2,741		$2,741		$2,741
	Reach Code Price		$3,362		$2,905		$3,396
	Incremental Price		$621		$164		$655
	PVS Energy Savings		$58		($16)		($78)
	B/C Ratio		0.1		No Savings		No Savings
	LCC Savings		($563)		($181)		($733)
2-story Single Family	Base Case Price		$1,892		$1,892		$1,892
	Reach Code Price		$2,321		$2,006		$2,345
	Incremental Price		$429		$114		$452
	PVS Energy Savings		$86		$135		$149
	B/C Ratio		0.2		1.2		0.3
	LCC Savings		($343)		$22		($303)
Low-rise Multifamily	Base Case Price	$3,362	$4,542	$3,362	$4,542	$3,362	$4,542
	Reach Code Price	$4,058	$5,571	$2,339	$4,814	$4,063	$5,627
	Incremental Price	$696	$1,030	($1,023)	$272	$701	$1,085
	PVS Energy Savings	$2,709	$572	$3,058	$1,162	$3,143	$1,457
	B/C Ratio	3.9	0.6	No Costs	4.3	4.5	1.3
	LCC Savings	$2,013	($458)	$4,081	$889	$2,442	$372
High-rise Multifamily	Base Case Price	$6,787		$6,787		$6,787	
	Reach Code Price	$8,193		$4,721		$8,202	
	Incremental Price	$1,406		($2,066)		$1,415	
	PVS Energy Savings	$7,811		$6,509		$6,509	
	B/C Ratio	5.6		No Costs		4.6	
	LCC Savings	$6,405		$8,574		$5,094	
Medium Office	Base Case Price	$17,371		$17,371		$17,371	
	Reach Code Price	$17,371		$10,011		$17,391	
	Incremental Price	$0		($7,361)		$19	
	PVS Energy Savings	-		$4,955		$5,781	
	B/C Ratio	-		No Costs		299.6	
	LCC Savings	$0		$12,316		$5,762	
Retail Standalone	Base Case Price	$23,372		$23,372		$23,372	
	Reach Code Price	$23,372		$13,469		$23,398	
	Incremental Price	$0		($9,904)		$26	
	PVS Energy Savings	-		$4,129		$4,955	
	B/C Ratio	-		No Costs		190.9	
	LCC Savings	$0		$14,033		$4,929	
Strip Mall	Base Case Price	$21,694		$21,694		$21,694	
	Reach Code Price	$21,694		$12,501		$21,718	
	Incremental Price	$0		($9,193)		$24	
	PVS Energy Savings	-		$4,158		$5,544	
	B/C Ratio	-		No Costs		230.1	
	LCC Savings	$0		$13,351		$5,520	

8.4.8 Climate Zone 8







Recommendations

Steep-Slope Reach Code: YES

The simulations show energy savings and life cycle costs savings for all prototypes at nearly all Reach Code levels. Therefore, the steep-slope Reach Code should be pursued by jurisdictions in Climate Zone 8.

The Tier 1 and Tier 2 Reach Code have roughly equivalent cost effectiveness, on average, but Tier 2 yields more energy savings. Tier 2 is recommended to maximize energy savings.

Low-Slope Reach Code: YES

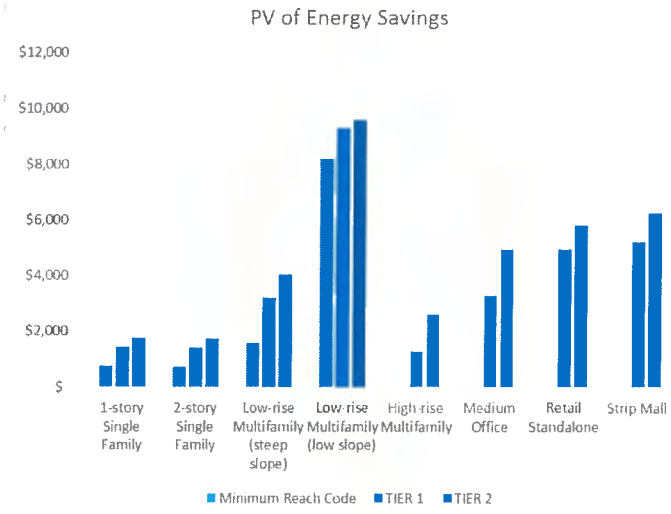
The simulations show energy savings and life cycle cost savings for all prototypes. Therefore, low-slope cool roofs should be pursued by jurisdictions in Climate Zone 8.

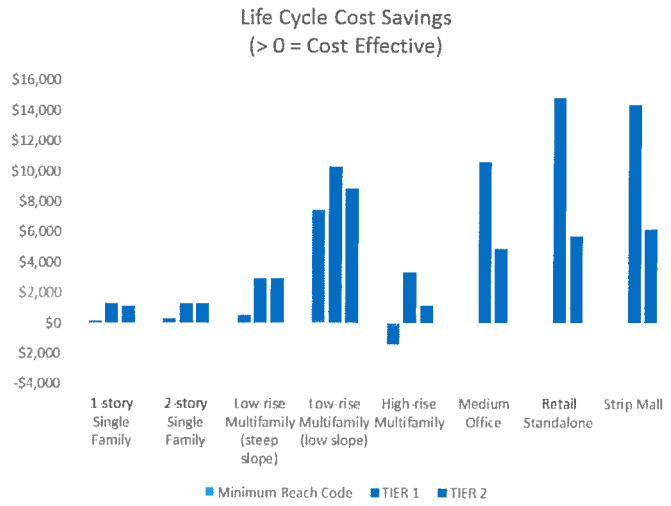
The Tier 1 Reach Code is the most cost effective, on average, while Tier 2 yields more energy savings. Tier 2 is recommended to maximize energy savings.

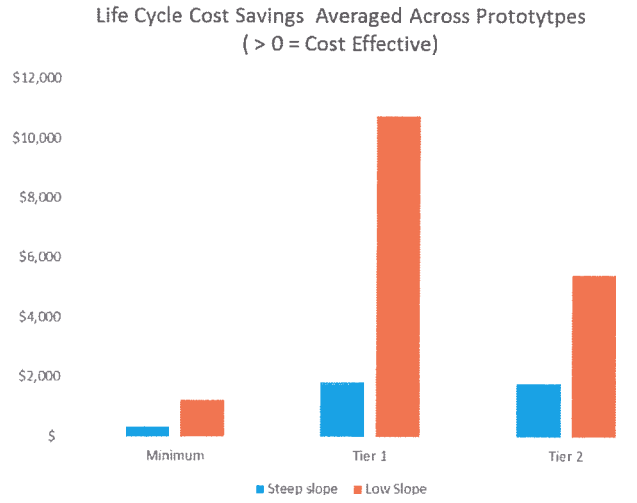
Cost-Effectiveness Study for Cool Roofs – Climate Zone 8 Results
Prepared for Pacific Gas & Electric Company by TRC Solutions

