ATTACHMENT C

City of San Mateo 2016 Building Energy Efficiency Reach Code

Cost Effectiveness Study

Final Report (May 9, 2016)

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EXECUTIVE SUMMARY

The City of San Mateo plans to implement a Reach code related to energy efficiency and solar energy. The California Energy Commission (CEC) require that a cost effectiveness study be completed to implement a Reach Code in the San Mateo Municipal Code. On behalf of the City, TRC investigated Reach Code options requiring that residential and nonresidential new construction use less energy than a building minimally compliant with 2016 Title 24 Building Energy Efficiency Standards (T24 Standards). The CEC Life Cycle Cost (LCC) Methodology was used to analyze potential cost effective energy efficiency measures. The LCC methodology involves estimating and quantifying the energy savings associated with measures using a Time Dependent Valuation (TDV) of energy savings.

TRC investigated cost effective energy efficiency and solar measures for single family residential, multifamily, and nonresidential office buildings. TRC leveraged previous energy savings, market research, and cost estimates when possible. Prototype buildings were developed for San Mateo based on feedback from City staff and simulated in Title 24 compliance software. TDV energy savings were developed through software simulations and CECPV Calculator.[1]

The benefit to cost ratio (B/C) is the indicator for cost effectiveness. A ratio greater than 1 indicates that the added cost of the measure is more than offset by the present value life cycle energy cost savings, and the measure is deemed to be cost effective. TRC found both cool roof and solar PV measures to be cost effective, as shown in Table 1 and Table 2. Thus, TRC recommends that San Mateo implement a Reach Code ordinance to exceed the 2016 Title 24 Standards by requiring cool roofs on multifamily and nonresidential buildings with low-sloped roofs and photovoltaic measures on all buildings.

Table 1. Cool Roofs Cost Effectiveness

Low-Sloped Cool Roof Measure				
Building Type	**% Above Title 24**	**Present Value of Energy Savings**	**Cost**	**Benefit to Cost Ratio**
Multifamily Residential	3.4%	$9,033	$1,843	4.9
Nonresidential Offices	0.1%	$2,788	$1,625	1.7

All PV system sizes up to 40 kW were found to be cost effective, including the sizes recommended for the San Mateo residential and nonresidential Reach Code.

[1] The CECPV Calculator was developed for use in the New Solar Homes Partnership. The calculator estimates monthly kWh and annual TDV production based on climate zone and system specifications. The tool is available online at: http://www.gosolarcalifornia.org/tools/nshpcalculator/index.php

Table 2. Solar PV Cost Effectiveness for Sizes in Reach Code Ordinance

Size (kW)	Cost	Residential Present Value of Energy Savings	Residential Benefit to Cost Ratio	Nonresidential Present Value of Energy Savings	Nonresidential Benefit to Cost Ratio
1	$2,193	$8,567	3.9	-	-
2	$4,386	$17,135	3.9	-	-
3	$6,578	$23,839	3.6	$12,250	1.9
5	-	-	-	$20,843	1.9

Based on the findings in this report, TRC recommends the San Mateo Municipal Code require new construction buildings exceed the 2016 Title 24 Standards by installing the following measures:

Cool Roofs

- Low-rise and high-rise multifamily residential new construction projects with low-sloped roofs, and nonresidential new construction projects with low-sloped roofs, shall install a cool roof with an ASR ≥ 0.70 and TE ≥ 0.85.

Solar Mandate

- Single family residential new construction projects shall install a ≥ 1 kW PV system.
- Low-rise and high-rise multifamily residential new construction projects:
  A. Buildings with 3-16 units shall install a ≥ 2 kW PV system.
  B. Buildings with ≥17 units shall install a ≥ 3 kW PV system.
- Nonresidential new construction projects shall comply with:
  A. Buildings <10,000 ft2 shall install a ≥ 3 kW PV system.
  B. Buildings ≥10,000 ft2 shall install a ≥ 5 kW PV system.
- All building types may comply by installing a solar hot water system with ≥ 40 ft^2 collector area.

Although solar thermal was not found to be cost effective for the San Mateo prototypes, this measure may be cost effective for space types with high hot water usage, such as gyms or spas. TRC recommends that San Mateo include a solar thermal system as an alternative compliance option to solar PV in the Reach Code.

1. INTRODUCTION

The City of San Mateo, located in California Climate Zone 3 (CZ3), plans to enact a Reach Code for the 2016 Title 24 Part 6 Building Energy Efficiency Standards (T24 Standards). The T24 Standards are the minimum energy efficiency requirements for building construction in California. San Mateo engaged TRC to provide a cost effectiveness study to support building Reach Code requirements above 2016 T24 Standards minimum requirements.

At the request of the City, TRC researched measures drawn from multiple sources in efforts to develop cost effective packages of measures. A full list of measures analyzed is included in Appendix B. Software modeling functionality or federally preemption very often limited which measures could be considered. Furthermore, the stringency of the 2016 Title 24 coupled with the mild climate of San Mateo reduced the energy savings impact of many measures.

Based on the results of TRC's analysis, the City decided to move forward with a Reach Code that would require that residential and nonresidential buildings install cool roofs, where applicable, to consume less energy than a building exactly compliant with the T24 Standards. Additionally, residential and nonresidential buildings would be required to install minimally-sized PV systems or solar thermal systems to offset some of the buildings energy consumption with a renewable energy source.

TRC found cool roofs to be technically and economically feasible for multifamily residential and nonresidential (office building) new construction with low-sloped roofs, and solar PV requirements to be technically and economically feasible for all residential and nonresidential (office building) new construction. TRC has prepared energy savings and cost effectiveness analyses for these measures to support the proposed Reach Code.

2. METHODOLOGY

TRC assessed the cost effectiveness of San Mateo's 2016 Reach Code by analyzing several measures applied to prototype buildings using the Life Cycle Cost (LCC) methodology approved and used by the California Energy Commission (CEC) to establish cost effective building energy standards (Title 24, Part 6).

2.1 Life Cycle Cost and Time Dependent Valuation

TRC used the CEC LCC Methodology to demonstrate cost effectiveness of the proposed Reach code.[2] The LCC methodology involves estimating and quantifying the energy savings associated with measures using a Time Dependent Valuation (TDV) of energy savings.[3]

TDV is a normalized format 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). TDV energy estimates are based on the present value of cost savings, but are presented in terms of "TDV kBTUs." TDV kBTUs allows savings to be evaluated in terms of energy units, and measures with different periods of analysis can be combined into a single value.[4]

The CEC developed the TDV values that were used in the analyses for this report, and are representative of San Mateo's climate zone.

2.2 Measure Analysis

TRC investigated measures for single family, low-rise multifamily, high-rise multifamily and nonresidential (office) buildings, with the goal of establishing cost effective packages of measures or individual measures above 2016 Title 24. With guidance from the City of San Mateo, TRC adjusted standard CEC prototypes to customized prototype buildings that represent

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[2] Architectural Energy Corporation (January 2011) Life-Cycle Cost Methodology. California Energy Commission. Available at: http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/general_cec_documents/2011-01-14_LCC_Methodology_2013.pdf

[3] E3 (July 2014) Time Dependent Valuation of Energy for Developing Building Efficiency Standards: 2016 Time Dependent Valuation (TDV) Data Sources and Inputs. California Energy Commission. Available at: http://www.energy.ca.gov/title24/2016standards/prerulemaking/documents/2014-07-09_workshop/2017_TDV_Documents/

[4] kBTUs = thousands of British Thermal Units.

new construction buildings typically built in San Mateo. These will be referred to as the San Mateo prototypes to differentiate from the CEC prototypes.

