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Statewide Nonresidential Reach Code Cost Effectiveness Analysis

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Executive Summary

Southern California Edison (SCE) engaged TRC to provide a cost effectiveness study to support nonresidential new construction reach code requirements above 2016 Title 24, Part 6, Building Energy Efficiency Standards (T24) in all California climate zones (CZs). The T24 Standards are the minimum energy efficiency requirements for building construction in California, and a reach code would require energy performance beyond the minimum in jurisdictions that adopt it.

Based on the results of TRC's analysis, the cities in all California CZs may move forward with a reach code requiring that nonresidential buildings improve energy performance by at least 10% better than the state minimum requirements, and 15% better in CZs 1, 3, 5, and 7.

TRC conducted cost data collection and energy simulations of four lighting and two envelope energy efficiency measures to show that nonresidential new construction can comply with a 10% reach code cost effectively:

- Reduced lighting power density
- Open office occupancy sensors
- Daylight dimming-plus-off
- Institutional tuning
- Reduced window solar heat gain coefficient
- Cool roofs

Note that the measures are not intended to serve as prescriptive measures, but one possible package achieving 10%. The 10% compliance margin improvement is measured in terms of Time Dependent Valuation (TDV). Measures were simulated in 2016 CBECC-Com compliance software to inform energy impacts using a medium office prototype. TRC quantified the incremental costs for the construction, maintenance, and replacement of the proposed measures relative to T24 through industry expert interviews and online research.

TRC's analysis consisted of two methods to estimate and quantify the value of the energy savings over the 15-year life of the measures:

- **TDV:** The California Energy Commission Life Cycle Cost (LCC) methodology using 2016 Time Dependent Valuation (TDV) of energy, and
- **On-Bill:** Customer cost effectiveness using utility rate schedules to value On-Bill energy impacts.

Each cost effectiveness methodology (TDV and On-Bill) determines cost effectiveness by comparing the incremental cost of a measure to the energy cost savings, in a combined Benefit to Cost (B/C) Ratio metric. The B/C Ratio is the incremental 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 offset by the discounted energy cost savings, and the measure is cost effective.

TRC's analysis shows that nonresidential buildings in all California CZs have a market-ready and cost effective set of measures to achieve at least 10% energy performance higher than the T24, through both the TDV and On-Bill cost effectiveness methodologies. Thus, all California jurisdictions have justification for adopting a 10% nonresidential reach code meeting the requirements of Section 10-106 of the California Code of Regulations Title 24, Part 1. Furthermore, TRC found 15% compliance margins cost effective in CZs 1, 3, 5 and 7, and recommends the a 15% nonresidential reach code in these climate zones (Figure 1). Final measure packages represent one possible way to achieve higher compliance margins, and are not intended to represent a mandatory or prescriptive set of measures.

Figure 1. Compliance Margin and Cost Effectiveness Summary Results

Climate Zone	Cost Effective Compliance Margin	B/C Ratio		Recommended Reach Code Compliance Margin
		TDV Methodology	On-Bill Methodology	
1	15.7%	3.0	5.3	15%
2	12.8%	1.4	2.3	10%
3	15.5%	1.2	2.0	15%
4	13.1%	1.4	2.3	10%
5	15.9%	1.2	2.0	15%
6	14.7%	1.4	1.5	10%
7	15.6%	1.4	2.3	15%
8	13.7%	1.4	1.5	10%
9	12.6%	1.4	1.5	10%
10	11.6%	1.5	2.5	10%
11	11.0%	1.6	2.5	10%
12	11.8%	1.4	2.2	10%
13	10.8%	1.6	2.5	10%
14	11.0%	1.6	1.8	10%
15	10.4%	1.9	2.1	10%
16	12.8%	1.5	2.3	10%

1. Introduction

Southern California Edison (SCE) engaged TRC to provide a cost effectiveness study to support nonresidential new construction reach code requirements above 2016 Title 24 Building Energy Efficiency Standards (T24), in all California climate zones (CZs). The T24 Standards are the minimum energy efficiency requirements for building construction in California, and a reach code would require energy performance beyond the minimum. The 2016 T24 Standards became effective on January 1, 2017.

Based on the results of TRC's analysis, the cities in all California CZs may move forward with a reach code requiring that nonresidential buildings improve energy performance by at least 10% better than the state minimum requirements, and 15% better in CZs 1, 3, 5, and 7.

1.1 Scope and Limitations

TRC attempted to show that nonresidential new construction can comply with a 10% reach code cost effectively by using CEC-approved compliance software and without triggering federal preemption.[1] The 10% compliance margin improvement is measured in terms of Time Dependent Valuation (TDV), described further in Section 2.1.1. TRC researched measures drawn from multiple sources in efforts to develop cost effective packages. Measures were simulated in compliance software to inform energy impacts, and costs were attained through expert interviews and online research. Final measure packages represent one possible way to achieve higher compliance margins, and are not intended to represent a mandatory or prescriptive set of measures.

This study has the following scope limitations:

- **Prototype.** The only building studied is a medium office prototype, further described in Section 2.2.3, because the California Energy Commission (CEC) nonresidential new construction forecast lists offices as being the most widely built building type for 2017 through 2019. Findings may not pertain to high-rise residential or other commercial spaces, such as restaurants and fitness centers, which have very different space conditioning loads and occupancy schedules. However, findings may be more pertinent to other nonresidential spaces, such as retail and school buildings, which have similar occupancy schedules, internal conditioning loads, and domestic water heating loads as office spaces. Using one representative prototype to estimate impacts on a broad range of building types aligns with analyses methods used in previous Title 24 Code and Standards Enhancement (CASE) studies and local reach code studies. Nonetheless, local jurisdictions can choose to analyze other prototypes during the Reach Code adoption process.
- **Federal Preemption.** The Department of Energy (DOE) regulates the minimum efficiencies required for all appliances, such as space conditioning or water heating equipment. State or city codes that mandate appliance efficiencies higher than the DOE's risk litigation by manufacturer industry organizations. Thus, TRC did not use increased equipment efficiencies as reach code measures, although these measures are often the simplest and most affordable measures to increase energy performance. While this study is limited by federal pre-emption, developers can use any package of measures to achieve reach code goals, including the use of high efficiency appliances that are federally regulated.
- **Modeling Capability.** TRC used CEC-approved compliance software, CBECC-Com, to ensure that a free and readily available software could be used by permit applicants to show compliance with the reach code. CEC-approved compliance software does not have the capability to model the energy

[1] List of CEC-approved simulation software available at: http://www.energy.ca.gov/title24/2016standards/2016_computer_prog_list.html

performance of some measures typically associated with energy savings, such as radiant systems, variable refrigerant flow, or chilled beams. TRC limited the packages to include measures that could be modeled in CEC-approved compliance software.

- **Non-Regulated Loads.** Energy consuming end-uses that are not regulated by the CEC, such as receptacle and process loads (e.g., computers and elevators), have been explicitly excluded from the scope of this study. CEC-approved simulation software does not allow compliance credit for energy efficiency improvements in these end-uses.
- **Renewable Generation, including Solar PV.** TRC did not consider on-site or off-site renewable solar generation as a means of complying with the reach code. The reach code measures solely improve the efficiency of building systems. Furthermore, the CEC does not currently allow compliance credit for solar generation.