Prototype	Climate Zone 8 (Results/Bldg.)	Minimum Reach Code		TIER 1		TIER 2	
		≤ 2:12	> 2:12	≤ 2:12	> 2:12	≤ 2:12	> 2:12
1-story Single Family	Base Case Price		$2,741		$2,741		$2,741
	Reach Code Price		$3,362		$2,905		$3,396
	Incremental Price		$621		$164		$655
	PVS Energy Savings		$567		$1,054		$1,262
	B/C Ratio		0.9		6.4		1.9
	LCC Savings		($55)		$889		$608
2-story Single Family	Base Case Price		$1,892		$1,892		$1,892
	Reach Code Price		$2,321		$2,006		$2,345
	Incremental Price		$429		$114		$452
	PVS Energy Savings		$497		$953		$1,172
	B/C Ratio		1.2		8.4		2.6
	LCC Savings		$68		$839		$720
Low-rise Multifamily	Base Case Price	$3,362	$4,542	$3,362	$4,542	$3,362	$4,542
	Reach Code Price	$4,058	$5,571	$2,339	$4,814	$4,063	$5,627
	Incremental Price	$696	$1,030	($1,023)	$272	$701	$1,085
	PVS Energy Savings	$7,164	$1,385	$8,188	$2,926	$8,453	$3,636
	B/C Ratio	10.3	1.3	No Costs	10.7	12.1	3.4
	LCC Savings	$6,468	$355	$9,211	$2,653	$7,752	$2,551
High-rise Multifamily	Base Case Price	$6,787		$6,787		$6,787	
	Reach Code Price	$8,193		$4,721		$8,202	
	Incremental Price	$1,406		($2,066)		$1,415	
	PVS Energy Savings	$6,509		$7,811		$6,509	
	B/C Ratio	4.6		No Costs		4.6	
	LCC Savings	$5,103		$9,876		$5,094	
Medium Office	Base Case Price	$17,371		$17,371		$17,371	
	Reach Code Price	$17,371		$10,011		$17,391	
	Incremental Price	$0		($7,361)		$19	
	PVS Energy Savings	-		$4,955		$5,781	
	B/C Ratio	-		No Costs		299.6	
	LCC Savings	$0		$12,316		$5,762	
Retail Standalone	Base Case Price	$23,372		$23,372		$23,372	
	Reach Code Price	$23,372		$13,469		$23,398	
	Incremental Price	$0		($9,904)		$26	
	PVS Energy Savings	-		$2,478		$2,478	
	B/C Ratio	-		No Costs		95.4	
	LCC Savings	$0		$12,381		$2,452	
Strip Mall	Base Case Price	$21,694		$21,694		$21,694	
	Reach Code Price	$21,694		$12,501		$21,718	
	Incremental Price	$0		($9,193)		$24	
	PVS Energy Savings	-		$4,158		$5,544	
	B/C Ratio	-		No Costs		230.1	
	LCC Savings	$0		$13,351		$5,520	

8.4.9 Climate Zone 9







Recommendations

Steep-Slope Reach Code: YES

The simulations show energy savings and life cycle costs savings for all prototypes. Therefore, the steep-slope Reach Code should be pursued by jurisdictions in Climate Zone 9.

The Tier 1 and Tier 2 Reach Code have roughly equivalent cost effectiveness, on average, but Tier 2 yields the most energy savings. Tier 2 is recommended to maximize energy savings.

Low-Slope Reach Code: YES

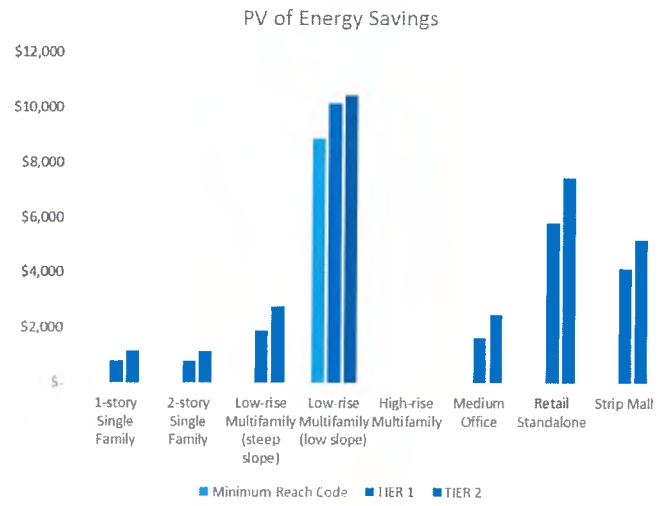
The simulations show energy savings and life cycle cost savings for all prototypes at nearly all Reach Code levels. Therefore, low-slope cool roofs should be pursued by jurisdictions in Climate Zone 9.

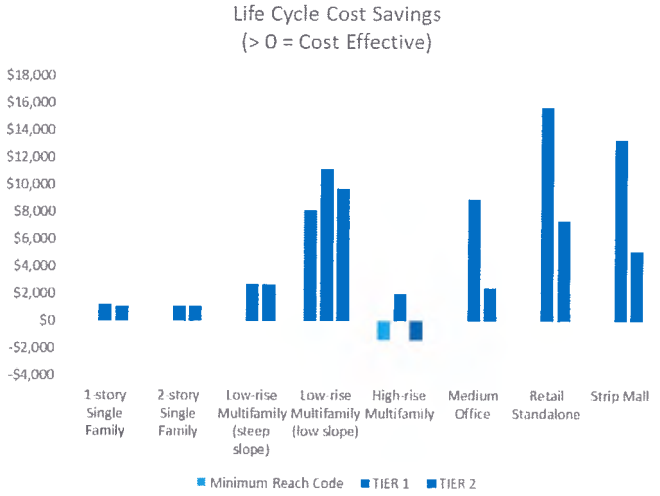
The Tier 1 Reach Code is the most cost effective, on average, while Tier 2 yields the most energy savings. Tier 2 is recommended to maximize energy savings.

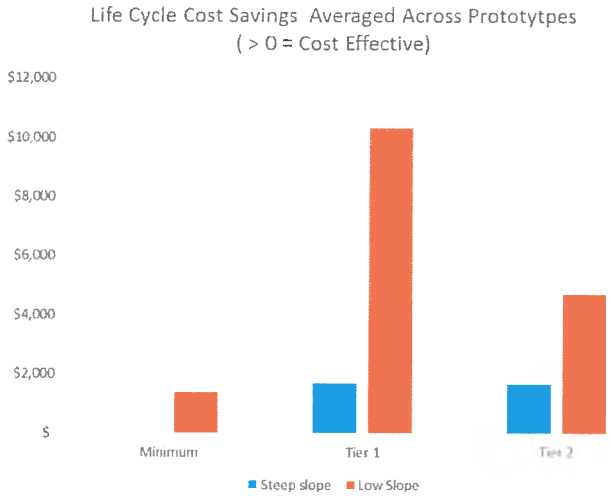
Cost-Effectiveness Study for Cool Roofs – Climate Zone 9 Results
Prepared for Pacific Gas & Electric Company by TRC Solutions

Prototype	Climate Zone 9 (Results/Bldg.)	Minimum Reach Code		TIER 1		TIER 2	
		≤ 2:12	> 2:12	≤ 2:12	> 2:12	≤ 2:12	> 2:12
1-story Single Family	Base Case Price		$2,741		$2,741		$2,741
	Reach Code Price		$3,362		$2,905		$3,396
	Incremental Price		$621		$164		$655
	PV$ Energy Savings		$768		$1,448		$1,773
	B/C Ratio		1.2		8.8		2.7
	LCC Savings		$147		$1,283		$1,118
2-story Single Family	Base Case Price		$1,892		$1,892		$1,892
	Reach Code Price		$2,321		$2,006		$2,345
	Incremental Price		$429		$114		$452
	PV$ Energy Savings		$726		$1,408		$1,742
	B/C Ratio		1.7		12.4		3.9
	LCC Savings		$297		$1,295		$1,290
Low-rise Multifamily	Base Case Price	$3,362	$4,542	$3,362	$4,542	$3,362	$4,542
	Reach Code Price	$4,058	$5,571	$2,339	$4,814	$4,063	$5,627
	Incremental Price	$696	$1,030	($1,023)	$272	$701	$1,085
	PV$ Energy Savings	$8,188	$1,577	$9,295	$3,215	$9,597	$4,028
	B/C Ratio	11.8	1.5	No Costs	11.8	13.7	3.7
	LCC Savings	$7,491	$547	$10,319	$2,942	$8,896	$2,942
High-rise Multifamily	Base Case Price	$6,787		$6,787		$6,787	
	Reach Code Price	$8,193		$4,721		$8,202	
	Incremental Price	$1,406		($2,066)		$1,415	
	PV$ Energy Savings	$0		$1,302		$2,604	
	B/C Ratio	No Savings		No Costs		1.8	
	LCC Savings	($1,406)		$3,367		$1,188	
Medium Office	Base Case Price	$17,371		$17,371		$17,371	
	Reach Code Price	$17,371		$10,011		$17,391	
	Incremental Price	$0		($7,361)		$19	
	PV$ Energy Savings	-		$3,303		$4,955	
	B/C Ratio	-		No Costs		256.8	
	LCC Savings	$0		$10,664		$4,936	
Retail Standalone	Base Case Price	$23,372		$23,372		$23,372	
	Reach Code Price	$23,372		$13,469		$23,398	
	Incremental Price	$0		($9,904)		$26	
	PV$ Energy Savings	-		$4,955		$5,781	
	B/C Ratio	-		No Costs		222.7	
	LCC Savings	$0		$14,859		$5,755	
Strip Mall	Base Case Price	$21,694		$21,694		$21,694	
	Reach Code Price	$21,694		$12,501		$21,718	
	Incremental Price	$0		($9,193)		$24	
	PV$ Energy Savings	-		$5,198		$6,237	
	B/C Ratio	-		No Costs		258.8	
	LCC Savings	$0		$14,390		$6,213	

8.4.10 Climate Zone 10







Recommendations

Steep-Slope Reach Code: YES

The simulations show energy savings and life cycle costs savings for all prototypes. Therefore, the steep-slope Reach Code should be pursued by jurisdictions in Climate Zone 10.