TRC used CBECC-Res 2016.1.0 (build 801) to simulate the residential San Mateo prototypes and CBECC-Com 2016.1.0 (build 803) for the nonresidential San Mateo prototypes.[5] CBECC is a free public-domain software developed by the CEC for use in complying with the Title 24 Standards. The software is currently used for the 2013 Standards, and preliminary versions for use with the 2016 Standards have been released. The 2016 software algorithms will be updated occasionally until the implementation date of the 2016 Standards (January 1st, 2017). CBECC-Com uses EnergyPlus v8.3 as the simulation engine to perform the analysis. Multifamily buildings are simulated in either the residential or nonresidential software depending on the number of residential stories; buildings with four or more stories are regulated by the nonresidential code. TRC simulated all San Mateo prototypes in Climate Zone 3, and initialized them to be exactly compliant with the minimum 2016 T24 requirements (0% compliance margin), or as close as possible. The TDV of energy savings for energy efficiency measures were derived by implementing the measure in a code compliant San Mateo prototype, as described in the *Measure Descriptions and Costs*.

2.2.1 Residential Prototypes

The residential San Mateo prototypes are based on the CEC prototypes fully defined by the CEC in the Residential Alternative Calculation Method reference manual.[6] The San Mateo prototypes are slightly revised in order to meet San Mateo typical building construction and to have equal geometry oriented facing north, east, south, and west. Two residential San Mateo prototypes were simulated:

- 2,700 ft^2 single family two-story home
- 10,440 ft^2 low-rise multifamily residential building, with three stories, twelve dwelling units, and an attached garage

Further San Mateo prototype details are provided in Table 3. Low-rise residential covers all residential construction that is three stores or less, including single and multifamily. TRC developed a low-rise multifamily residential prototype with a slightly varied roof construction from the CEC prototype for the cool roof analysis. The default roof is a steep-sloped asphalt shingle roof; the adjusted roof is a low-sloped gravel roof. This low-sloped roof prototype was only used for the low-sloped cool roof analysis. Details of this analysis are provided in Section 3.

It is important to note that CEC considers mid-rise and high-rise multifamily buildings four stories or greater to be non-residential buildings.

[5] More information on CBECC-Res available at: http://www.bwilcox.com/BEES/BEES.html. More information on CBECC-Com available at: http://bees.archenergy.com/software.html

[6] 2016 Residential Alternative Calculation Method, California Energy Commission. Available at: http://www.energy.ca.gov/2015publications/CEC-400-2015-024/CEC-400-2015-024-CMF.pdf

Table 3. Residential San Mateo Prototypes Summary

Building Type	Two-Story Single Family	Low-Rise Multifamily
Dwelling Units	1	12
Area (ft^2)	2,700	10,440
Ceiling Area (ft^2)	1,450	3,480
Roof Area (ft^2)	1,740	3,480[1]
# of floors	2	3
Window-to-Floor Area Ratio	20%	15%
Attic/Roof Assembly	Tile Roof, Wood Sheathing, R13 Below Roof Deck Insulation (air space), 2x4 @ 16" OC	
Roof Reflectance	Steep-Sloped: SR = 0.10, TE = 0.85	Low-Sloped: SR = 0.10, TE = 0.85[1]
Above Grade Wall Assembly	R-19 Cavity Insulation, R5 Synthetic Stucco, 0.051 U-factor	
Cooling System	Split Air Conditioner, 14 SEER	
Heating System	Gas Furnace, 78% AFUE	Gas Furnace , 80% AFUE
HVAC Distribution System	Ducts in Attic	Ducts in Conditioned Space
Thermal Zones	2	4
Domestic Water Heating Prescriptive Baseline 1	Natural Gas Instantaneous Water Heater, 0 Gallon Tank, EF=0.82	12x Natural Gas Instantaneous Water Heater, 0 Gallon Tank, EF=0.82
Domestic Water Heating Prescriptive Baseline 2[2]	Natural Gas Small Storage, 50 Gallon Tank, EF = 0.6, plus HERS Measures	Central Natural Gas Small Storage, 50 Gallon Tank, EF = 0.6, 40 MBH Input Rating, 0.20 Solar Fraction

[1] The CEC low-rise residential multifamily prototype typically has a steep-sloped roof. TRC developed a low-rise multifamily prototype with a low-sloped roof to test the impact of cool roofs on this prototype.

[2] TRC only used the natural gas storage hot water system for the solar thermal cost effectiveness analysis. All other measures were analyzed with a natural gas instantaneous water heater.

2.2.2 Nonresidential Prototypes

The nonresidential San Mateo prototypes are based on CEC prototypes detailed in the Nonresidential Alternative Calculation Method reference manual.[7] The prototypes are slightly revised in order to meet San Mateo typical building construction.

- 75,050 ft^2 high-rise multifamily building, with four stories, 79 units, an attached garage, and 3,000 ft^2 retail

[7] 2016 Nonresidential Alternative Calculation Method, California Energy Commission. Available at: http://www.energy.ca.gov/2015publications/CEC-400-2015-025/CEC-400-2015-025-CMF.pdf

- 85,000 ft^2 five-story medium office building with 5,000 ft^2 retail
- 195,060 ft^2 four-story large office building with 5,000 ft^2 retail

Results using these San Mateo prototypes are intended to represent findings for all nonresidential buildings. Further details are provided in Table 4.

Table 4. Nonresidential Prototypes Summary

<table>
<tr><th>Building Type</th><th colspan="2">High-Rise Multifamily</th><th>Medium Office</th><th>Large Office</th></tr>
<tr><td>Total Conditioned Floor Area (ft^2)</td><td colspan="2">84,360</td><td>85,000</td><td>192,060</td></tr>
<tr><td>Retail Floor Area (ft^2</td><td colspan="2">3,040</td><td>5,550</td><td>5,442</td></tr>
<tr><td># of floors</td><td colspan="2">4</td><td>5</td><td>4</td></tr>
<tr><td>Window-to-Floor Area Ratio</td><td colspan="2">7%</td><td>13%</td><td>9%</td></tr>
<tr><td>Roof Construction</td><td colspan="4">1/16" Metal Standing Seam, R-29 Continuous Insulation Board</td></tr>
<tr><td>Roof Reflectance (Low-sloped)</td><td colspan="2">No Requirement[1]</td><td colspan="2">SR=0.63, TE = 0.85</td></tr>
<tr><td>Cooling System</td><td colspan="2">Direct Expansion, 13 SEER</td><td>Direct Expansion, 9.8 EER</td><td>Chiller and Cooling Tower</td></tr>
<tr><td>Heating System</td><td colspan="4">Boiler, 80% Thermal Efficiency</td></tr>
<tr><td>HVAC Distribution System</td><td colspan="2">Packaged VAV System</td><td>5 Packaged VAVs (1 per story) with Economizer and Hot Water Reheat</td><td>4 VAVs (1 per story) with Economizer and Hot Water Reheat</td></tr>
<tr><td>Conditioned Thermal Zones</td><td colspan="2">22</td><td>30</td><td>24</td></tr>
<tr><td>Domestic Water Heating[2]</td><td>79x Natural Gas Instantaneous Water Heater, 0 Gallon Tank, EF=0.82</td><td>Central Natural Gas Small Storage, 122 Gallon Tank, 78 Thermal Efficiency, 0.20 Solar Fraction</td><td>Gas Storage, 95 Gallons, 78% Thermal Efficiency</td><td>Gas Storage, 45 Gallons, 61% Thermal Efficiency</td></tr>
<tr><td>Regulated Lighting Power Density</td><td colspan="2">(Retail Only) 1.20 W/ft^2</td><td colspan="2">0.75 Watts/ft^2</td></tr>
<tr><td>Daylighting Controls</td><td colspan="2">(Retail Only) Continuous, 0.20 Dimming Light/Power Fraction</td><td colspan="2">Continuous, 0.20 Dimming Light/Power Fraction</td></tr>
<tr><td>Occupancy Sensors</td><td colspan="2">(Retail Only) Not Required</td><td colspan="2">Required in Private Offices, Conference Rooms, and Multipurpose Rooms. Not Required in Open Offices</td></tr>
</table>

[1] Although there is no prescriptive requirement in CZ3 for high-rise residential, the model assumes ASR=0.08 and TE=0.75 as per section 110.8(i)1 of the Title 24 Standards.
[2]TRC only used the natural gas storage hot water system for the solar thermal cost effectiveness analysis. All other measures were analyzed with a natural gas instantaneous water heater.