2. METHODOLOGY

TRC assessed the cost effectiveness of 2016 reach code packages by analyzing several energy efficiency measures applied to prototype buildings. TRC's analysis consisted of two methods to capture benefits and costs:

1. **TDV:** The CEC Life Cycle Cost (LCC) methodology using 2016 Time Dependent Valuation (TDV) of energy, and
2. **On-Bill:** Customer cost effectiveness using utility rate schedules to value On-Bill energy impacts.

Both methodologies require estimating and quantifying the value of the energy impact associated with energy efficiency measures over the life of the measures (15 years) as compared to the baseline T24 medium office prototype. The main difference between the methodologies is how they value energy and the associated cost savings of reduced energy consumption, described in Section 2.1.

Both methodologies also require quantifying the incremental costs for the construction, maintenance, and replacement of the proposed measure relative to the 2016 Title 24 Standards prescriptive requirements. Incremental costs for each measure are described in Section 3.

2.1 Cost Effectiveness Methodologies

With each of the cost effectiveness methodologies (TDV and On-Bill), TRC determined cost effectiveness by comparing the incremental costs of a measure to the energy cost savings, in a combined Benefit to Cost (B/C) Ratio metric. The B/C Ratio is the incremental 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 offset by the discounted energy cost savings, and the measure is cost effective.

2.1.1 Life Cycle Cost Methodology Using Time Dependent Valuation

The CEC LCC Methodology is approved and used by the CEC to establish cost effective statewide building energy standards.[2] The methodology uses 2016 TDV of energy savings as the primary metric for energy savings, which reflects not only the retail costs to the end-user, but also the value of reduced energy demand, such as reduced greenhouse gas emissions and reduced strain to the electric grid.[3] The TDV methodology assigns dollar values to electricity and natural gas delivered for each hour in the year. TDV accounts for retail rates, greenhouse gas emissions, and several other factors to value electricity generation. The TDV of gas generally hovers around one value in the spring and summer, and higher value in the fall and winter, without much fluctuation.

TDV values are based on long term discounted costs over 15 years. The period of analysis is associated with the associated measure life – lighting, air conditioning, or water heating measures may only be in place for 15 years. Envelope measures, such as windows and roofs are typically operational for 30 years, but TRC assumed a 15 year period of analysis for simplification.

The CEC developed the 2016 TDV values for all climate zones used in this study. TDV energy estimates are presented in terms of "TDV kBtus," which combine electricity and natural gas energy units. [4] Compliance

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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.

software calculates TDV energy savings in terms of per-square-foot of the building. The present value of the energy savings is calculated by multiplying the TDV savings/ft^2 by the building conditioned floor area, and then by the Net Present Value (NPV) factor. The NPV factor is $0.089/TDV kBtu for all nonresidential measures with a 15-year useful life.

2.1.2 Customer Cost Effectiveness Using On-Bill Impacts

The customer cost effectiveness methodology captures the energy cost savings from energy efficiency measures resulting from lower energy bills. TRC determined the NPV of the On-Bill savings over a 15-year lifetime, including a 3% discount rate and a 3% energy cost inflation rate.

On-Bill savings were estimated by calculating monthly electricity (kWh) and natural gas (therms) savings resulting energy efficiency measures using current commercial utility (IOU) rate schedules as shown in Figure 2. The commercial IOUs represent a large majority of California residents, and were the primary supporters of this study. Please see *Appendix B – Utility Rate Schedules* for further detail.

Figure 2. Investor-Owned Utility (IOU) Rate Schedules

Climate Zones	Utility	Commodity	Schedule
1, 2, 3, 4, 5, 11, 12, 13, 16	Pacific Gas and Electric Company	Electric	A-10 (TOU)
		Gas	G-NR1
6, 8, 9, 14, 15	Southern California Edison	Electric	TOU-GS-2-A
	Southern California Gas Company	Gas	G-10
7, 10	San Diego Gas and Electric Company	Electric	AL-TOU
		Gas	GN-3

2.2 Measure Analysis

TRC used CBECC-Com 2016.2.1 (build 868) for simulating energy efficiency measures in the medium office prototype.[5] CBECC is a free public-domain software developed by the CEC for use in complying with the Title 24 Standards. Software algorithms are updated continuously, and new versions of the software are released periodically. CBECC-Com 2.1 uses EnergyPlus v8.5 as the simulation engine to perform the analysis.

2.2.1 Energy Savings

CEC approved compliance software simulations output TDV, kWh, and therms energy totals for a proposed building, and compare them to a prescriptive standard building. The 10% compliance margin goal is determined by comparing the proposed building TDV energy usage to the standard building TDV energy usage – the proposed building should use 10% less than the standard building's TDV energy usage. The TDV energy budget

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

and compliance margin is a standard output for building permit applicants completing a performance calculation. The TDV energy budget requirements are described in 2016 T24 Sections 100.2 and 140.1.

Because TDV combines electric and gas energy impacts, different energy efficiency measures can have different kWh and therms impacts while having the same TDV impact. The measure packages in Section 4 represent one possible way to achieve a higher compliance margin – these packages are not intended to represent a mandatory set of reach code measures. Other packages of measures can also achieve higher compliance margins, but will have different kWh and therms impacts.

TRC investigated potential energy efficiency measures to apply to the medium office prototype in each climate zone. TRC utilized previous reach code studies and program experience to investigate reach code measures that would have the greatest impact on reducing the largest energy consuming end uses (see Figure 6). TRC conducted market research to assess measure feasibility, costs, and potential energy impact.

2.2.2 Costs

TRC gathered costs for four regions within California to best represent localized costs (Figure 3). TRC reviewed previous studies for relevant cost data, such as Codes and Standards Enhancement (CASE) studies, if available. TRC conducted cost research by accessing online retailers and interviews with contractors and distributors serving each region. Costs include upfront costs, maintenance, and replacement if the end of useful life is prior to the end of the measure life for a product. For replacements, a three percent (3%) inflation rate was assumed. Detailed costs are provided in *Appendix A – Cost Data*.

The main cause of variation in costs among the regions is due to labor rates, based on RS Means research. There are also slight changes in material costs from region to region, based on local quotes received. Taxes and contractor markups were added as appropriate.

Figure 3. Climate Zones Grouped by Geographic Region

Region	Climate Zone
North Coastal	1-5
South Coastal	6-10
Central	11-13
Inland	14-16

Specifically, when gathering cost data on windows and lighting improvements, TRC found that stakeholders were supportive of the potential measures and in general agreement on TRC's assumptions for potential costs, but would not provide specific cost data themselves. Further detail is provided in Section 3.

2.2.3 Prototype

TRC used a 53,628 ft^2 medium office prototype to run simulations in all California CZs. This prototype is a DOE building model used for analysis of ASHRAE Standard 90.1, but is often used to justify nonresidential T24 standard enhancements and is summarized in the 2016 T24 Nonresidential Alternative Calculation Method

(ACM) Reference Manual.[6] TRC chose an office prototype because, according to the CEC new construction forecast, offices are projected to be the most widely built building type during the 2016 T24 code cycle (Figure 4). TRC chose the medium office (as opposed to a small or large office) to represent an average sized office, and a building type that is likely to get built in both small and large California cities.