The Tier 1 and Tier 2 Reach Code have roughly equivalent cost effectiveness, on average, but Tier 2 yields the most energy savings.

Low-Slope Reach Code: YES, EXCEPT HIGH-RISE MULTIFAMILY

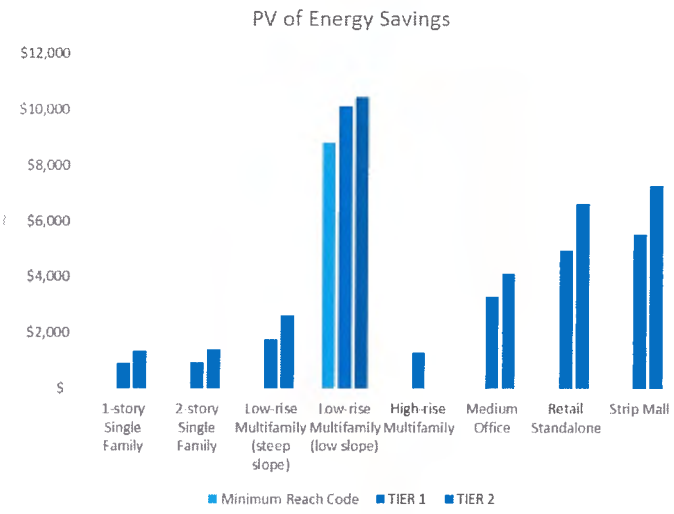
The simulations show energy savings and life cycle cost savings for all prototypes except the High-Rise Multifamily prototype. Therefore, low-slope cool roofs should be pursued for low-rise multifamily and nonresidential buildings by jurisdictions in Climate Zone 10.

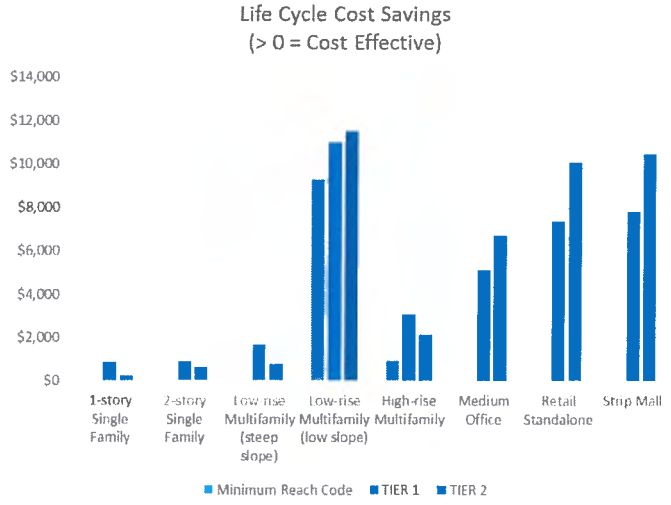
For low-rise multifamily and nonresidential buildings, the Tier 1 Reach Code is the most cost effective, on average, while Tier 2 yields the most energy savings. Tier 2 is recommended to maximize energy savings.

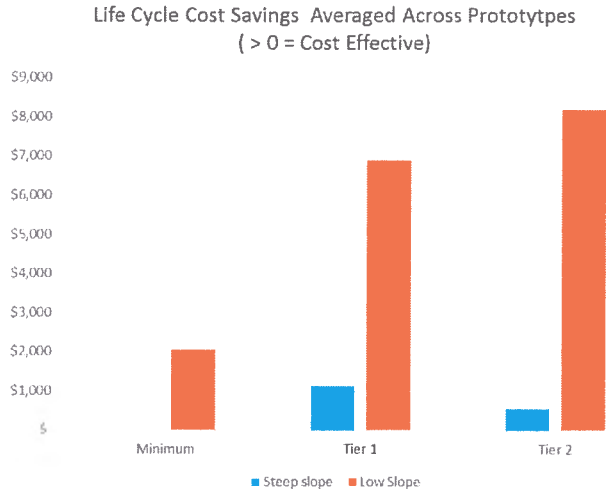
Cost-Effectiveness Study for Cool Roofs – Climate Zone 10 Results
Prepared for Pacific Gas & Electric Company by TRC Solutions

Prototype	Climate Zone 10 (Results/Bldg.)	Minimum Reach Code		TIER 1		TIER 2	
		≤ 2:12	> 2:12	≤ 2:12	> 2:12	≤ 2:12	> 2:12
1-story Single Family	Base Case Price		$3,362		$3,362		$3,362
	Reach Code Price		$3,362		$2,905		$3,396
	Incremental Price		$0		($457)		$33
	PVS Energy Savings		-		$783		$1,144
	B/C Ratio		-		No Costs		34.2
	LCC Savings		$0		$1,240		$1,111
2-story Single Family	Base Case Price		$2,321		$2,321		$2,321
	Reach Code Price		$2,321		$2,006		$2,345
	Incremental Price		$0		($316)		$23
	PVS Energy Savings		-		$780		$1,142
	B/C Ratio		-		No Costs		49.4
	LCC Savings		$0		$1,096		$1,119
Low-rise Multifamily	Base Case Price	$3,362	$5,571	$3,362	$5,571	$3,362	$5,571
	Reach Code Price	$4,058	$5,571	$2,339	$4,814	$4,063	$5,627
	Incremental Price	$696	$0	($1,023)	($757)	$701	$55
	PVS Energy Savings	$8,874	-	$10,162	$1,908	$10,463	$2,769
	B/C Ratio	12.7	-	No Costs	No Costs	14.9	49.9
	LCC Savings	$8,178	$0	$11,186	$2,666	$9,762	$2,714
High-rise Multifamily	Base Case Price	$6,787		$6,787		$6,787	
	Reach Code Price	$8,193		$4,721		$8,202	
	Incremental Price	$1,406		($2,066)		$1,415	
	PVS Energy Savings	$0		$0		$0	
	B/C Ratio	No Savings		No Savings		No Savings	
	LCC Savings	($1,406)		$2,066		($1,415)	
Medium Office	Base Case Price	$17,371		$17,371		$17,371	
	Reach Code Price	$17,371		$10,011		$17,391	
	Incremental Price	$0		($7,361)		$19	
	PVS Energy Savings	-		$1,652		$2,478	
	B/C Ratio	-		No Costs		128.4	
	LCC Savings	$0		$9,013		$2,458	
Retail Standalone	Base Case Price	$23,372		$23,372		$23,372	
	Reach Code Price	$23,372		$13,469		$23,398	
	Incremental Price	$0		($9,904)		$26	
	PVS Energy Savings	-		$5,781		$7,433	
	B/C Ratio	-		No Costs		286.3	
	LCC Savings	$0		$15,685		$7,407	
Strip Mall	Base Case Price	$21,694		$21,694		$21,694	
	Reach Code Price	$21,694		$12,501		$21,718	
	Incremental Price	$0		($9,193)		$24	
	PVS Energy Savings	-		$4,158		$5,198	
	B/C Ratio	-		No Costs		215.7	
	LCC Savings	$0		$13,351		$5,173	

8.4.11 Climate Zone 11







Recommendations

Steep-Slope Reach Code: YES

The simulations show energy savings and life cycle cost savings for all prototypes. Therefore, the steep-slope Reach Code should be pursued by jurisdictions in Climate Zone 11.