2.2.3 Energy Efficiency Measures

TRC investigated potential energy efficiency measures to apply to the San Mateo residential and nonresidential prototypes. TRC utilized the 2016 Title 24 Codes and Standards Enhancement (CASE) reports developed on behalf of the IOUs as the basis of our measure analysis and selection. The CASE studies to support Title 24 proposed updates contain detailed energy savings, market research, and cost estimates for measures, and serve as comprehensive data sources for the Reach Code analysis. For measures where no CASE study exists, such as HVAC fan efficiency increase or drain water heat recovery, TRC conducted internal market research to assess measure feasibility, costs, and potential energy impact. Additionally, TRC identified measures that are potential topics for the 2019 CASE process and, lastly, measures being investigated for green building codes such as CALGreen (Title 24, Part 11) and ASHRAE Standard 189.1.

A full list of energy efficiency measures that TRC reviewed is provided in *Appendix B – Energy Efficiency Measure List.*

2.2.4 Solar Measures

The California Public Utilities Commission (CPUC) set goals that California residential new construction will be Zero Net Energy (ZNE) by 2020[8] and nonresidential new construction by 2030[9]. The state will realize these goals partly through more stringent Building Energy Efficiency Standards and partly through renewable energy policy. TRC investigated the cost effectiveness and feasibility of photovoltaics (PV) and solar thermal water heating for residential and nonresidential new construction.

2.3 Cost Effectiveness

Using the CEC's LCC methodology, TRC determined cost effectiveness by assessing the incremental costs of a measure and comparing them to the energy cost savings. Incremental costs represent the construction and maintenance costs of the proposed measure relative to the 2016 Title 24 Standards minimum requirements.

The Benefit to Cost (B/C) Ratio is the incremental TDV energy costs savings divided by the total incremental costs. 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.

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[8] CA Energy Efficiency Strategic Plan: New Residential Zero Net Energy Action Plan 2015 – 2020, CPUC and CEC. June 2015. Available online at: http://www.cpuc.ca.gov/General.aspx?id=4125

[9] CA Energy Efficiency Strategic Plan: Zero Net Energy Commercial Building Sector 2010-2012. Engage 360. June 2011. Available online at: http://www.cpuc.ca.gov/General.aspx?id=4125

2.3.1 Energy Savings

To estimate the energy savings of energy efficiency measures, TRC used the California building simulation compliance software, CBECC-Res and CBECC-Com, used for residential and nonresidential projects, respectively. The full energy benefit of PV is not captured in the compliance software; therefore, TRC used the CECPV calculator to estimate PV energy savings impacts.

Energy Efficiency Measures

For most measures, TRC used CBECC-Res and CBECC-Com to estimate the TDV savings and percent improvement beyond the T24 Standards. Measure specific modeling parameters are described in Section 3. A full list of measures that TRC investigated is provided in *Appendix B – Energy Efficiency Measure List*. Measures that are not capable of being modeled in the current CBECC software were analyzed through spreadsheet analysis.

TDV energy savings are calculated in terms of per-square-foot of the building, similar to the output of CBECC software. The present value of the energy savings is calculated by multiplying the TDV savings/ft^2 by the building area, and finally by the Net Present Value (NPV) factor. The NPV factor is $0.173/TDV kBtu for residential measures, $0.154/TDV kBtu for nonresidential envelope measures, and $0.089/TDV kBtu for all other nonresidential measures.

To determine nonresidential energy savings for each measure, TRC used a straight average of the energy savings of each nonresidential prototype. When calculating multifamily buildings savings, savings are calculated by averaging results when using the nonresidential NPV factor for high-rise and the residential NPV factor for low-rise.

The minimally compliant energy consumption of the residential and nonresidential San Mateo prototypes are summarized in Table 5 and Table 6.

Table 5. Residential San Mateo Prototype TDV Energy Consumption

Prototypes	**Single Family 2-story (kBtu/ft^2-yr)**	**Low-Rise Multifamily (steep-sloped roof) (kBtu/ft^2-yr)**	**Low-Rise Multifamily (low-sloped roof) (kBtu/ft^2-yr)**
Space Heating	8.92	2.03	2.09
Space Cooling	0.22	4.63	4.64
IAQ Ventilation	1.15	2.47	2.47
Water Heating	8.74	16.45	16.45
Total Standard Design TDV	**19.03**	**25.58**	**25.65**

Table 6. Nonresidential San Mateo Prototype TDV Energy Consumption

End Use	High-Rise Multifamily (kBtu/ft^2-yr)	Medium Office (kBtu/ft^2-yr)	Large Office (kBtu/ft^2-yr)
Space Heating	5.6	10.8	10.1
Space Cooling	5.1	47.5	38.7
Indoor Fans	17.9	19.5	16.3
Pumps & Miscellaneous	2.8	0.7	0.7
Domestic Hot Water	10.8	2.4	2.2
Indoor Lighting	35.9	37.0	34.3
Total Standard Design TDV	**78.1**	**117.9**	**102.3**

Solar Measures

The CEC currently allows a limited credit for low-rise residential buildings with PV in Climate Zone 3 (7.8% compliance margin for single family, 3.4% compliance margin for low-rise multifamily). The credit is attained by inputting PV into CBECC-Res. The PV credit does not capture the full energy benefits of PV, and is intended to promote energy efficient design before renewables. Similar modeling and credit are not currently available for nonresidential buildings in CBECC-Com.

To calculate the cost effectiveness of PV as a standalone measure, TRC calculated the TDV energy savings from PV using the CECPV calculator, rather than using the limited TDV output from compliance software. The CECPV calculator is specifically designed for use in the California New Solar Homes Partnership program, and has inputs for PV module, inverter, installation heights and orientation, and climate zone.[10] The software provides a TDV output that represents the total output of the array.

Compliance software models solar thermal through the use of a solar savings fraction, which represents the fraction of hot water demand met by a solar thermal system. Solar thermal benefits are not explicitly limited in compliance software (a solar fraction of 1 is possible to input). However, benefits only apply to the domestic hot water heating load, and the software appears to reduce the therms savings below what would be expected with the solar savings fraction input.

[10] Note that PV arrays installed in Palo Alto homes are not eligible for New Solar Homes Partnership incentives, as the program is funded by the statewide investor-owned utilities. The CECPV Calculator is available at http://www.gosolarcalifornia.org/tools/nshpcalculator/download_calculator.php

2.3.2 Costs

TRC reviewed CASE studies for relevant cost data. To better align the accuracy of costs for San Mateo, TRC conducted further cost research through interviews and online retailers serving the city to supplement CASE data. Building material and labor costs were localized, and taxes and contractor markups were added as appropriate, as described in Section 3. TRC used a straight average to blend the costs for the measures for the two office and two multifamily prototypes.