Figure 4. CEC Nonresidential New Construction Forecast

Building Type	2017 – 2019 Forecasted Construction (% of total)
Small, Medium, and Large Office	22%
Retail	16%
Warehouse	14%
Restaurant/Food	7%
School	5%
Hotel	5%
College	4%
Hospital	4%
Miscellaneous	23%

TRC initialized the medium office prototype to be exactly compliant with the prescriptive minimum 2016 T24 requirements (0% compliance margin) in each climate zone, summarized in Figure 5. The prototype has a 33% window-to-wall ratio area (WWR) with the glazing area evenly distributed in the four geometry facings – north, east, south, and west – to ensure that results are applicable regardless of the orientation of a building. The TDV of energy savings for energy efficiency measures were derived by applying packages to the minimally code compliant prototype.

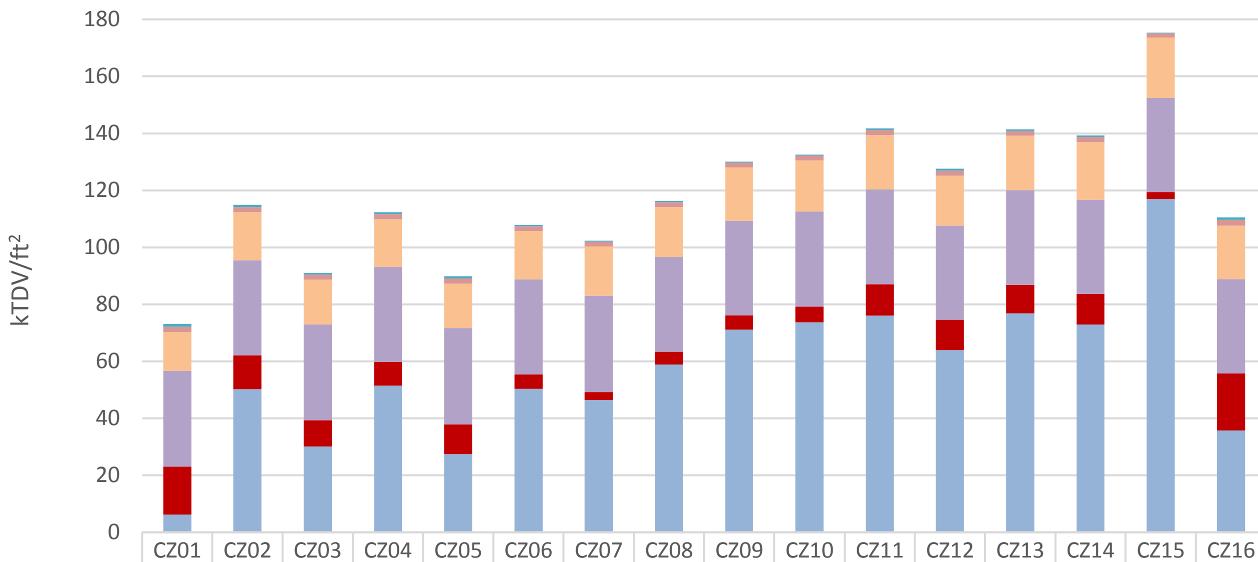
[6] Available at: http://www.energy.ca.gov/title24/2016standards/nonresidential_manual.html

Figure 5. Medium Office Prototype Summary

Building Type		Medium Office
Floor Area (ft2)		53,628
# of floors		3
Window-to-Wall Area Ratio		33%
HVAC Distribution System		3x Packaged Variable Air Volume with VAV Hot Water Reheat
Cooling System		Direct Expansion, 9.8 EER, Economizer
Heating System		Boiler, 80% Thermal Efficiency
Conditioned Thermal Zones		15
Domestic Water Heating		Natural Gas Small Storage, EF = 0.64
Roof Insulation (U-Value)		0.034 / 0.049 depending on CZ
Low-sloped Roof Solar Reflectance		0.63
Metal-framed Wall Insulation (U-Value)		0.062 / 0.069 / 0.082 depending on CZ
Window (fixed)	U-factor	0.36
	Solar Heat Gain Coefficient (SHGC)	0.25
	Visible Transmittance (VT)	0.42
Lighting Power Density (W/ft^2)		0.75

The minimally compliant energy consumption of the medium office prototype in each climate zone is summarized by end-use in Figure 6. Note that outdoor lighting, receptacle and process loads (such as computers or elevators) are not regulated end uses in T24, and thus cannot count be modeled as efficiency measures. Except for CZ 1, the largest energy consumers in the medium office prototype are space cooling and indoor lighting. The total energy values in Figure 6 represent only the regulated energy end uses.

Figure 6. Medium Office Prototype Compliance kTDV/ft² by End-use



	CZ01	CZ02	CZ03	CZ04	CZ05	CZ06	CZ07	CZ08	CZ09	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Pumps & Misc	1	1	1	1	1	0	0	0	0	0	1	1	1	1	0	1
DHW	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Indoor Fans	14	17	16	17	16	17	17	18	19	18	19	18	19	20	21	19
Indoor Lighting	34	33	33	33	34	33	34	33	33	33	33	33	33	33	33	33
Heating	17	12	9	8	10	5	3	4	5	5	11	11	10	11	2	20
Cooling	6	50	30	51	27	50	46	59	71	74	76	64	77	73	117	36

3. MEASURE DESCRIPTIONS AND COSTS

This section provides a description, general modeling parameters, market overview, and summarized costs for energy efficiency measures. After initial investigation and analysis of several energy efficiency measures, TRC selected the measures described below and the subsequent packages described in Section 4 based on cost effectiveness and technical feasibility in the California nonresidential new construction market:

- Lighting measures
  - Reduced lighting power density (LPD)
  - Open office occupancy sensors
  - Daylighting dimming-plus-off
  - Institutional tuning
- Envelope measures
  - Cool roof
  - Reduced window solar heat gain coefficient (SHGC)

Detailed measure costs are available in *Appendix A – Cost Data*.

TRC investigated the possible inclusion of several heating, ventilation, and air-conditioning (HVAC) measures, but was unable to find a market-ready measure that would not trigger federal pre-emption (such as improving IEER or AFUE values) and was able to be modeled in CBECC-Com. Furthermore, HVAC systems are highly integrated – meaning it is difficult to isolate a singular component to improve in efficiency without effecting other parts of the system, and subsequently requiring a whole system redesign. All of these issues proved challenging to isolating costs and energy impacts, and thus cost effectiveness, within the scope of this study.

3.1 Lighting Measures

TRC proposed lighting measures are all Power Adjustment Factors (PAFs) in 2016 Title 24, except the Reduced LPD measure. For Title 24 compliance, PAFs allow a building to install wattages that are higher than prescriptively allowed, due to improvements in controls. For the analysis, TRC did not assume that the PAF was being used to install higher wattages elsewhere in the building, as this would negate any energy impact from the measures.

3.1.1 Reduce Lighting Power Density

This measure reduces the lighting power density (LPD) from the 2016 Title 24 prescriptive requirement of 0.75 W/ft^2 for open office areas to 0.65 W/ft^2. TRC's analysis assumes LED as the primary light source type to achieve this lower LPD. Lighting design varies depending on lighting goals, interior layout, and technology types. TRC reached out to several lighting manufacturer representatives, but because of the large variety of lighting designs possible, representatives were reticent to provide general cost data points. Where necessary, TRC calculated the lighting layouts using Visual Interior Tool v2.0.3.1, and products recommended by manufacturer representatives. In addition to cost data provided by manufacturer representatives, TRC used product costs available on retail websites such as 1000bulbs.com, lightingdirect.com, grainger.com, globalindustrial.com, cesco.com, and homedepot.com.