The Tier 1 Reach Code is the most cost effective, on average, while Tier 2 yields the most energy savings. Tier 2 is recommended to maximize energy savings.

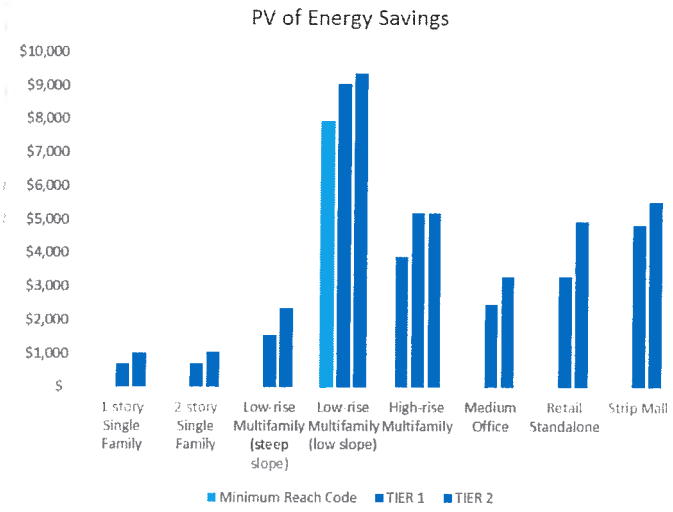
Low-Slope Reach Code: YES

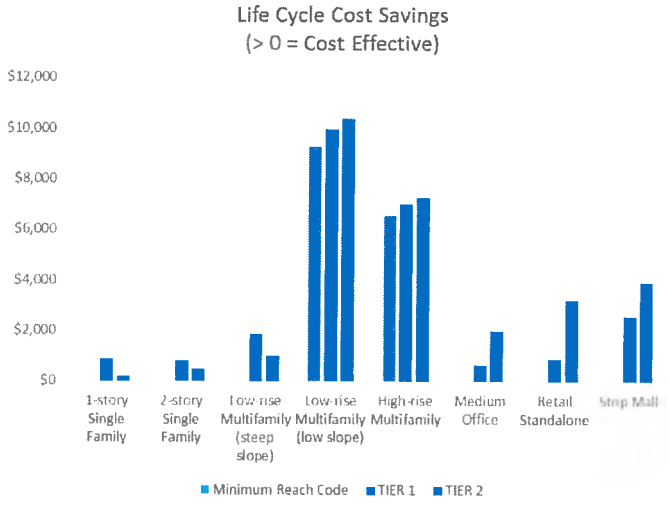
The simulations show energy savings and life cycle cost savings for all prototypes. Therefore, low-slope cool roofs should be pursued by jurisdictions in Climate Zone 11.

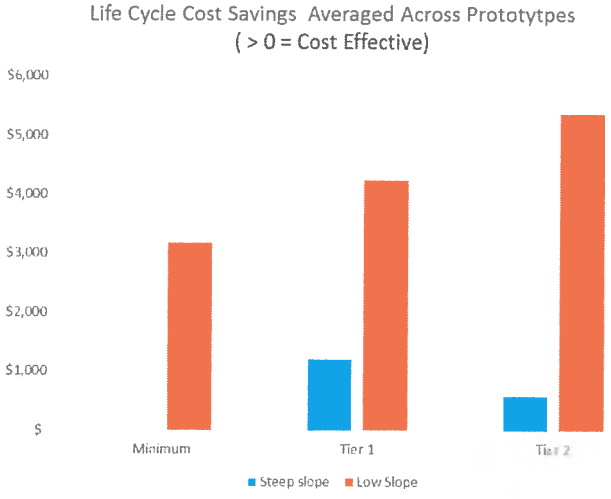
The Tier 2 Reach Code is the most cost effective, on average, and yields the most energy savings. Tier 2 is recommended to maximize energy savings.

Prototype	Climate Zone 11 (Results/Bldg)	Minimum Reach Code		TIER 1		TIER 2	
		≤ 2:12	> 2:12	≤ 2:12	> 2 12	≤ 2:12	> 2:12
1-story Single Family	Base Case Price		$3,137		$3,137		$3,137
	Reach Code Price		$3,137		$3,203		$4,253
	Incremental Price		$0		$65		$1,115
	PVS Energy Savings		-		$906		$1,350
	B/C Ratio		-		13.9		1.2
	LCC Savings		$0		$841		$235
2-story Single Family	Base Case Price		$2,166		$2,166		$2,166
	Reach Code Price		$2,166		$2,211		$2,936
	Incremental Price		$0		$45		$770
	PVS Energy Savings		-		$923		$1,392
	B/C Ratio		-		20.5		1.8
	LCC Savings		$0		$878		$622
Low-rise Multifamily	Base Case Price	$2,784	$5,199	$2,784	$5,199	$2,784	$5,199
	Reach Code Price	$2,328	$5,199	$1,906	$5,307	$1,729	$7,047
	Incremental Price	($456)	$0	($878)	$108	($1,055)	$1,848
	PVS Energy Savings	$8,826	-	$10,126	$1,770	$10,451	$2,613
	B/C Ratio	No Costs	-	No Costs	16.4	No Costs	1.4
	LCC Savings	$9,282	$0	$11,005	$1,662	$11,506	$765
High-rise Multifamily	Base Case Price	$5,621		$5,621		$5,621	
	Reach Code Price	$4,700		$3,848		$3,491	
	Incremental Price	($921)		($1,773)		($2,129)	
	PVS Energy Savings	$0		$1,302		$0	
	B/C Ratio	No Savings		No Costs		No Savings	
	LCC Savings	$921		$3,075		$2,129	
Medium Office	Base Case Price	$9,965		$9,965		$9,965	
	Reach Code Price	$9,965		$8,158		$7,403	
	Incremental Price	$0		($1,807)		($2,562)	
	PVS Energy Savings	-		$3,303		$4,129	
	B/C Ratio	-		No Costs		No Costs	
	LCC Savings	$0		$5,110		$6,692	
Retail Standalone	Base Case Price	$13,407		$13,407		$13,407	
	Reach Code Price	$13,407		$10,976		$9,960	
	Incremental Price	$0		($2,431)		($3,448)	
	PVS Energy Savings	-		$4,955		$6,607	
	B/C Ratio	-		No Costs		No Costs	
	LCC Savings	$0		$7,386		$10,055	
Strip Mall	Base Case Price	$12,445		$12,445		$12,445	
	Reach Code Price	$12,445		$10,188		$9,245	
	Incremental Price	$0		($2,257)		($3,200)	
	PVS Energy Savings	-		$5,544		$7,277	
	B/C Ratio	-		No Costs		No Costs	
	LCC Savings	$0		$7,801		$10,477	

8.4.12 Climate Zone 12







Recommendations

Steep-Slope Reach Code: YES

The simulations show energy savings and life cycle costs savings for all prototypes. Therefore, the steep-slope Reach Code should be pursued by jurisdictions in Climate Zone 12.

The Tier 1 Reach Code is the most cost effective, on average, while Tier 2 yields the most energy savings. Tier 2 is recommended to maximize energy savings.