3. Measure Descriptions and Costs

This section provides a description, general modeling parameters, market overview, and summarized costs for cool roof and solar measures.

After initial investigation and analysis of several energy efficiency measures, cool roofs was selected based on its cost effectiveness and technical feasibility in the San Mateo new construction market. A full list of energy efficiency measures that were analyzed and a brief description of why they were not pursued for this Reach Code is provided in *Appendix B – Energy Efficiency Measure List*.

3.1 Cool Roofs

In CEC Climate Zone 3, cool roofs are prescriptively required in 2016 Title 24 for nonresidential new construction; neither high-rise nor low-rise residential new construction have cool roof requirements. Title 24 currently separates cool roof requirements based on the slope of the roof – low-sloped, defined as having a slope ≤ 2:12, and steep-sloped.[11] TRC investigated increasing the stringency of the 2016 Title 24 nonresidential low-sloped cool roof requirements and introducing cool roof requirements for high-rise and low-rise residential roofs, both steep- and low-sloped. If cost effective, this measure would increase the required minimum 3-year aged solar reflectance (ASR) for roofs. Title 24 cool roof requirements for Climate Zone 3 are outlined in Table 7.

Table 7. Prescriptive Cool Roof Requirements in CZ3

Building Sector	Slope	3-Year Aged Solar Reflectance	Thermal Emittance
Low-Rise Residential	Low-Sloped	No Requirement	
	Steep-Sloped		
High-Rise Residential	Low-Sloped	No Requirement	
	Steep-Sloped	0.20	0.75
Nonresidential	Low-Sloped	0.63	0.75
	Steep-Sloped	0.20	0.75

This measure, if cost effective, would have the following ASR requirements:

[11] Steep-sloped roofs have a slope of > 2:12. In California, steep-sloped roofs are more typical of low-rise residential construction and are generally constructed with asphalt shingles or tiles; however, some commercial construction also employs steep-sloped roofs.

- Nonresidential low-sloped roofs: ASR = 0.70, compared to ASR = 0.63 prescriptive requirement
- High-rise and low-rise multifamily residential low-sloped roofs: ASR = 0.70, compared to no prescriptive requirement[12]
- High-rise and steep-sloped roofs: ASR = 0.28, compared to ASR = 0.20
- Low-rise residential (including single family) steep-sloped roofs: ASR = 0.28, compared to no prescriptive requirement[12]

The measure does not change the modeling default Thermal Emittance (TE) = 0.85, as this value is sufficient for cool-roof products.

Low-sloped roofs are generally found on multifamily and commercial construction, and can be built with a variety of roofing products, typically field applied coatings, membranes or "cool caps", or single ply thermoplastic roofing. Steep-sloped roofs are more typical of low-rise residential construction in California, and are built with asphalt shingles or concrete or clay tile.

To develop cost estimates, TRC conducted interviews regarding roofing products with roofers and roof supply distributors in the San Francisco Bay Area. In addition to interviews, TRC reviewed product material costs from online retailers serving the San Mateo area. Multiple roofers and product distributors stated that there is little or no additional labor to install cool roof products for either low- or steep-sloped roofs.

3.1.1 Low-Sloped Roofs

For low-sloped roofs, most products that meet the cool roof requirements do not introduce a cost increase over non-cool roof products, and based on feedback from roofers and distributors, there are even cost savings for some products. Additionally, according to Cool Roof Rating Council[13] certified product directory, there are about three times as many cool roof products available at the proposed ASR = 0.70 value than at the current required ASR = 0.63.

The 2013 Nonresidential Cool Roofs CASE Report supports how cool roofs can be cheaper than their darker, non-cool roof counterparts:[14]

> "Within the cool roof market, many of the products with [ASR] values close to 0.55 are actually tinted versions of the more conventional white versions of the same product. The products with

[12] The default modeling assumption is ASR=0.08 for standard high-rise residential roofing product and ASR=0.10 for standard low-rise residential roofing product. There are no supporting details for these values in the ACM Reference Manuals.

[13] Available at: http://coolroofs.org/products/results

[14] California Utilities Statewide Codes and Standards Team (October 2011) Nonresidential Cool Roofs Codes and Standards Enhancement Initiative. Available at: http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/current/Reports/Nonresidential/Envelope/2013_CASE_NR_Cool_Roofs_Oct_2011.pdf

the darker reflectance can, therefore, actually have a higher initial cost while also driving higher energy costs."

To estimate the incremental cost for high- and low-rise multifamily buildings (ASR = 0.10 to ASR = 0.70), TRC assumed a baseline of a market standard non-cool roof and data from the 2013 Nonresidential Cool Roofs CASE Report. The cost analysis shows there are no additional material costs to implement cool roofs for low-sloped roofs compared to market standard roofing products. TRC used the average incremental cost for roofing types including single-ply TPO, membranes, and field applied coatings.

To be conservative, TRC estimated a small incremental cost for products that meet the proposed nonresidential low-sloped cool roof requirements (ASR = 0.63 to ASR = 0.70). This incremental cost represent product types that may have higher costs to meet the proposed values, even though cost analysis suggests there is no incremental cost on average. To estimate this cost, TRC looked at the cost difference between two products of the same type from the same manufacturer that meet the current ASR value and the proposed ASR value.

The incremental costs of going from the base case to a cool roof are summarized in Table 8 and Table 9. Additional details for the cost analysis are provided in *Appendix A – Low-Sloped Roof* Cost Details.

Table 8. Multifamily Low-Sloped Cool Roof Incremental Costs Summary

Base Case	Proposed Update	Incremental $/ ft² roof	High-Rise Multifamily		Low-Rise Multifamily	
			Units/ Bldg	$/Bldg	Units/ Bldg	$/Bldg
No Requirement[1]	ASR=0.70, TE=0.85	$0.15	21,090	$3,164	3,480	$522
		Average ($/Bldg)	$1,843			

[1] Although there is no prescriptive requirement in CZ3 for residential roofs, the model assumes ASR=0.08 for high-rise, ASR=0.10 for low-rise, and TE=0.75 to represent standard roofing materials.

Table 9. Nonresidential Low-Sloped Cool Roof Incremental Costs Summary

Base Case	Proposed Update	Incremental $/ ft² roof	Medium Office		Large Office	
			Units/ Bldg	$/ Bldg	Units/ Bldg	$/Bldg
ASR=0.63, TE=0.85	ASR=0.70, TE=0.85	$0.05	17,000	$850	48,015	$2,401
		Average ($/Bldg)	$1,625			

3.1.2 Steep-Sloped Roofs

TRC gathered costs for asphalt shingles and concrete and clay tile that meet the current and proposed ASR values (ASR = 0.10 to ASR = 0.28). Several interviewees mention that the cool roof properties of tile do not impact costs, and that costs are associated with color and other characteristics. Therefore, there is no incremental cost for tile meeting the proposed ASR value.

Asphalt shingles, however, can carry a cost premium for cool roof products. The proposed cool roof requirements can be met with white shingles, which have no incremental cost over current market standard shingles, but shingles in a variety of colors that meet the cool roof values have an increased cost over their non-cool roof equivalents. Based on interviews, there are no additional labor costs for steep-sloped cool roofs.