Lighting costs are dependent on a variety of factors, including lighting output, number of luminaires in the space, and product quality. TRC's Cost research shows that, depending on the lighting design goals and product quality, some T8 fluorescent luminaires may be more costly than LED luminaires. This is because fluorescent fixtures require dimming ballasts to comply with Title 24 multilevel lighting requirements, while most LED fixtures include a dimming driver automatically. In many cases, the cost may be equivalent or very similar once the dimming ballast cost is considered. Lighting manufacturer representatives and online retail sources show cost equivalency for linear fluorescent troffers with dimming ballasts and LED troffers. Although several manufacturer representatives would not provide cost data, their general feedback is that LEDs are now considered the market standard design and that it is feasible to design a project with LEDs at a lower LPD than prescriptive requirements with no incremental cost.

TRC's found that it is technologically feasible to achieve 0.65 W/ft^2 design at no incremental cost. The products in Figure 7 represent basic quality luminaires that provide 50 footcandles of illuminance to the space (calculated with no internal furniture or cubicle walls). Although the cost analysis is based on LEDs, research identified that it is feasible to reach an LPD of 0.65 with some fluorescent luminaires at no additional cost. For example, Cooper Lighting 2AC 232 UNV EB81 U linear fluorescent troffer can achieve this LPD, depending on layout, and is less expensive than some fluorescent luminaires meeting the prescriptive LPD.

Figure 7. Reduced LPD Incremental Cost Summary

Base Case	Proposed Measure	Base Case Cost ($/ft^2)	Proposed Case ($/ft^2)	Incremental Cost ($/ft^2)	Total Incremental Cost ($/bldg)
Linear Fluorescent Troffer at 0.75 W/ft^2 + Dimming Ballast	LED Troffer at 0.65 W/ft^2	$2.33	$2.06	($0.27)	None

3.1.2 Open Office Occupancy Sensors

This measure draws from the findings of the 2013 Indoor Lighting Controls CASE Report.[7] This CASE report investigates the use of occupancy controls in open office spaces at various control group sizes and proposes one occupancy sensor for every four workstations (approximately 500 ft^2). The energy savings associated with occupancy sensors are based on the 0.20 PAF credit in Table 140.6-A of the 2016 T24 Standards. In other words, TRC assumes that installing open office occupancy sensors is equivalent to a 20% reduction in installed LPD in open office areas. TRC assumes that 53% of the building is open office, equating to a net reduction of 11% in LPD.

Occupancy controls have been commercially available for several decades, and the technology is readily available from a wide variety of manufacturers. Both passive infrared and ultrasonic occupancy sensors are widely accepted in office buildings, have been acknowledged to save energy successfully, and are frequently required by codes. The incremental costs for this measure include the costs of the sensors and installation labor, according to the CASE report. The cost for the sensor from online retailers and a manufacturer rep is $126.47 per sensor. The cost for installation and commissioning varies by region. Costs summarized in Figure 8 assume 59 sensors for the medium office and that recommissioning would occur in year 10 after initial commissioning. Costs can be reduced in areas where daylighting sensors will be installed if the selected controls include both passive infrared and daylighting sensing abilities.

[7] California Utilities Statewide Codes and Standards Team (October 2011) Nonresidential Indoor Lighting Controls Codes and Standards Enhancement Initiative. Available at: http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/current/Reports/Nonresidential/Lighting_Controls_Bldg_Power/2013_CASE_NR_Indoor_Lighting_Controls_Oct_2011.pdf

Figure 8. Open Office Occupancy Sensors Incremental Costs Summary

CA Region	Base Case	Proposed Measure	PIR Sensor Cost ($/sensor)	Commissioning Cost ($/sensor)	Total Cost + Maintenance
North Coast	No occupancy sensors	Occupancy sensors in open office	$126.47	$75.35	$14,894
South Coast			$126.47	$55.81	$12,967
North Central			$126.47	$54.49	$12,837
Inland			$126.47	$51.86	$12,577

3.1.3 Daylight Dimming-Plus-Off

This measure revises the control settings for mandatory daylight sensors to be able to shut-off completely when adequate daylight levels are provided to the space. Current requirements are for sensors to dim lighting to 20% full power. TRC used a report by the Pacific Northwest National Laboratory for guidance on the feasibility of this measure.[8] To model this measure in CBECC-Com, TRC revised the daylight control type from Continuous (with a minimum dimming light and power fractions of 0.20), to Continuous Plus Off (which effectively reduces the dimming light and power fractions to 0).

There is no associated cost with this measure, as the 2013 T24 Standards already require multilevel lighting and daylight sensors in primary and secondary daylit spaces. This measure is simply a revised control strategy, and does not increase the number of sensors required or labor to install and program a sensor.

3.1.4 Institutional Tuning

Institutional tuning is currently a PAF in the 2016 T24 Standards. To show compliance with this measure, a designer should meet the requirements of 2016 Title 24 Section 140.6(d). This measure works in conjunction with dimmable ballasts, which were adopted as a requirement in the 2013 T24 Standards. Tuning addresses the frequent practice of designing light levels in a space to exceed that needed for the tasks of the space. Based on space factors and normal lighting design practices, a lighting designer typically overdesigns the light levels specified for a space to ensure adequate lighting is provided. The higher light levels are often a result of designing a space to meet the required light levels while satisfying the luminaire spacing or ceiling layout. The resulting design provides more light (e.g. 65 footcandles) than is necessary or recommended in the space (e.g. 50 footcandles). [9]

Institutional tuning sets the maximum light levels in a space at a lower level than the fully installed light levels, but still at an acceptable level for occupants. The maximum power use is thus lower and energy is continuously saved. Tuning requires that lighting designers commission the lighting system after installation and tune down the lighting to meet the design criteria. In the previous example, the lighting designer may tune down the

[8] Pacifica Northwest National Laboratory (August 2013) Analysis of Daylighting Requirements within ASHRAE 90.1. Available at: http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22698.pdf

[9] A footcandle is the illuminance on a one square foot surface from a uniform source of light. It is a commonly used metric for lighting design.

lighting from 65 footcandles to 55. The designer wants to maintain initial light levels above the minimum requirement to account for depreciation in lamp efficacy over time.

TRC conservatively assumes a 10% reduction in LPD for an office (assuming this measure is in conjunction with the LPD reduction measure above), in line with the PAF factor of 0.10 in Table 140.6-A. Note in this table that institutional tuning has a lower PAF of 0.05 for daylit spaces. TRC did not use this lower PAF in daylit spaces because CBECC-Com already models the impact of daylighting, thus the interactive effects of tuning and daylighting controls do not need to be manually accounted for in the reduced LPD.

The additional cost for this measure is the labor required to tune the lighting in each space, as shown in Figure 9. This cost is dependent on the particular design of an office and the number of unique areas that a lighting designer must address. Based on a field study report by Seventhwave[10] the labor cost required to implement institutional tuning is $0.06 per square foot of space where tuning occurs. The study is representative of lighting installations in Minnesota. TRC used RSMeans Online to compare Minnesota labor rates with California labor rates for interior commercial LED installations. On average, considering several California city labor rates, the Minnesota labor rate and California labor rates are close in value; therefore, the cost estimate applies in California.

Figure 9. Institutional Tuning Incremental Costs Summary

Base Case	Proposed Measure	Commissioning Cost	Total Cost
0.75 W/ft² (no tuning)	0.68 W/ft² (with tuning)	$0.06/ft²	$3,218

3.1.5 Modeling All Lighting Measures

Figure 10 summarizes the LPD impact from the lighting measures described above. The final LPD modeled in CBECC-Com is 0.52 W/ft². The impact of daylighting dimming-plus-off is not captured through a reduced LPD, but rather through a separate simulation control, and so is not included in Figure 10.