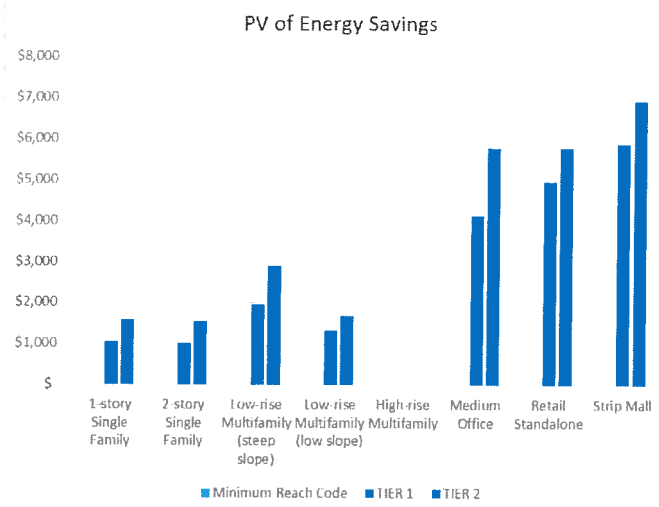
Low-Slope Reach Code: YES

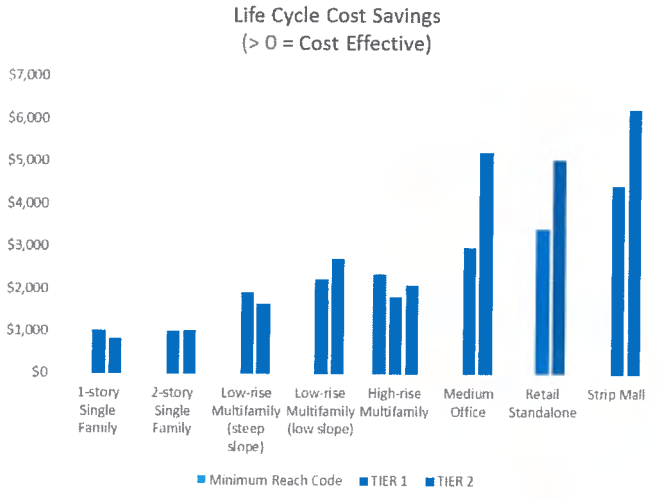
The simulations show energy savings and life cycle cost savings for all prototypes. Therefore, low-slope cool roofs should be pursued by jurisdictions in Climate Zone 12.

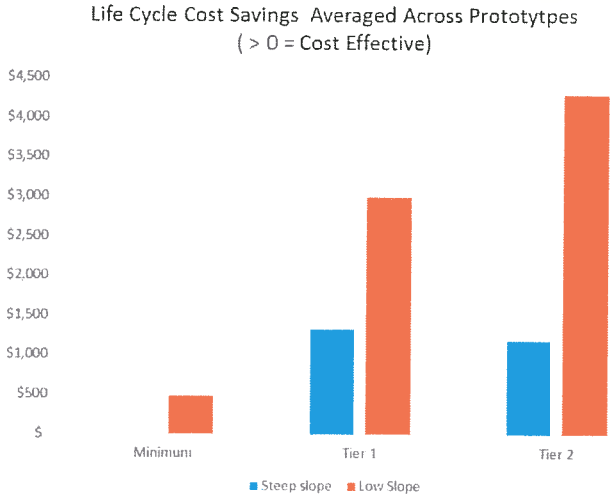
The Tier 2 Reach Code is the most cost effective, on average, and yields the most energy savings. Tier 2 is recommended to maximize energy savings.

Prototype	Climate Zone 12 (Results/Bldg.)	Minimum Reach Code		TIER 1		TIER 2	
		≤ 2:12	> 2:12	≤ 2:12	> 2:12	≤ 2:12	> 2:12
1-story Single Family	Base Case Price		$2,989		$2,989		$2,989
	Reach Code Price		$2,989		$2,804		$3,793
	Incremental Price		$0		($185)		$804
	PVS Energy Savings		-		$699		$1,028
	B/C Ratio		-		No Costs		1.3
	LCC Savings		$0		$884		$224
2-story Single Family	Base Case Price		$2,064		$2,064		$2,064
	Reach Code Price		$2,064		$1,936		$2,619
	Incremental Price		$0		($128)		$555
	PVS Energy Savings		-		$710		$1,060
	B/C Ratio		-		No Costs		1.9
	LCC Savings		$0		$838		$505
Low-rise Multifamily	Base Case Price	$2,812	$4,953	$2,812	$4,953	$2,812	$4,953
	Reach Code Price	$1,486	$4,953	$1,906	$4,647	$1,787	$6,285
	Incremental Price	($1,326)	$0	($906)	($306)	($1,025)	$1,332
	PVS Energy Savings	$7,959	-	$9,055	$1,571	$9,368	$2,354
	B/C Ratio	No Costs	-	No Costs	No Costs	No Costs	1.8
	LCC Savings	$9,285	$0	$9,961	$1,878	$10,393	$1,022
High-rise Multifamily	Base Case Price	$5,677		$5,677		$5,677	
	Reach Code Price	$3,001		$3,848		$3,607	
	Incremental Price	($2,676)		($1,829)		($2,070)	
	PVS Energy Savings	$3,905		$5,207		$5,207	
	B/C Ratio	No Costs		No Costs		No Costs	
	LCC Savings	$6,582		$7,036		$7,277	
Medium Office	Base Case Price	$6,362		$6,362		$6,362	
	Reach Code Price	$6,362		$8,158		$7,649	
	Incremental Price	$0		$1,796		$1,287	
	PVS Energy Savings	-		$2,478		$3,303	
	B/C Ratio	-		1.4		2.6	
	LCC Savings	$0		$682		$2,017	
Retail Standalone	Base Case Price	$8,560		$8,560		$8,560	
	Reach Code Price	$8,560		$10,976		$10,291	
	Incremental Price	$0		$2,417		$1,731	
	PVS Energy Savings	-		$3,303		$4,955	
	B/C Ratio	-		1.4		2.9	
	LCC Savings	$0		$887		$3,224	
Strip Mall	Base Case Price	$7,945		$7,945		$7,945	
	Reach Code Price	$7,945		$10,188		$9,552	
	Incremental Price	$0		$2,243		$1,607	
	PVS Energy Savings	-		$4,851		$5,544	
	B/C Ratio	-		2.2		3.5	
	LCC Savings	$0		$2,608		$3,937	

8.4.13 Climate Zone 13







Recommendations

Steep-Slope Reach Code: YES

The simulations show energy savings and life cycle costs savings for all prototypes. Therefore, the steep-slope Reach Code should be pursued by jurisdictions in Climate Zone 13.

The Tier 1 and Tier 2 Reach Code show roughly equivalent cost effectiveness, on average, but Tier 2 yields the most energy savings. Tier 2 is recommended to maximize energy savings.

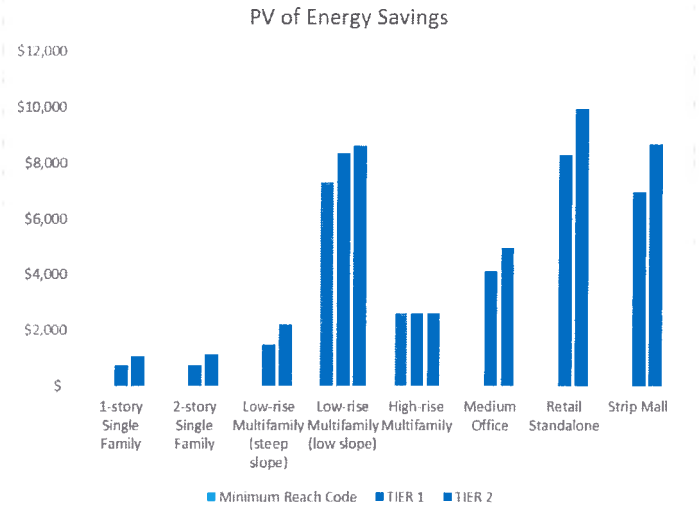
Low-Slope Reach Code: YES, ALL EXCEPT HIGH-RISE MULTIFAMILY

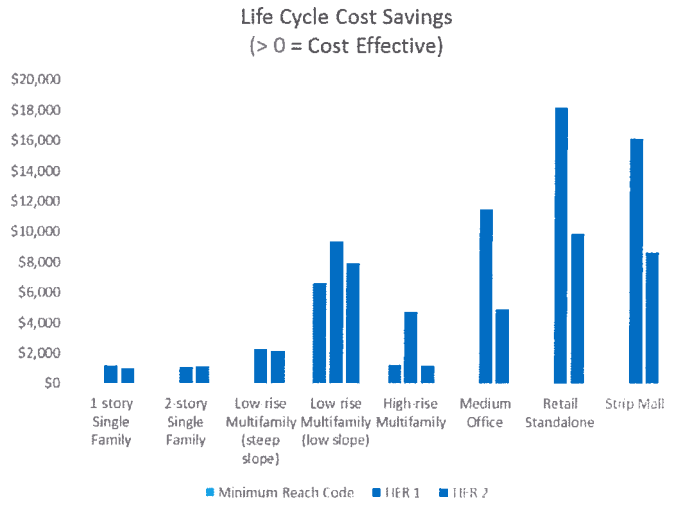
The simulations show energy savings and life cycle cost savings for all prototypes except the High-Rise Multifamily prototype. Therefore, low-slope cool roofs should be pursued for low-rise multifamily and nonresidential buildings by jurisdictions in Climate Zone 13.