The steep-sloped cool roof cost is only applied to the low-rise residential prototypes, as it is not common for high-rise residential or commercial construction to have steep-sloped roofs. This is also reflected in the prototype buildings. Table 10 provides the incremental cost to go from the base case (no requirement) to a cool roof requirement for steep-sloped roofs. This cost assumption is a straight average of the asphalt shingle and tile incremental cost estimates.

Table 10. Low-Rise Residential Steep-Sloped Cool Roof Incremental Costs Summary

Base Case	Proposed Update	Incremental $/ ft^2 roof	Two-Story Single Family		Low-Rise Multifamily	
			Units/ Bldg	$/Bldg	Units/ Bldg	$/Bldg
No Requirement[1]	ASR=0.28, TE=0.85	$0.23	1740	**$400**	3,771	**$867**

[1] Although there is no prescriptive requirement in CZ3 for residential roofs, the model assumes ASR=0.08 for high-rise, ASR=0.10 for low-rise, and TE=0.75 to represent standard roofing materials.

3.2 Solar Measures

3.2.1 Photovoltaics

Costs for solar PV were estimated using statewide data from the New Solar Homes Partnership (NSHP) program.[15] TRC retrieved costs for both small systems (less than 10 kW) and larger systems (between 10 kW and 100 kW). Average and median costs (in $/Watt installed) were extracted from the NSHP database, and median costs were found to be higher and more conservative. Although array costs ($/Watt installed) for large systems are less than costs for small systems, TRC used only the cost of small systems in cost effectiveness analysis, to remain conservative.

For 2015 NSHP program data, the median cost for small PV systems was $4.90/Watt. Several studies have tracked the installation costs of PV to provide market trends. Lawrence Berkeley National Laboratory, for example, found that national median installed prices in 2014 declined year-over-year by 9% for both residential and nonresidential systems. This decline in cost is similar to what TRC observes in the NSHP database, and a recent CEC report.[16,17] By applying this

[15] Available at: https://www.newsolarhomes.org/WebPages/Public/Reports.aspx

[16] E3 (May 2013) Cost-Effectiveness of Rooftop Photovoltaic Systems for Consideration in California's Building Energy Efficiency Standards. Prepared for the California Energy Commission. Available at: http://www.energy.ca.gov/2013publications/CEC-400-2013-005/CEC-400-2013-005-D.pdf

cost reduction through to 2017, the median installed cost of PV is expected to be $4.06/Watt, as shown in Table 11.

PV systems installed in San Mateo are eligible for both the NSHP rebate and the federal solar Investment Tax Credit (ITC), which rebates 30% of the cost of the system.[18] Note that TRC observed the NSHP incentive to decline year-over-year by 19%, and projected the decline to continue through to 2017. When accounting for the NSHP rebate and ITC, the estimated net cost for installed solar PV in 2017 is $2.19/Watt.

Table 11. Costs for Solar PV

Installed Cost ($/Watt)	2015	2016	2017
Median Cost	$4.90	$4.46	$4.06
Federal ITC	-	-	-$0.93
NSHP Incentive	-	-	-$0.94
Net Cost	-	-	**$2.19**

3.2.2 Solar Thermal

Costs for solar thermal hot water systems were based on the California Solar Initiative (CSI) program data, and represent installed costs for all components, including tanks.[19] Costs for baseline systems were developed through the 2016 Instantaneous Water Heaters CASE Report and RSMeans[20] when necessary.

Solar hot water installations in the City of San Mateo qualify for the CSI incentives as well as the Federal ITC. Incentive amounts vary depending on the therms displaced by the solar thermal system. To estimate incentive amounts, TRC estimated the size (in ft^2) of a typical solar hot water system for each prototype, attained the solar savings fraction using the Solar Water Heater Calculator from the CEC[21], and entered the solar fraction into 2016 Title 24 software to attain the therms saved. These therms were then input into the program formulas used to determine incentive amounts.

Incremental costs from baseline systems were estimated in the following ways, and summarized in Table 12:

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[17] Barbose, G., et al. (August 2015) Tracking the Sun VIII: The Installed Price of Residential and Non-Residential Photovoltaic Systems in the United States. Available at: https://emp.lbl.gov/sites/all/files/lbnl-188238_1.pdf

[18] More information available at: http://www.seia.org/policy/finance-tax/solar-investment-tax-credit

[19] Available at: http://www.csithermalstats.org/

[20] Available at: https://rsmeansonline.com/

[21] Available at: http://www.energy.ca.gov/title24/swh_calculator/

- Single family – The prescriptive baseline for single family buildings is an instantaneous tankless water. A storage water heater is an alternate prescriptive baseline, as long as Compact DHW, Pipe Insulation, and QII HERS measures are also implemented.

  TRC analyzed incremental costs from each of these baselines. The cost of an instantaneous water heater is one baseline, while the cost of the storage water heater serves as the second baseline. The cost of the HERS measures is not accounted for in the baseline, because they would still be prescriptively required even with a solar thermal system.

- Multifamily – The prescriptive baseline for multifamily buildings is an instantaneous tankless water serving each individual dwelling unit. A central storage water with a solar thermal system with a solar savings fraction of 0.20 is an alternate compliance baseline (the prescriptive compliance path for systems serving multiple dwelling units).

  CBECC-Res shows that a central storage water heater with a solar thermal savings fraction of 1.0 is necessary to generate energy savings beyond that of 8 instantaneous water heaters. Even though solar fractions approaching 1.0 are challenging to design, a solar thermal array with a solar fraction of 0.80 was used for cost effectiveness analysis to demonstrate that, even with this conservative sizing, solar thermal would not be cost effective. The cost of 8 instantaneous water heaters was thus subtracted from the cost of the 0.80 solar thermal system to estimate the incremental cost.

  The central storage + 0.20 solar fraction baseline was subtracted from the cost of a central storage system + 0.40 solar fraction, to attain the incremental cost of the 0.40 solar fraction system.

- Nonresidential – The prescriptive compliance path is for a storage water heater. The cost of the storage water heater is subtracted from the cost of the solar thermal system.

Table 12. Solar Thermal System Costs

	Single Family		Low-Rise Multifamily		Nonresidential
Solar Thermal System Size (ft^2)	40		700	100	100
Solar Thermal Solar Savings Fraction	0.70		0.80	0.39	0.20
Solar Thermal System Therms Displaced	70		433	163	233
Solar Thermal System Gross Cost	$12,778		$114,053	$29,352	$21,065
CSI Incentive	$2,090		$8,742	$7,016	$4,704
Federal Investment Tax Credit	$3,833		$31,593	$6,701	$4,079
Assumed Baseline System	Instantaneous Water Heater	Storage Water Heater	Instantaneous Water Heater	Storage Water Heater + 0.20 Solar Fraction	Storage Water Heater
Baseline System Cost	$1,979	$3,078	$23,748	$8,944	$8,206
Solar Thermal System Net Cost	**$4,876**	**$3,777**	**$49,970**	**$6,691**	**$4,076**

4. Energy Savings and Cost Effectiveness Results

The results for the cool roof and solar measures are presented below for single family, multifamily, and nonresidential San Mateo prototypes. Results include measure compliance margin, present value of energy savings, costs, and benefit to cost (B/C) ratio. 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.

4.1 Energy Efficiency Measures

4.1.1 Cool Roofs

As shown below in Table 13, low-sloped cool roofs have relatively small incremental costs and are cost effective for multifamily and nonresidential buildings in Climate Zone 3. The low-sloped multifamily residential results are an average for the low-rise and high-rise prototypes. Based on this analysis, steep-sloped cool roofs are not cost effective for San Mateo.