Figure 10. LPD Impact from All Lighting Measures

Base Case	+ LED Fixtures	+ Open Office Occupancy Sensors (11% LPD Reduction)	+ Institutional Tuning (10% LPD Reduction)
0.75 W/ft²	0.65 W/ft²	0.58 W/ft²	0.52 W/ft²

[10] Schuetter, S., Li, J., and M. Lord. 2015. Adjusting lighting levels in commercial buildings: energy savings from institutional tuning. August 2015.

3.2 Envelope Measures

3.2.1 Reduced Window Solar Heat Gain Coefficient

2016 Title 24 prescriptive requirements vary by fenestration type, including fixed windows, curtainwalls, and storefront windows. TRC used fixed windows for the analysis, which have prescriptive requirements for a maximum U-factor of 0.36, a maximum relative solar heat gain coefficient (RSHGC) of 0.25, and a minimum visual transmittance (VT) of 0.42. The U-factor depicts the rate of heat transfer of a product, and includes the entire window assembly (glass and frame). The RSHGC is reflective of the heat gain through a window from direct sun exposure, and can be impacted by coatings and tints. The VT is a metric that describes the appearance of a window and ability of light to enter in through the window. A higher VT allows for more light to enter the space and promotes daylighting. In currently available products, RSHGC and VT are linked because factors that may lower RSHGC – such as tinting – can also reduce VT. TRC considered several window values to balance the benefits from reducing RSHGC and increasing daylighting with higher VT. Additionally, higher VTs are more market acceptable for appearance and occupant comfort.

TRC analyzed windows ranging from RSHGC 0.20 to 0.23 with VTs greater than or equal to 0.42, which is the prescriptive minimum value. To be conservative, TRC modeled all windows with the prescriptive minimum VT of 0.42 even though windows were identified with higher VT (which will provide more daylighting energy savings benefits). Based on feedback from glass manufacturers and window fabricators about market acceptance of low RSHGC windows, which tend to be heavily tinted, TRC selected RSHGC 0.22, which has a wider range of product availability without significant tinting.

However, in Climate Zone 15, which has a substantial cooling load, TRC used an RSHGC of 0.20. TRC initially considered 0.20 RSHGC for all climate zones, but feedback indicated that the commercial market is generally unaccepting of most products that can achieve this lower RSHGC because of heavy tint that may give a blue or green appearance.

To gather costs associated with reduced RSHGC, TRC contact several window fabricators and glass manufacturers. Window components are often manufactured at separate facilities under independent organizations, and then a fabricator will design and combine the final product; therefore, the individuals TRC contacted often did not feel confident providing pricing if they only deal with one component, such as the glass. Additionally, contacts noted that the price of windows can fluctuate substantially by the size of the project and the windows, further adding to the hesitation to provide cost information. TRC overcame this barrier by identifying or asking about similar products from each manufacturer that only varied in solar heat gain coefficient (SHGC) value. SHGC is only a feature of the glass, so isolating this value eliminated variation in price from components that do not impact SHGC, such as framing, and allowed the analysis to use costs provided for only the glass.

The cost for reducing the SHGC of a fixed window from 0.25 to 0.22 and 0.20 is summarized in Figure 11. The prototype building has 7,027 ft^2 of fenestration. Based on discussions with window manufacturers and fabricators, cost increases are not directly correlated with SHGC reductions because of the variety of coating and tinting available. There is not a significant cost escalation for going to an SHGC of 0.20 versus 0.22 for the particular products that TRC researched.

Note that Title 24 also allows for modelers to reach an RSHGC of 0.20 by using permanent exterior shading through overhangs or fins, as well as interior automated blinds. For the purposes of the cost effectiveness analysis, TRC modeled and assumed costs for a window with SHGC of 0.20 in Climate Zone 15 instead of exterior shading elements, but notes that shading is an alternative option for builders who want low RSHGCs but want to avoid blue or green appearances on their windows.

Figure 11. Reduced Window RSHGC Incremental Cost Summary

Source	RSHGC	Incremental Cost ($/square foot of window)	Incremental Cost per Building ($)
Manufacturer 1	0.25 (baseline)	n/a	n/a
	0.22 (proposed)	$3.59	$25,227
	0.20 (proposed)	($3.88)	($27,265)
Manufacturer 2	0.25 (baseline)	n/a	n/a
	0.22 (proposed)	$5.00	$35,135
	0.20 (proposed)	$10.00	$70,270
Average 0.22 RSHGC		**$4.44**	**$31,172**
Average 0.20 RSHGC		**$4.45**	**$31,256**

3.2.2 Cool Roofs

The 2016 T24 Standards prescriptively require a Cool Roof Rating Council certified minimum 3-year aged solar reflectance (ASR) based on roof pitch, where steep slope is defined as a slope of > 2:12, and low slope is ≤ 2:12. Low slope cool roofs are typically constructed of field applied coatings, modified bitumen, or single ply thermoplastic roofing. Steep slope roofs are typically constructed of asphalt or tile shingles. Low-sloped roofs are much more common for offices and other commercial buildings, and the medium office prototype has a low-sloped roof. This measure proposes an aged solar reflectance ASR = 0.70 for low slopes, compared to ASR = 0.63 prescriptive requirements. TRC maintained the modeling default of Thermal Efficiency (TE) = 0.85 because most products can achieve this value.

TRC conducted interviews regarding low slope roof products with roofers and roof supply distributors throughout California, and supplemented the interviews with costs available through online retailers. Multiple roofers and product distributors made the statement that there is little or no additional labor to install cool roof products, and in some instances, there is even material cost savings associated with choosing a low sloped cool roof. The cost of cool roof products meeting the Reach Code ASR can be cheaper than their darker, non-cool roof counterparts, depending on the product type. Additionally, according to Cool Roof Rating Council[11] 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.

Costs for cool roof materials varied by climate zone region and tend to be highest in the North and South Coast regions where cool roofs may not be as prominent. Lowest costs tend to be in the North Central and Inland regions with significant cooling loads. To be conservative, TRC estimated an incremental cost in all climate zones by climate region for products that meet the proposed nonresidential low sloped cool roof requirements (ASR = 0.63 to ASR = 0.70), summarized in Figure 12. This incremental cost represents product types that may have

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

higher costs to meet the proposed values, and varies by region. To estimate this cost, TRC averaged the incremental costs for all cool roof types to meet the proposed ASR value. The incremental cost for a cool roof ASR = 0.70 ranges from $0.05 to $0.20 per square foot of roof, depending on the California region. Individual product types range from $(0.10) to $(0.51) per square foot of roof depending on climate region and product type; membranes (e.g. cool caps) are the most expensive cool roof option. Based on product specification sheets, TRC assumed that a cool roof would need maintenance or an entirely new roof after 10 years. The cost for a new roof after 10 years with a 3% inflation rate is included in the total cost estimate in Figure 12.