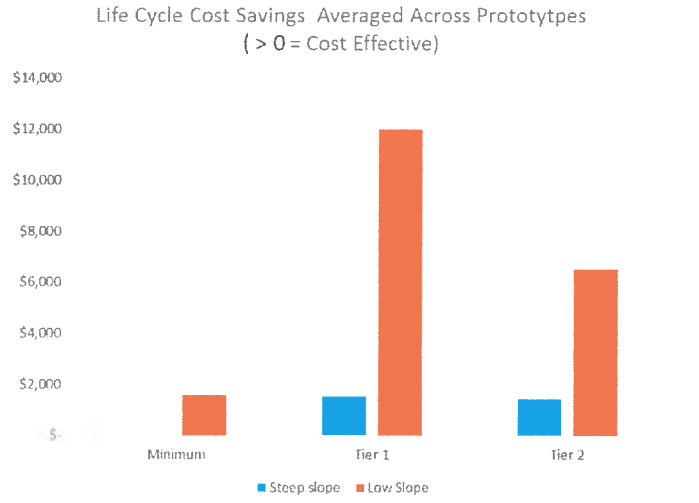
For low-rise multifamily and nonresidential buildings, The Tier 2 Reach Code is the most cost effective, on average, and yields the most energy savings. Tier 2 is recommended to maximize energy savings.

Prototype	Climate Zone 13 (Results/Bldg.)	Minimum Reach Code		TIER 1		TIER 2	
		≤ 2:12	> 2:12	≤ 2:12	> 2:12	≤ 2:12	> 2:12
1-story Single Family	Base Case Price		$3,108		$3,108		$3,108
	Reach Code Price		$3,108		$3,129		$3,849
	Incremental Price		$0		$21		$742
	PVS Energy Savings		-		$1,055		$1,588
	B/C Ratio		-		50.6		2.1
	LCC Savings		$0		$1,035		$846
2-story Single Family	Base Case Price		$2,146		$2,146		$2,146
	Reach Code Price		$2,146		$2,160		$2,658
	Incremental Price		$0		$14		$512
	PVS Energy Savings		-		$1,023		$1,544
	B/C Ratio		-		71.0		3.0
	LCC Savings		$0		$1,009		$1,032
Low-rise Multifamily	Base Case Price	$2,812	$5,150	$2,812	$5,150	$2,812	$5,150
	Reach Code Price	$1,638	$5,150	$1,906	$5,185	$1,766	$6,379
	Incremental Price	$0	$0	($906)	$35	($1,046)	$1,229
	PVS Energy Savings	-	-	$1,337	$1,951	$1,686	$2,896
	B/C Ratio	-	-	No Costs	56.4	No Costs	2.4
	LCC Savings	$0	$0	$2,243	$1,916	$2,732	$1,667
High-rise Multifamily	Base Case Price	$5,677		$5,677		$5,677	
	Reach Code Price	$3,307		$3,848		$3,565	
	Incremental Price	($2,370)		($1,829)		($2,112)	
	PVS Energy Savings	$0		$0		$0	
	B/C Ratio	No Savings		No Savings		No Savings	
	LCC Savings	$2,370		$1,829		$2,112	
Medium Office	Base Case Price	$7,012		$7,012		$7,012	
	Reach Code Price	$7,012		$8,158		$7,558	
	Incremental Price	$0		$1,146		$546	
	PVS Energy Savings	-		$4,129		$5,781	
	B/C Ratio	-		3.6		10.6	
	LCC Savings	$0		$2,984		$5,235	
Retail Standalone	Base Case Price	$9,435		$9,435		$9,435	
	Reach Code Price	$9,435		$10,976		$10,169	
	Incremental Price	$0		$1,541		$735	
	PVS Energy Savings	-		$4,955		$5,781	
	B/C Ratio	-		3.2		7.9	
	LCC Savings	$0		$3,414		$5,046	
Strip Mall	Base Case Price	$8,757		$8,757		$8,757	
	Reach Code Price	$8,757		$10,188		$9,439	
	Incremental Price	$0		$1,431		$682	
	PVS Energy Savings	-		$5,891		$6,930	
	B/C Ratio	-		4.1		10.2	
	LCC Savings	$0		$4,460		$6,248	

8.4.14 Climate Zone 14







Recommendations

Steep-Slope Reach Code: YES

The simulations show energy savings and life cycle costs savings for all prototypes. Therefore, the steep-slope Reach Code should be pursued by jurisdictions in Climate Zone 14.

The Tier 1 and Tier 2 Reach Code show roughly equivalent cost effectiveness, on average, but Tier 2 yields the most energy savings. Tier 2 is recommended to maximize energy savings.

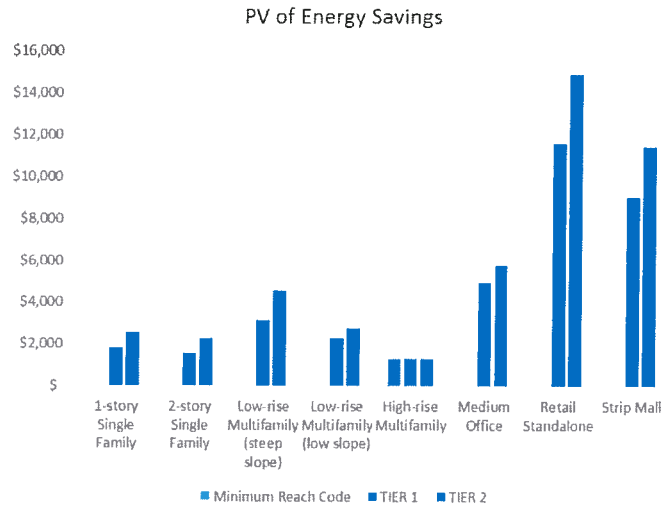
Low-Slope Reach Code: YES

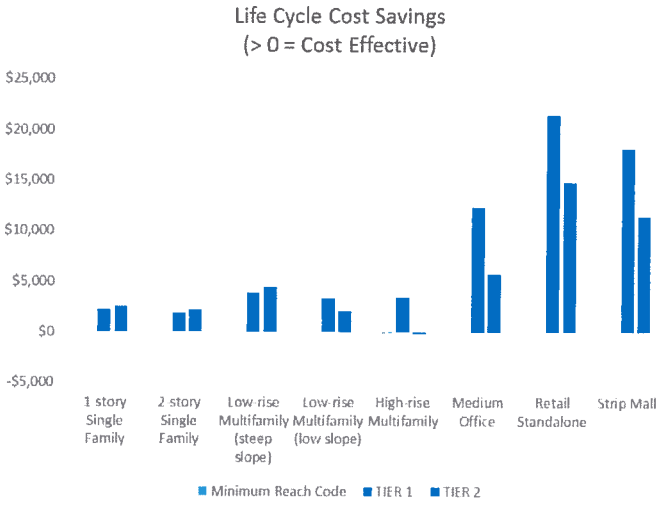
The simulations show energy savings and life cycle cost savings for all prototypes. Therefore, low-slope cool roofs should be pursued by jurisdictions in Climate Zone 14.