Table 13. Low-Sloped Cool Roof Cost Effectiveness

Cool Roof Measure					
Building Type	**Roof Slope**	**% Above Title 24**	**Present Value of Energy Savings**	**Cost**	**Benefit to Cost Ratio**
Single Family Residential	Steep-Sloped	0%	$0	$400	0
Low-Rise Multifamily Residential	Steep-Sloped	1.8%	$850	$867	0.98
Multifamily Residential	Low-Sloped	3.4%	$9,033	$1,843	4.9
Nonresidential Office	Low-Sloped	0.1%	$2,788	$1,625	1.7

4.2 Solar Measures

Solar PV was found to be cost effective at all sizes. Solar thermal hot water was not found to be cost effective for the building types analyzed.

4.2.1 Solar PV

Solar PV is cost effective at all sizes as shown in Table 14 below. Nonresidential benefit-to-cost ratios are lower than residential because the NPV factor for nonresidential is lower than residential, as described in Section 2.3.1.

Table 14. Solar PV Cost Effectiveness

Size (kW)	Cost	Residential Present Value of Energy Savings	Residential Benefit to Cost Ratio	Nonresidential Present Value of Energy Savings	Nonresidential Benefit to Cost Ratio
1	$2,193	$8,567	3.9	-	-
2	$4,386	$17,135	3.9	-	-
3	$6,578	$23,839	3.6	$12,250	1.9
5	-	-	-	$20,843	1.9

4.2.2 Solar Thermal

Solar hot water (thermal) is not cost effective under any scenario analyzed, as shown in Table 15, even in multifamily buildings with a pre-existing solar hot water system. However, solar hot water may be cost effective in buildings with high hot water demands, such as gyms or spas.

Table 15. Solar Thermal Cost Effectiveness

Building	Baseline	Cost	Present Value of Energy Savings	Benefit to Cost Ratio
Single Family	Instantaneous Water Heater	$4,876	$2,004	0.4
	Storage Water Heater	$3,777	$1,649	0.4
Multifamily	Instantaneous Water Heater	$49,970	$2,153	0.0
	Storage Water Heater + 0.20 Solar Fraction	$6,691	$1,205	0.2
Nonresidential	Storage Water Heater	$4,076	$3,783	0.9

4.3 Reach Code Recommendation

Cool roof requirements and solar PV proved cost effective for prototypes in the City of San Mateo. Although solar thermal was not found to be cost effective for the San Mateo prototypes, this measure may be cost effective for space types with high hot water usage, such as gyms or spas. TRC recommends that San Mateo include a solar thermal system as an alternative compliance option to solar PV in the Reach Code.

TRC recommends the San Mateo Municipal Code require new construction buildings exceed the 2016 Title 24 Standards by installing the following measures:

Cool Roofs

- Low-rise and high-rise multifamily residential new construction projects with low-sloped roofs, and nonresidential new construction projects with low-sloped roofs, shall install a cool roof with an ASR ≥ 0.70 and TE ≥ 0.85.

Solar Mandate

- Single family residential new construction projects shall install a ≥ 1 kW PV system.
- Low-rise and high-rise multifamily residential new construction projects:
  - C. Buildings with 3-16 units shall install a ≥ 2 kW PV system.
  - D. Buildings with ≥17 units shall install a ≥ 3 kW PV system.
- Nonresidential new construction projects shall comply with:
  - C. Buildings <10,000 ft2 shall install a ≥ 3 kW PV system.
  - D. Buildings ≥10,000 ft2 shall install a ≥ 5 kW PV system.
- All building types may comply by installing a solar hot water system with ≥ 40 ft^2 collector area.

4.3.1 Compliance

Compliance can be checked both on construction documents as well as compliance software reports. The compliance software output reports that are submitted to the building department identify the slope, ASR and TE of a proposed building's roof assembly and the proposed PV system size.

4.4 Greenhouse Gas Savings

New construction complying with the proposed Reach Code will result in greenhouse gas (GHG) savings through saving electricity and natural gas. Electricity and natural gas usage are estimated in CBECC simulations for each prototype building. Saved energy is multiplied by a factor of 0.65 lbs of CO_2 equivalent (CO_2e) per kWh, and 11.7 lbs of CO_2e per therm, as per Environmental Protection Agency research.[22] As shown in Table 16:

- 14% GHG savings are achieved for each newly constructed single family building
- 1% GHG savings are achieved for each newly constructed multifamily building
- 1% GHG savings are achieved for each newly constructed nonresidential building

[22] United States Environmental Protection Agency. 2015. "Emission Factors for Greenhouse Gas Inventories." Available at: https://www.epa.gov/sites/production/files/2015-12/documents/emission-factors_nov_2015.pdf.

An estimate of annual city-wide GHG savings is attained by multiplying the CO_2e savings per building against the number of new construction buildings permitted in San Mateo during the 2015 Calendar year, provided by the City of San Mateo. GHG savings are expressed in metric tons of carbon dioxide equivalent ($MTCO_2e$).

Table 16. Greenhouse Gas Savings Summary

Single Family Measures							
Measure	**Gas Therms / Home**	**Electric kWh / Home**	**lbs CO2e**	**lbs CO2e Avoided / Home**	**GHG Savings**	**Homes Affected / Year**	**$MTCO_2e$ Avoided / Year Citywide**
Code Compliant Building	320	5,361	7,231	-	-	31	14
Solar PV	320	3,795	6,213	1,018	14%		
Multifamily Measures							
Measure	**Gas Therms / Building**	**Electric kWh / Building**	**lbs CO2e**	**lbs CO2e Avoided / Building**	**GHG Savings**	**Buildings Affected / Year**	**$MTCO_2e$ Avoided / Year Citywide**
Code Compliant Building	5,112	198,581	188,928	-	-	15	19
Cool Roof + PV	5,197	192,798	186,162	2,766	1%		
Nonresidential Measures							
Measure	**Gas Therms / Building**	**Electric kWh / Building**	**lbs CO2e**	**lbs CO2e Avoided / Building**	**GHG Savings**	**Buildings Affected / Year**	**$MTCO_2e$ Avoided / Year Citywide**
Code Compliant Building	9422	1,019,900	773,444	-	-	7	18
Cool Roof + PV	9473	1,012,070	768,948	5,666	1%		
Total, All Building Types							**51**

*GHG percentage savings include unregulated loads, such as residential lighting, plug loads, and federally pre-emptive appliances. Percentages would be higher if including only regulated loads.