Figure 12. Cool Roof Incremental Cost Summary

CA Region	Base Case	Proposed Case	Incremental Cost[12] ($/square foot of roof)	Incremental Cost ($/building)
North Coast	ASR = 0.63 TPO/PVC, Membrane, or Field Applied Coating	ASR = 0.70 TPO/PVC, Membrane, or Field Applied Coating	$0.15	$6,106
South Coast			$0.20	$8,279
North Central			$0.11	$4,762
Inland			$0.05	$2,040

An important consideration in cool roof design is the potential for condensation and ice to build up under the roof membrane in cold climates. In traditional roof construction (non-cool roofs), the roof heats up in between periods of precipitation, allowing any wet areas on the roof or under points of roof failures to dry out. Cool roofs may prevent roofs from getting hot enough to completely dry out in between periods of precipitation, and moisture continues to accumulate. The cool roof is not the sole cause of moisture issues; there must be a failure that allows water to enter from the exterior or significant interior humidity levels, both which allow moisture to enter the assembly. Important practices to ensure that cool roofs do not exacerbate moisture-related roof failures are to:

- Ensure proper roof construction and drainage[13]
- Maintain appropriate interior relative humidity[14]
- Add insulation above the roof deck[14] (as per Joint Appendix JA4)

TRC assumed that these practices are part of standard design practice for new construction in a high precipitation climate, and did not assume any additional costs to prevent condensation solely resulting from the construction of a cool roof. The majority of cited condensation and moisture issues with cool roofs are for re-roofs where an existing failure had been maintained by periods of drying, and this wet/dry balance being upset by the addition of a cool roof.

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[12] Incremental cost assumes that reroof will occur in year 10 after construction.

[13] Department of Energy. Available at: https://energy.gov/energysaver/cool-roofs

[14] Dregger, P. 2012. "Cool" Roofs Cause Condensation – Fact or Fiction? *Western Roofing*, January/February 2012, 48-62 or March 2013, 19-26. Available at: http://www.epdmroofs.org/attachments/2012-jan_coolroofscausecondensation_dregger_wr01123.pdf

4. Cost Effectiveness Results and Recommendations

The results for the medium office energy efficiency packages are presented in this section for each climate zone. TRC determined cost effectiveness by comparing the incremental cost of each package to the NPV of energy cost savings over the 15-year period. Incremental costs represent the construction, maintenance, and replacement costs of the proposed measure relative to the 2016 Title 24 Standards prescriptive requirements.

Results include measure compliance margin, present value of energy savings, costs, and benefit to cost (B/C) ratio. The B/C ratio is the incremental 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 offset by the discounted energy cost savings and the measure is cost effective. See Section 2.1 for further detail.

Nonresidential buildings in all California CZs have a market-ready and cost effective set of measures to achieve at least 10% higher than the Title 24 Standards, both through the TDV and On-Bill cost effectiveness methodologies. Thus, all California jurisdictions have proper justification for adopting a 10% nonresidential reach code meeting the requirements of Section 10-106 of the California Code of Regulations Title 24, Part 1. Furthermore, TRC found 15% compliance margins cost effective in CZs 1, 3, 5 and 7.

Note that the only prototype that required use of an RSHGC-0.20 window to achieve the 10% compliance margin cost effectively was in Climate Zone 15 – all other climate zones could achieve a 10% compliance margin using a 0.22 RSHGC window.

4.1 Life Cycle Cost Methodology Using TDV

The CEC LCC Methodology uses a Time Dependent Valuation (TDV) of energy savings, intended to capture the concept that energy efficiency measure savings should be valued differently depending on which hours of the year the savings occur to the utility system, to better reflect the actual costs of energy to consumers. The net present value is calculated using a 15-year lifetime.

As shown in Figure 14, all climate zones achieve a 10% or greater compliance margin cost effectively, indicated by the B/C ratio being equal to or greater 1.0. Climate zones 1, 3, 5, and 7 can achieve a 15% compliance margin cost effectively.

Figure 13. TDV Cost Effectiveness Results

CZ	Cool Roof ASR	Reduced RSHGC	Reduced LPD	Institutional Tuning	Lighting Controls (Daylight Dimming Plus Off, Open Office Occupancy Sensors)	Compliance %	NPV of Savings (kTDV)	Incremental Cost	B/C Ratio
1	n/a	n/a	0.65	x	x	15.7%	$55,509	$18,112	3.0
2	0.70	0.22	0.65	x	x	12.8%	$70,400	$48,902	1.4
3	0.70	0.22	0.65	x	x	15.5%	$67,202	$55,390	1.2
4	n/a	0.22	0.65	x	x	13.1%	$70,448	$49,284	1.4
5	0.70	0.22	0.65	x	x	15.9%	$68,300	$55,390	1.2
6	0.70	0.22	0.65	x	x	14.7%	$75,603	$55,636	1.4
7	0.70	0.22	0.65	x	x	15.6%	$76,319	$55,636	1.4
8	0.70	0.22	0.65	x	x	13.7%	$75,984	$55,636	1.4
9	0.70	0.22	0.65	x	x	12.6%	$78,466	$55,636	1.4
10	0.70	0.22	0.65	x	x	11.6%	$73,646	$48,676	1.5
11	0.70	0.22	0.65	x	x	11.0%	$74,075	$47,098	1.6
12	0.70	0.22	0.65	x	x	11.8%	$71,546	$51,988	1.4
13	0.70	0.22	0.65	x	x	10.8%	$73,216	$47,098	1.6
14	0.70	0.22	0.65	x	x	11.0%	$73,264	$45,781	1.6
15	0.70	0.20	0.65	x	x	10.4%	$87,058	$45,865	1.9
16	0.70	0.22	0.65	x	x	12.8%	$67,298	$45,781	1.5

4.2 Customer Cost Effectiveness Using On-Bill Impacts

The customer cost effectiveness methodology uses utility rate schedules to estimate the retail On-Bill cost savings of energy efficiency to the customer. The net present value is calculated using a 15-year lifetime, including a 3% rate of energy inflation and a 3% discount rate. TRC used Time of Use (TOU) rate schedules, which results in more value applied to energy savings that occur during peak periods.

Using customer cost effectiveness results, B/C ratios improve over the TDV cost effectiveness results. As shown in Figure 14, all climate zones achieve a 10% or greater compliance margin cost effectively, and CZs 1, 3, 5, and 7 can achieve a 15% compliance margin cost effectively.

Figure 14. On-Bill Cost Effectiveness Results

CZ	Cool Roof ASR	Reduced RSHGC	Reduced LPD	Institutional Tuning	Lighting Controls (Daylight Dimming Plus Off, Open Office Occupancy Sensors)	Compliance %	Annual kWh Savings	Annual Therm Savings	On-Bill Savings	Incremental Cost	B/C Ratio
1	n/a	n/a	0.65	x	x	15.7%	26,084	(366)	$95,361	$18,112	5.3
2	0.70	0.22	0.65	x	x	12.8%	31,026	(433)	$114,859	$41,164	2.8
3	0.70	0.22	0.65	x	x	15.5%	29,508	(405)	$109,322	$45,243	2.4
4	n/a	0.22	0.65	x	x	13.1%	31,028	(322)	$114,311	$43,339	2.6
5	0.70	0.22	0.65	x	x	15.9%	30,179	(414)	$111,303	$45,243	2.5
6	0.70	0.22	0.65	x	x	14.7%	32,792	(185)	$82,359	$55,636	1.5
7	0.70	0.22	0.65	x	x	15.6%	32,678	(222)	$129,100	$44,389	2.9
8	0.70	0.22	0.65	x	x	13.7%	33,398	(240)	$83,662	$44,389	1.9
9	0.70	0.22	0.65	x	x	12.6%	33,510	(242)	$85,235	$44,389	1.9
10	0.70	0.22	0.65	x	x	11.6%	32,649	(244)	$121,226	$40,469	3.0
11	0.70	0.22	0.65	x	x	11.0%	32,640	(351)	$118,022	$40,373	2.9
12	0.70	0.22	0.65	x	x	11.8%	31,968	(371)	$116,533	$44,214	2.6
13	0.70	0.22	0.65	x	x	10.8%	32,744	(325)	$119,413	$40,373	3.0
14	0.70	0.22	0.65	x	x	11.0%	33,216	(353)	$80,520	$39,290	2.0
15	0.70	0.20	0.65	x	x	10.4%	38,959	(181)	$96,324	$45,320	2.1
16	0.70	0.22	0.65	x	x	12.8%	30,153	(603)	$106,614	$39,290	2.7