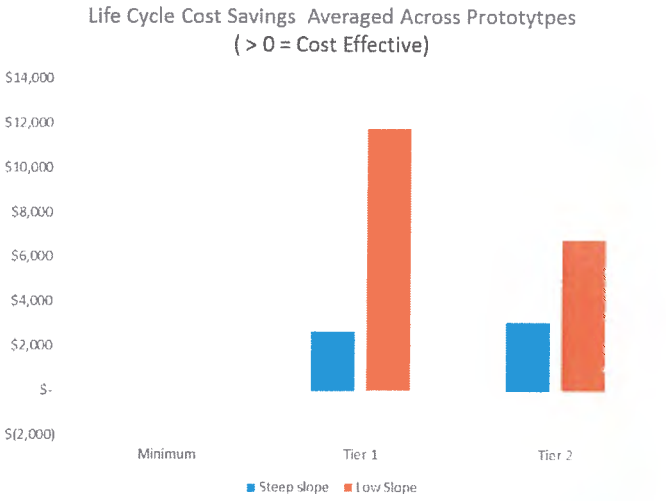
The Tier 1 Reach Code is the most cost effective, on average, while Tier 2 yields the most energy savings. Tier 2 is recommended to maximize energy savings.

Prototype	Climate Zone 14 (Results/ Bldg.)	Minimum Reach Code		TIER 1		TIER 2	
		≤ 2:12	> 2:12	≤ 2:12	> 2:12	≤ 2:12	> 2:12
1-story Single Family	Base Case Price		$3,362		$3,362		$3,362
	Reach Code Price		$3,362		$2,905		$3,396
	Incremental Price		$0		($457)		$33
	PVS Energy Savings		-		$718		$1,057
	B/C Ratio		-		No Costs		31.6
	LCC Savings		$0		$1,175		$1,024
2-story Single Family	Base Case Price		$2,321		$2,321		$2,321
	Reach Code Price		$2,321		$2,006		$2,345
	Incremental Price		$0		($316)		$23
	PVS Energy Savings		-		$752		$1,130
	B/C Ratio		-		No Costs		48.9
	LCC Savings		$0		$1,068		$1,107
Low-rise Multifamily	Base Case Price	$3,362	$5,571	$3,362	$5,571	$3,362	$5,571
	Reach Code Price	$4,058	$5,571	$2,339	$4,814	$4,063	$5,627
	Incremental Price	$696	$0	($1,023)	($757)	$701	$55
	PVS Energy Savings	$7,309	-	$8,332	$1,487	$8,597	$2,191
	B/C Ratio	10.5	-	No Costs	No Costs	12.3	39.5
	LCC Savings	$6,612	$0	$9,355	$2,244	$7,896	$2,136
High-rise Multifamily	Base Case Price	$6,787		$6,787		$6,787	
	Reach Code Price	$8,193		$4,721		$8,202	
	Incremental Price	$1,406		($2,066)		$1,415	
	PVS Energy Savings	$2,604		$2,604		$2,604	
	B/C Ratio	1.9		No Costs		1.8	
	LCC Savings	$1,197		$4,669		$1,188	
Medium Office	Base Case Price	$17,371		$17,371		$17,371	
	Reach Code Price	$17,371		$10,011		$17,391	
	Incremental Price	$0		($7,361)		$19	
	PVS Energy Savings	-		$4,129		$4,955	
	B/C Ratio	-		No Costs		256.8	
	LCC Savings	$0		$11,490		$4,936	
Retail Standalone	Base Case Price	$23,372		$23,372		$23,372	
	Reach Code Price	$23,372		$13,469		$23,398	
	Incremental Price	$0		($9,904)		$26	
	PVS Energy Savings	-		$8,259		$9,910	
	B/C Ratio	-		No Costs		381.8	
	LCC Savings	$0		$18,162		$9,884	
Strip Mall	Base Case Price	$21,694		$21,694		$21,694	
	Reach Code Price	$21,694		$12,501		$21,718	
	Incremental Price	$0		($9,193)		$24	
	PVS Energy Savings	-		$6,930		$8,663	
	B/C Ratio	-		No Costs		359.5	
	LCC Savings	$0		$16,123		$8,638	

8.4.15 Climate Zone 15







Recommendations

Steep-Slope Reach Code: YES

The simulations show energy savings and life cycle cost savings for all prototypes. Therefore, the steep-slope Reach Code should be pursued by jurisdictions in Climate Zone 15.

The Tier 1 and Tier 2 Reach Code show roughly equivalent cost effectiveness, on average, but Tier 2 yields the most energy savings. Tier 2 is recommended to maximize the energy savings.

Low-Slope Reach Code: YES, FOR LOW-RISE MULTIFAMILY AND NONRESIDENTIAL BUILDINGS, AND TIER 1 FOR HIGH-RISE MULTIFAMILY BUILDINGS

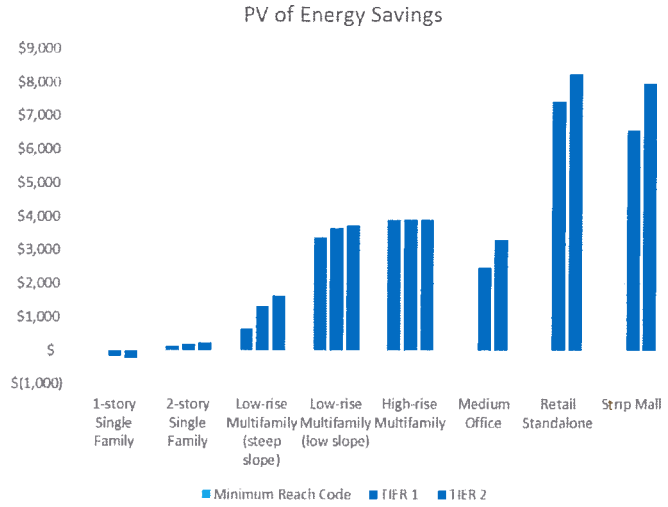
The simulations show energy savings and life cycle cost savings for all Low-Rise Multifamily and nonresidential prototypes. The High-Rise Multifamily prototype shows energy savings from all Reach Code levels, but only shows life cycle cost savings from the Tier 1 Reach Code. Therefore, low-slope cool roofs should be pursued for low-rise multifamily nonresidential buildings by jurisdictions in Climate Zone 15, and Tier 1 cool roofs for high-rise multifamily buildings. (Please note that jurisdictions should consider Tier 2, because as cool roofs get more prevalent, their prices will drop in the long term and may become cost effective).

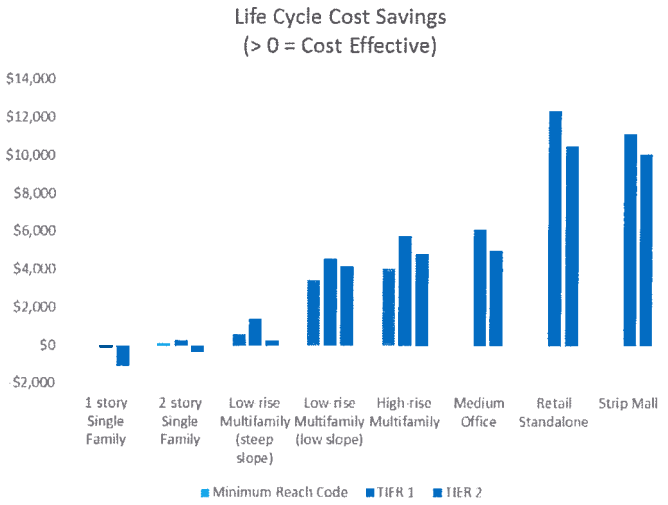
For low-rise multifamily and nonresidential buildings, the Tier 2 Reach Code is the most cost effective, on average, and yields the most energy savings.