5. Appendix A – Low–Sloped Roof Cost Details

Table 17. Low-Sloped Cool Roof Detailed Costs

Product Type	Product Name	Product ASR	Product TE	Cost ($/ft²)	Vendor	Location
TPO/PVC	GAF - ANY	Any	Any	$0.39	CentiMark	Hayward
TPO/PVC	GAF Everguard TPO White	0.68	0.83	$0.58	Elite Roofing Supply	San Jose
Membrane: ModBit/BUR	GAF Ruberoid EnergyCap Torch Granule FR (white)	0.7	0.82	$1.05	Elite Roofing Supply	San Jose
Membrane: ModBit/BUR	GAF GAFGLAS EnergyCap	*0.7*	*0.91*	$0.60	Elite Roofing Supply	San Jose
Membrane: ModBit/BUR	Cool Cap	0.7	Unknown	$0.70	Roofing Supply Group	Central CA
Membrane: ModBit/BUR	CertainTeed CoolStar Flintastic GTA	0.59	0.85	$0.70	Sierra Roofing Supply	Northern CA
Membrane: ModBit/BUR	CertainTeed CoolStar	0.59	0.85	$1.00	Advantage Roofing Inc	Daly City
Membrane: ModBit/BUR	GAF Triple-Ply BUR Granule Cap Sheet: white	<0.55	Unknown	$0.33	Home Depot	Oakland
Membrane: ModBit/BUR	GAF Tri-Ply ModBit Rolled Roofing in Black	<0.55	Unknown	$0.10	Home Depot	Palo Alto
Membrane: ModBit/BUR	GAF Tri-Ply Smooth APP-ModBit Membrane: Black	<0.55	Unknown	$0.72	Home Depot	Palo Alto
Membrane: ModBit/BUR	GAF Tri-Ply Granule Bit Membrane: White	<0.55	Unknown	$0.72	Home Depot	Palo Alto
Membrane: ModBit/BUR	Farco White fiberglass mineral surface roll	<0.55	Unknown	$0.49	Home Depot	Palo Alto
Membrane: ModBit/BUR	General Cool Cap for BUR	<0.55	Unknown	$0.70	Sierra Roofing Supply	Northern CA
Membrane: ModBit/BUR	General Cool Cap for Mod Bit	<0.55	Unknown	$0.35	Sierra Roofing Supply	Northern CA
Membrane: ModBit/BUR	Cap Sheet	<0.55	Unknown	$0.80	Advantage Roofing Inc	Daly City
Membrane: ModBit/BUR	Cool Cap	<0.55	Unknown	$0.35	Roofing Supply Group	Central CA
Membrane: ModBit/BUR	Standard cap sheet product	<0.55	Unknown	$0.22	Elite Roofing Supply	San Jose
Field Applied Coating	Henro Co: 687 Enviro-White	0.8	0.9	$0.57	Home Depot	Palo Alto

Product Type	Product Name	Product ASR	Product TE	Cost ($/ft^2)	Vendor	Location
	Henro Co: 687 Enviro-White	0.8	0.9	$0.51	Home Depot	Salinas
Field Applied Coating	Henry 687 Enviro-White	0.8	0.9	$0.59	Home Depot	Placerville
Field Applied Coating	APOC 272/252	0.77	0.9	N/A	Precisions Roofing Inc	Daly City
Field Applied Coating	Tropical Roofing: Asphalt 921 Re-Flex	0.74	0.89	$0.53	Elite Roofing Supply	San Jose
Field Applied Coating	Henry 587 Dura-Brite	0.73	0.91	$0.49	Home Depot	Placerville
Field Applied Coating	Henry Co: 587 Dura-Brite	0.73	0.91	$0.40	Home Depot	Placerville
Field Applied Coating	Henry Co: 587 Dura-Brite	0.73	0.91	$0.40	Home Depot	Salinas
Field Applied Coating	Henry Co: 587 Dura-Brite	0.73	0.91	$0.40	Lowes	Salinas
Field Applied Coating	Black Jack Ultra Roof 1000	0.72	0.88	$0.56	Lowes	Sunnyvale
Field Applied Coating	Henry Co: 287 Solar-FLex	0.72	0.82	$0.28	Home Depot	Placerville
Field Applied Coating	Henry Co: 287 Solar-FLex	0.72	0.82	$0.28	Home Depot	Salinas
Field Applied Coating	Henry Co: 587 Dura-Brite	0.72	0.82	$0.40	Home Depot	Salinas
Field Applied Coating	Black Jack Ultra Roof 1000	0.72	0.88	$0.37	Lowes	Fremont
Field Applied Coating	Henry Co: 287 Solar-FLex	0.72	0.82	$0.28	Lowes	Fremont
Field Applied Coating	Henry Co: 287 Solar-FLex	0.72	0.82	$0.28	Home Depot	San Mateo
Field Applied Coating	Henry Co: 287 Solar-FLex	0.72	0.82	$0.28	Home Depot	Salinas
Field Applied Coating	Black Jack Ultra Roof 1000	0.72	0.88	$0.37	Lowes	Gilroy
Field Applied Coating	APOC/Gardner Sta-Kool 780	0.72	0.88	$0.45	Home Depot	Palo Alto
Field Applied Coating	Silicone coating	0.70	Unknown	$0.39	Wedge Roofing	Petaluma
Field Applied Coating	Tropical Roofing: Asphalt 911 Eternalastic	0.69	0.91	$0.53	Elite Roofing Supply	San Jose
Field Applied Coating	Gardner Sta-Kool 770	0.65	0.88	$0.51	Home Depot	Placerville
Field Applied Coating	Gardner Sta-Kool 770	0.65	0.88	$0.58	Home Depot	Placerville
Field Applied Coating	Gardner Sta-Kool 770	0.65	0.88	$0.61	Home Depot	Salinas
Field Applied Coating	Black Jack Roof-Gard 700	0.65	0.88	$0.29	Lowes	Fremont
Field Applied Coating	Gardner Sta-Kool 770	0.65	0.88	$0.58	Home Depot	San Mateo
Field Applied Coating	Gardner Sta-Kool 770	0.65	0.88	$0.58	Home Depot	Salinas

Product Type	Product Name	Product ASR	Product TE	Cost ($/ft²)	Vendor	Location
Field Applied Coating	Gaco: Gacoflex S1000	0.56	0.89	$0.66	Lowes	Reno
Field Applied Coating	Black Jack Maxx-Cool	*0.5*	Unknown	$0.76	Lowes	Reno
Field Applied Coating	Henry 555 Premium Aluminum Roof Coating	0.42	0.56	$0.85	Home Depot	Palo Alto
Field Applied Coating	ANY Field Applied Coating	*0.3*	Unknown	$0.39	CentiMark	Hayward
Field Applied Coating	Henry 201 Fibered Black Roof Coating	*0.3*	Unknown	$0.24	Home Depot	Palo Alto
Field Applied Coating	Black Jack Roof-Gard 700	0.65	0.88	$0.51	Lowes	Sunnyvale

In addition to the cost data, distributors and roofers provided the following feedback regarding low-sloped cool roofs:

> "For TPO, if the reflectance you want is a product they sell, there is no cost increase."
>
> "For BUR, at the manufacturing level, products typically come out as standard white, then they color it for aesthetic reasons. Colored products are more expensive because it is non-standard."
>
> "For [field applied] coatings, what makes the cost difference is the solid content. This is a quality characteristic that has nothing to do with reflectance properties."
>
> "…more expensive to use cool roof cap sheet product than standard."

Table 18. Low-Sloped Cool Roof Cost Summary

Product Type	Average Cost ($/ft²)			Incremental Cost ($/ft²)	
	"No Req't"	ASR=0.63	ASR=0.70	"No Req't" to ASR=0.70	ASR=0.63 to ASR=0.70
TPO	$0.49	$0.49	$0.49	$0	$0
Membrane	$0.44	$1.01	$0.88	$0.43	($0.13)
Field Applied Coating	$0.56	$0.53	$0.42	($0.14)	($0.10)
			Average	**$0.15**	**($0.08)**

Table 19. Low-Sloped Cool Roof Representative Incremental Cost (ASR=0.63 to ASR=0.70)

Product Type	Product Line	ASR	Cost ($/ft²)
Field Applied Coating	Black Jack Roof Gard 700	0.65	$0.51
Field Applied Coating	Black Jack Ultra Roof 1000	0.70	$0.56
		Incremental Cost	**$0.05**

6. Appendix B – Energy Efficiency Measure List

TRC researched measures drawn from multiple sources in efforts to develop cost effective packages of measures. The following table outlines estimated energy savings, costs, and B/C ratios using building simulation outputs, abbreviated research, and previous team experience. Software modeling functionality or federally preemption very often limited which measures could be considered. Furthermore, the stringency of the 2016 Title 24 coupled with the mild climate of San Mateo reduced the energy savings impact of many measures. TRC performed further research on selected measures, with guidance from City of San Mateo staff.