4.3 Greenhouse Gas Savings

New construction commercial buildings complying with the reach code will reduce energy consumption and thereby reduce greenhouse gas (GHG) emissions. TRC multiplied saved energy 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, to attain estimates of GHG savings.[15] Jurisdictions adopting a reach code can use Figure 15 below to approximate the typical reductions of GHG emissions in a typical nonresidential building, expressed in pounds of carbon dioxide equivalent (lbs CO_2e)

Figure 15. Estimated GHG Savings per Building

Climate Zone	kWh Savings / Bldg	Therms Savings / Bldg	Lbs CO2e Avoided/Prototype	Lbs CO2e Avoided/ft^2	% GHG Savings per Bldg
1	26,084	(366)	12,686	0.24	4%
2	31,026	(433)	15,111	0.28	4%
3	29,508	(405)	14,454	0.27	5%
4	31,028	(322)	16,413	0.31	5%
5	30,179	(414)	14,789	0.28	5%
6	29,806	(219)	16,819	0.31	5%
7	32,678	(222)	18,655	0.35	6%
8	33,398	(240)	18,912	0.35	6%
9	33,510	(242)	18,962	0.35	6%
10	32,649	(244)	18,378	0.34	5%
11	32,640	(351)	17,120	0.32	5%
12	31,968	(371)	16,455	0.31	5%
13	32,744	(325)	17,494	0.33	5%
14	33,216	(353)	17,472	0.33	5%
15	38,959	(181)	23,216	0.43	6%
16	30,153	(603)	12,556	0.23	3%

These GHG reduction estimates are based on complying with the 10% packages using the measures analyzed in this study. Compliance with the 10% Reach Code may be achieved through a variety of measures, each of which will have varying electric and natural gas usages, and therefore varying GHG savings. Note also that these are percentage savings of the total greenhouse gas emissions from the buildings, including unregulated loads, which currently are not regulated within the constraints of Title 24, Part 6.

Each jurisdiction can estimate annual city-wide GHG savings by multiplying the CO_2e savings per square foot by the new construction commercial square footage constructed within city limits during an average year.

4.4 Reach Code Recommendations

TRC recommends that California jurisdictions adopt reach codes meeting the compliance margin requirements in Figure 16. Recommended reach code values are more lenient than the levels found to be cost effective –

[15] 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.

compliance margins are rounded down. Final measure packages represent one possible way to achieve higher compliance margins, and are not intended to represent a mandatory or prescriptive set of measures.

Figure 16. Compliance Margin and Cost Effectiveness Summary Results

Climate Zone	Cost Effective Compliance Margin	B/C Ratio		Recommended Reach Code Compliance Margin
		TDV Methodology	On-Bill Methodology	
1	15.7%	3.0	5.3	15%
2	12.8%	1.4	2.3	10%
3	15.5%	1.2	2.0	15%
4	13.1%	1.4	2.3	10%
5	15.9%	1.2	2.0	15%
6	14.7%	1.4	1.5	10%
7	15.6%	1.4	2.3	15%
8	13.7%	1.4	1.5	10%
9	12.6%	1.4	1.5	10%
10	11.6%	1.5	2.5	10%
11	11.0%	1.6	2.5	10%
12	11.8%	1.4	2.2	10%
13	10.8%	1.6	2.5	10%
14	11.0%	1.6	1.8	10%
15	10.4%	1.9	2.1	10%
16	12.8%	1.5	2.3	10%

5. Appendix A – Cost Data

Figure 17. Reduced LPD Detailed Costs

Product	Lamp Technology	LPD[1]	Product Cost ($/luminaire)	Dimming Ballast Cost ($/ballast)	Total Cost per square foot[2] ($/ft^2)
Lithonia 2RT8S 232 MVOLT GEB10IS + dimming ballast	Fluorescent	0.73	$138.74	$52.00	$2.29
2VT8 232 ADP GEB10IS + dimming ballast	Fluorescent	0.73	$145.60	$52.00	$2.37
Lithonia 2BLT4 40L ADSM EZ1 LP840	LED	0.60	$138.39	n/a	$2.06
Cooper Lighting 2AC 232 UNV EB81 U	Fluorescent	0.63	$123.50	$52.00	$1.83

[1] Normalized to provide 50 footcandles of illuminance
[2] Square footage covered to provide 50 footcandles of illuminance

Figure 18. Occupancy Sensor Detailed Costs

Product	Coverage (ft^2)	Installation	Viewing Angle	Proposed Cost ($/unit)
Acuity Sensor Switch Occupancy Sensor	452	Ceiling	360 Degrees	$133.15
Acuity Sensor Switch Occupancy Sensor	500	Ceiling	360 Degrees	$115.20
Acuity Lithonia Occupancy Sensor	452	Ceiling	360 Degrees	$158.25
Acuity Lithonia Occupancy Sensor	452	Ceiling	360 Degrees	$146.40
Hubbel Wiring Device-Kellems Occupancy Sensors	450	Ceiling	360 Degrees	$150.75
Hubbel Wiring Device-Kellems Occupancy Sensors	450	Ceiling	360 Degrees	$110.95
Hubbel Wiring Device-Kellems Occupancy Sensors	450	Ceiling	360 Degrees	$159.25
Hubbel Wiring Device-Kellems Occupancy Sensors	450	Ceiling	360 Degrees	$154.25
Leviton Self-Contained	530	Ceiling	360 Degrees	$64.45
Leviton Occupancy Sensor	450	Ceiling	360 Degrees	$100.90
Leviton Occupancy Sensor	530	Ceiling	360 Degrees	$128.50
Leviton Occupancy Sensor	600	Ceiling	284 Degrees	$54.40

Leviton Ceiling Mount Dual tech	500	Ceiling	360 Degrees	$85.86
Sensor Switch CM9 D	500	Ceiling	360 Degrees	$107.90
Watt Stopper Occupancy Sensor	500	Ceiling	360 Degrees	$127.45
Watt Stopper Occupancy Sensor	500	Ceiling	360 Degrees	$123.50
Watt Stopper Occupancy Sensor	500	Ceiling	360 Degrees	$156.75

Figure 19. Reduced Window SHGC Detailed Costs

Source	Product	SHGC	VT	Incremental Cost from SHGC 0.25 ($/ft^2)
Manufacturer 1	VNE1-63 with silkscreen	0.25	53%	n/a
	VUE24-50	0.25	52%	n/a
	VNE1-53	0.23	49%	($4.61) to ($4.21)
	VNE8-63	0.22	44%	$3.39 to $3.79
	VNE6-53	0.20	42%	($4.08) to ($3.68)
Manufacturer 2	EFCO 325X F with SolarBan70XL	0.25	>42%	n/a
	EFCO PX32 F	0.23	>42%	$0 - $10
	EFCO 325X F with SunGuard SNX 51/23	0.20	>42%	$5 - $15