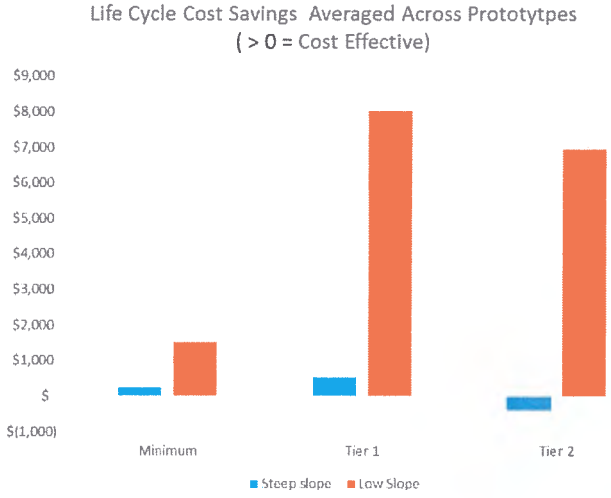
Cost-Effectiveness Study for Cool Roofs – Climate Zone 15 Results
Prepared for Pacific Gas & Electric Company by TRC Solutions

Prototype	Climate Zone 15 (Results/Bldg.)	Minimum Reach Code		TIER 1		TIER 2	
		≤ 2:12	> 2:12	≤ 2:12	> 2:12	≤ 2:12	> 2:12
1-story Single Family	Base Case Price		$3,362		$3,362		$3,362
	Reach Code Price		$3,362		$2,905		$3,396
	Incremental Price		$0		($457)		$33
	PVS Energy Savings		-		$1,780		$2,536
	B/C Ratio		-		No Costs		75.8
	LCC Savings		$0		$2,237		$2,502
2-story Single Family	Base Case Price		$2,321		$2,321		$2,321
	Reach Code Price		$2,321		$2,006		$2,345
	Incremental Price		$0		($316)		$23
	PVS Energy Savings		-		$1,569		$2,263
	B/C Ratio		-		No Costs		97.9
	LCC Savings		$0		$1,885		$2,240
Low-rise Multifamily	Base Case Price	$3,362	$5,571	$3,362	$5,571	$3,362	$5,571
	Reach Code Price	$4,058	$5,571	$2,339	$4,814	$4,063	$5,627
	Incremental Price	$696	$0	($1,023)	($757)	$701	$55
	PVS Energy Savings	-	-	$2,276	$3,113	$2,745	$4,539
	B/C Ratio	-	-	No Costs	No Costs	3.9	81.8
	LCC Savings	$0	$0	$3,299	$3,870	$2,044	$4,484
High-rise Multifamily	Base Case Price	$6,787		$6,787		$6,787	
	Reach Code Price	$8,193		$4,721		$8,202	
	Incremental Price	$1,406		($2,066)		$1,415	
	PVS Energy Savings	$1,302		$1,302		$1,302	
	B/C Ratio	0.9		No Costs		0.9	
	LCC Savings	($104)		$3,367		($113)	
Medium Office	Base Case Price	$17,371		$17,371		$17,371	
	Reach Code Price	$17,371		$10,011		$17,391	
	Incremental Price	$0		($7,361)		$19	
	PVS Energy Savings	-		$4,955		$5,781	
	B/C Ratio	-		No Costs		299.6	
	LCC Savings	$0		$12,316		$5,762	
Retail Standalone	Base Case Price	$23,372		$23,372		$23,372	
	Reach Code Price	$23,372		$13,469		$23,398	
	Incremental Price	$0		($9,904)		$26	
	PVS Energy Savings	-		$11,562		$14,866	
	B/C Ratio	-		No Costs		572.6	
	LCC Savings	$0		$21,466		$14,840	
Strip Mall	Base Case Price	$21,694		$21,694		$21,694	
	Reach Code Price	$21,694		$12,501		$21,718	
	Incremental Price	$0		($9,193)		$24	
	PVS Energy Savings	-		$9,009		$11,435	
	B/C Ratio	-		No Costs		474.5	
	LCC Savings	$0		$18,202		$11,410	

8.4.16 Climate Zone 16







Recommendations

Steep-Slope Reach Code: YES, FOR LOW-RISE MULTIFAMILY BUILDINGS

The simulations show low or negative energy savings, and some positive life cycle costs for the single family prototypes. However, the Low-Rise Multifamily prototype shows energy savings and life cycle cost savings for all levels of the Reach Code. Therefore, the steep-slope Reach Code should be pursued for low-rise multifamily buildings by jurisdictions in Climate Zone 16.

For low-rise multifamily buildings, the Tier 1 Reach Code is the most cost effective, on average, while Tier 2 yields the most energy savings. Tier 2 is recommended to maximize the energy savings.

Low-Slope Reach Code: YES

The simulations show energy savings and life cycle cost savings for all prototypes. Therefore, low-slope cool roofs should be pursued by jurisdictions in Climate Zone 16.

The Tier 1 Reach Code is the most cost effective, on average, while Tier 2 yields the most energy savings. Tier 2 is recommended to maximize the energy savings.

Prototype	Climate Zone 16 (Results/Bldg.)	Minimum Reach Code		TIER 1		TIER 2	
		≤ 2:12	> 2:12	≤ 2:12	> 2:12	≤ 2:12	> 2:12
1-story Single Family	Base Case Price		$2,961		$2,961		$2,961
	Reach Code Price		$3,009		$2,909		$3,803
	Incremental Price		$47		($52)		$842
	PVS Energy Savings		$25		($151)		($233)
	B/C Ratio		0.5		No Savings		No Savings
	LCC Savings		($22)		($98)		($1,074)
2-story Single Family	Base Case Price		$2,045		$2,045		$2,045
	Reach Code Price		$2,077		$2,009		$2,626
	Incremental Price		$33		($36)		$581
	PVS Energy Savings		$156		$206		$245
	B/C Ratio		4.8		No Costs		0.4
	LCC Savings		$124		$242		($336)
Low-rise Multifamily	Base Case Price	$2,977	$4,907	$2,977	$4,907	$2,977	$4,907
	Reach Code Price	$2,905	$4,986	$2,050	$4,821	$2,507	$6,302
	Incremental Price	($72)	$78	($927)	($87)	($469)	$1,395
	PVS Energy Savings	$3,383	$662	$3,648	$1,337	$3,733	$1,650
	B/C Ratio	No Costs	8.5	No Costs	No Costs	No Costs	1.2
	LCC Savings	$3,455	$584	$4,575	$1,423	$4,202	$255
High-rise Multifamily	Base Case Price	$6,009		$6,009		$6,009	
	Reach Code Price	$5,864		$4,139		$5,062	
	Incremental Price	($145)		($1,871)		($948)	
	PVS Energy Savings	$3,905		$3,905		$3,905	
	B/C Ratio	No Costs		No Costs		No Costs	
	LCC Savings	$4,050		$5,776		$4,853	
Medium Office	Base Case Price	$12,434		$12,434		$12,434	
	Reach Code Price	$12,434		$8,776		$10,732	
	Incremental Price	$0		($3,658)		($1,702)	
	PVS Energy Savings	-		$2,478		$3,303	
	B/C Ratio	-		No Costs		No Costs	
	LCC Savings	$0		$6,136		$5,005	
Retail Standalone	Base Case Price	$16,729		$16,729		$16,729	
	Reach Code Price	$16,729		$11,807		$14,439	
	Incremental Price	$0		($4,922)		($2,290)	
	PVS Energy Savings	-		$7,433		$8,259	
	B/C Ratio	-		No Costs		No Costs	
	LCC Savings	$0		$12,355		$10,548	
Strip Mall	Base Case Price	$15,528		$15,528		$15,528	
	Reach Code Price	$15,528		$10,959		$13,402	
	Incremental Price	$0		($4,569)		($2,125)	
	PVS Energy Savings	-		$6,584		$7,970	
	B/C Ratio	-		No Costs		No Costs	
	LCC Savings	$0		$11,152		$10,095	