Table 20. Other Measures Considered

Measure Name	Building Type	Source(s) for Analysis	Compliance Margin (%)	NPV Savings ($)	Cost Estimate ($)	B/C
Combined hydronic space and water heating	Res - SF	Internal	(no savings)	-	-	-
Compact distribution (HERS)	Res - SF	Internal and CASE	4%	$329	$445	0.7
Condensing gas water heater	Res - SF	ARUP 2012[23]	(federally pre-emptive)			
Drain water heat recovery	Res - SF	Internal	4%	$356	$800	0.4
Heat pump water heater	Res - SF	Internal	(CBECC-Res limitation)	-	-	-
On-demand recirculation	Res - SF	Internal	(no savings)	-	-	-
Point of Use (HERS), 3 water heaters	Res - SF	Internal, supported by CASE	9%	$765	$800	1.0
Water heater efficiency increase	Res - SF	Internal	(federally pre-emptive)	-	-	-
Piping insulation, All lines	Res - SF	Internal, supported	2%	$214	$167	1.3

[23] ARUP. (December 2012.) The Technical Feasibility of Zero Net Energy Buildings in California. Available online at: http://www.energydataweb.com/cpucfiles/pdadocs/904/california_zne_technical_feasibility_report_final.pdf

(HERS)		by CASE				
Reduced window SHGC	Res - SF	Internal, supported by CASE	(no savings)	-	-	-
Cool roof	Res - SF	Internal, supported by CASE	(no savings)	-	-	-
Quality insulation installation (HERS)	Res - SF	Internal, supported by CASE	9%	$801	$519	1.5
Ducts in conditioned space	Res - SF	2016 CASE	(2016 Prescriptive)			
Radiant barrier	Res - SF	2016 CASE	(2016 Prescriptive)			
Reduced window U-factor	Res - SF	Internal, supported by CASE	3%	$267	$1,490	0.2
Condensing gas space heating	Res - SF	ARUP 2012	(federally pre-emptive)			
Cooling SEER increase	Res - SF	Internal	(federally pre-emptive)			
Fan efficacy increase	Res - SF	Internal	1%	$53	$300	0.2
Heating AFUE increase	Res - SF	Internal	(federally pre-emptive)			
Hydronic space heating	Res - SF	Internal	(CBECC-Res limitation)			
Reduced duct leakage	Res - SF	Internal, supported by CASE	1%	$89	$200	0.4
Mini split heat pumps	Res - SF	Internal	(CBECC-Res limitation)			
Multispeed compressor	Res - SF	Internal	(no savings)			
Quality HVAC (FDD, Sizing)	Res - SF	Internal, supported by CASE	(CBECC-Res limitation)			
Radiant heating and cooling	Res - SF	Internal, supported by CASE	(CBECC-Res limitation)			
Verified refrigerant charge	Res - SF	Internal, supported by CASE	1%	$89	$100	0.9
Whole house fan	Res - SF	Internal	(no savings)			
Combined hydronic space and water heating	Res - LRMF	Internal	(no savings)			
Compact distribution (HERS), central water heater	Res - LRMF	Internal, supported by CASE	(CBECC-Res limitation)			

Drain water heat recovery	Res - LRMF	Internal	6%	$2,759	$2,400	6%
On-demand recirculation	Res - LRMF	Internal	(2016 Prescriptive)			
Parallel piping (HERS), central water heater	Res - LRMF	Internal, supported by CASE	(CBECC-Res limitation)			
Piping insulation, All lines (HERS), central water heater	Res - LRMF	Internal, supported by CASE	(CBECC-Res limitation)			
Point of Use (HERS), central water heating	Res - LRMF	Internal, supported by CASE	(CBECC-Res limitation)			
Cool roof	Res - LRMF	Internal, supported by CASE	2%	$828	$867	1.0
Quality insulation installation (HERS)	Res - LRMF	Internal, supported by CASE	2%	$736	$1,018	0.7
Reduced window U-factors	Res - LRMF	Internal	(no savings)			
Multispeed compressor	Res - LRMF	Internal	(no savings)			
All-electric compliance package	Res - LRMF	Internal	(CBECC-Res limitation)			
Reduced miscellaneous electric loads	Res - LRMF	Internal	(CBECC-Res limitation)			
Verified refrigerant charge	Res - LRMF	Internal, supported by CASE	1%	$552	$500	1.1
Combined hydronic space and water heating	Nonres - HRMF	Internal	(CBECC-Com limitation)			
Drain water heat recovery	Nonres - HRMF	Internal	2%	$23,725	$15,800	1.5
Cool roof	Nonres - HRMF	Internal, supported by CASE	1.5%	$15,590	$1,476	10.6
Reduced window U-factors	Nonres - HRMF	Internal	0.1%	$1,299		
Overhang on south-facing windows	Nonres - HRMF	ARUP 2012	0.3%	$2,598		
Quality insulation installation (HERS)	Nonres - HRMF	Internal, supported by CASE	1%	$5,158	$2,444	2.1
Reduced fan pressure drop	Nonres - HRMF	ARUP 2012	6%	$62,359		
Cool roof	Nonres - MedOff	Internal, supported	0.2%	$2,618	$1,190	2.2

		by CASE				
Increased wall insulation	Nonres - MedOff	Internal, supported by CASE	0.3%	$5,236	$10,649	0.5
Reduced window SHGC	Nonres - MedOff	Internal, supported by CASE	1.9%	$28,798	$57,314	0.5
Add economizer	Nonres - MedOff	Internal	(2016 Prescriptive)			
Variable speed fans	Nonres - MedOff	Internal	(2016 Prescriptive)			
Fan efficiency increase	Nonres - MedOff	Internal	(not feasible)			
Daylight dimming plus off	Nonres - MedOff	Internal, supported by CASE	1%	$12,487	$1,000	12.5
Interior lighting LPDs based on LEDS	Nonres - MedOff	Internal	8%	$67,785	$191,250	0.4
Open office occupancy sensors	Nonres - MedOff	Internal, supported by CASE	3%	$23,190	$10,916	2.1
Manual on time switch control	Nonres - MedOff	Internal	2%	$17,838	$3,000	5.9
Tuning (office space only)	Nonres - MedOff	Internal, supported by CASE	3%	$27,234	$5,100	5.3
Cool roof	Nonres - LaOff	Internal, supported by CASE	0.1%	$2,958	$3,361	0.9
Increased wall insulation	Nonres - LaOff	Internal, supported by CASE	0.3%	$8,101	$13,089	0.6
Reduced window SHGC	Nonres - LaOff	Internal, supported by CASE	1%	$35,105	$90,370	0.4
Increased cooling tower efficiency	Nonres - LaOff	Internal	(federally pre-emptive)			
Fan efficiency increase	Nonres - LaOff	Internal	(not feasible)			
Water side economizer	Nonres - LaOff	Internal	1%	$13,502		
Daylight dimming plus off	Nonres - LaOff	Internal, supported by CASE	3%	$45,258	$1,000	45.3
Open office occupancy sensors	Nonres - LaOff	Internal, supported by CASE	3%	$53,061	$24,620	2.2

Tuning (office space only)	Nonres - LaOff	Internal, supported by CASE	4%	$64,955	$11,524	5.6
Manual on time switch control	Nonres - LaOff	Internal	3%	$40,576	$2,400	16.9