Figure 20. Low-Slope Cool Roof Detailed Costs

Product Type	ASR	Average Cost ($/ft²)			
		North Coast	South Coast	North Central	Inland
TPO	0.63	$0.75	$0.94	$0.75	$0.75
	0.70	$0.85	$0.85	$0.85	$0.85
	Incremental Cost	$0.09	-$0.10	$0.09	$0.09
Membrane	0.63	$0.63	$1.13	$1.07	$1.07
	0.70	$1.07	$1.64	$1.19	$1.19
	Incremental Cost	$0.44	$0.51	$0.12	$0.12
Field Applied Coating	0.63	$0.55	$0.60	$0.48	$0.57
	0.70	$0.46	$0.79	$0.61	$0.50
	Incremental Cost	-$0.09	$0.19	$0.13	-$0.07
	Average Incremental Cost	**$0.15**	**$0.20**	**$0.11**	**$0.05**

6. Appendix B – Utility Rate Schedules

Below are hyperlinks to the rates used for each utility. Detailed rate schedules are provided in subsequent sections.

- Southern California Edison
  - Electric: Schedule TOU-GS-2-A. Available at: https://www.sce.com/NR/sc3/tm2/pdf/ce329.pdf
- Southern California Gas
  - Electric: Schedule No. G-10. Available at: https://www.socalgas.com/regulatory/tariffs/tm2/pdf/G-10.pdf
- Pacific Gas and Electric
  - Electric: Schedule A-10, Table B (TOU). Available at: https://www.pge.com/tariffs/tm2/pdf/ELEC_SCHEDS_A-10.pdf
  - Gas: Schedule G-NR1. Available at: https://www.pge.com/tariffs/tm2/pdf/GAS_SCHEDS_G-NR1.pdf
- San Diego Gas and Electric
  - Electric: Schedule AL-TOU. Available at: http://regarchive.sdge.com/tm2/pdf/ELEC_ELEC-SCHEDS_AL-TOU.pdf
  - Gas: Schedule GN-3. Available at: http://regarchive.sdge.com/tm2/pdf/GAS_GAS-SCHEDS_GN-3.pdf

6.1 Electric Rates

Figure 21. Southern California Edison Commercial Electric Rates (TOU-GS-2-A)

Southern California Edison (SCE) Commercial Electric Rates	
Rate TOU-GS-2-A	Effective 1/1/2017
Winter ($/kWh) (Oct 1 through May 31)	
Mid-Peak (8AM - 9PM weekdays except holidays)	$0.07589
Off-Peak	$0.06573
Summer ($/kWh) (Jun 1 through Sept 31)	
On-Peak (12-6PM weekdays except holidays)	$0.34167
Mid-Peak (8AM - 12PM and 6PM - 11PM weekdays, except holidays)	$0.11601
Off-Peak	$0.05918
Additional Charges	
Facilities Related Demand Charge ($/kW/meter/month)	$15.48
Customer Charge ($/meter/month)	$220.30
Single Phase Service ($/month)	($11.71)
Voltage Discount, Demand ($/kW)	
2kV to 50kV	($0.20)
50kV to <220kV	($6.79)
220kV	($11.27)
Voltage Discount, Energy ($/kWh)	
2kV to 50kV	($0.00165)

50kV to <220kV	($0.00391)
220kV	($0.00395)
CA Alternate Rates for Energy Discount (%)	100%
TOU Option ($/meter/month RTEM)	$71.01
CA Climate Credit ($/kWh)	($0.00416)

Figure 22. Pacific Gas and Electric Commercial Electric Rate (Schedule A-10, Table B)

Pacific Gas and Electric (PG&E) Commercial Electric Rates	
Rate Schedule A-10, Table B	Effective 3/1/2017
Winter ($/kWh) (Nov 1 through Apr 30)	
Mid-Peak (8:30AM-9:30PM, weekdays except holidays)	$0.13641
Off-Peak	$0.11935
Summer ($/kWh) (May 1 through Oct 31)	
On-Peak (12-6PM, weekdays except holidays)	$0.21972
Mid-Peak (8:30AM-12PM and 6-9:30PM, weekdays except holidays)	$0.16459
Off-Peak	$0.13652
Demand Charge ($/kW/meter/month)	
Summer	$16.78
Winter	$9.45
Additional Charges	
Customer Charge ($/meter/day)	$4.59959
CA Climate Credit ($/kWh)	($0.0038)

Figure 23. San Diego Gas and Electric Commercial Electric Rate (AL-TOU)

San Diego Gas and Electric (SDG&E) Commercial Electric Rates	
Rate AL-TOU	Effective 3/1/2017
Winter ($/kWh) (Nov 1 through Apr 30)	
On-Peak (5-8PM, weekdays except holidays)	$0.11085
Mid-Peak (6AM-5PM and 8-10PM, weekdays except holidays)	$0.09574
Off-Peak	$0.07492
Summer ($/kWh) (May 1 through Oct 31)	
On-Peak (11AM-6PM, weekdays except holidays)	$0.12252
Mid-Peak (6-11AM and 6-10PM, weekdays except holidays)	$0.11305
Off-Peak	$0.08294
Demand Charge ($/kW/meter/month)	
Non-Coincident	$24.51
Summer - On-Peak	$20.84
Winter - On-Peak	$7.57
Additional Charges	
Basic Service Fee ($/meter/month)	$116.44

6.2 Gas Rates

Figure 24. Southern California Gas Commercial Natural Gas Rate (G-10)

Southern California Gas (SCG) Commercial Gas Rates	
Rate G-10	Effective 3/10/2107
Base Charges ($/therm)	
TIER 1 (up to 250 therms)	$0.89387
TIER 2 (251 to 4,167 therms)	$0.65334
TIER 3 (>4,167 therms)	$0.49206
Additional Charges	
Customer charge ($/meter/day)	$0.49315

Figure 25. Pacific Gas and Electric Commercial Natural Gas Rates (G-NR1)

Pacific Gas and Electric (PG&E) Commercial Gas Rates	
Rate G-NR1	Effective 3/1/2017
Winter ($/therm) May 1 - Nov 30	
TIER 1 (up to 4,000 therms)	$1.13678
TIER 2 (>4,000 therms)	$0.83428
Summer ($/therm) Dec 1 - Apr 30	
TIER 1 (up to 4,000 therms)	$1.02592
TIER 2 (>4,000 therms)	$0.77060
Additional Charges	
Customer charge ($/meter/day) 0 - 5.0 ADU[1]	$0.27048
Customer charge ($/meter/day) 5.1 - 16.0 ADU[1]	$0.52106
Customer charge ($/meter/day) 16.1 - 41.0 ADU[1]	$0.95482

[1]ADU is Average Daily Usage. It is the usage for the entire billing period divided by the number of days within the billing period.

Figure 26. San Diego Gas and Electric Commercial Natural Gas Rates (GN-3)

San Diego Gas and Electric (SDG&E) Commercial Gas Rates	
Rate GN-3	Effective 3/10/2017
Base Charges ($/therm)	
TIER 1 (up to 1,000 therms)	$0.80449
TIER 2 (1,001 to 21,000 therms)	$0.68176
TIER 3 (>21,000 therms)	$0.64710
Additional Charges	
Customer charge ($/meter/month)	$10.000