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PROPOSED NEW CONSTRUCTION ENERGY EFFICIENCY REQUIREMENTS AND ASSOCIATED COST-EFFECTIVENESS STUDIES[1]

STUDIES:

1) Title: CALGreen Cost Effectiveness Study
   Prepared For: Marshall Hunt
   Codes and Standards Program, Pacific Gas and Electric Company Prepared By: Davis Energy Group, Inc.; Enercomp, Inc.; Misti Bruceri & Associates, LLC
   Last Modified: November 16, 2016

2) Title: 2016 Title 24 Residential Reach Code Recommendations: Cost Effectiveness Analysis for All California Climate Zones
   Prepared For: California Statewide Codes and Standards Enhancement (CASE) Program
   Prepared By: TRC Energy Services
   Last Modified: August 2017

3) Title: CALGreen All-Electric Cost Effectiveness Study
   Prepared For: Marshall Hunt
   Codes and Standards Program, Pacific Gas and Electric Company Prepared By: Davis Energy Group, Inc.; Enercomp, Inc.; Misti Bruceri & Associates, LLC
   Last Modified: October 11, 2017

4) Title: Statewide Nonresidential Reach Code Cost Effectiveness Analysis
   Prepared For: Southern California Edison
   Prepared By: TRC Energy Services
   Last Modified: July 2017

[1] Details about all studies are located here: http://localenergycodes.com/content/performance-ordinances

PROPOSED NEW CONSTRUCTION ENERGY EFFICIENCY REQUIREMENTS AND ASSOCIATED COST-EFFECTIVENESS STUDIES[2]

REQUIREMENT/OPTION	STUDY
Requirements for new single-family homes that are less than 4,000 square feet	
Option 1: 15% more efficient than state code if no solar is installed	CALGreen Cost Effectiveness Study (Page 13)
Option 2: 20% more efficient than state code if solar is installed	CALGreen Cost Effectiveness Study (Page 14)
Option 3: All-electric home at baseline	*No study* – does not exceed state standards, and a cost-effective alternative is provided.
Requirements for new single-family homes that are greater than 4,000 square feet	
Option 1: 35% more efficient than state code and EDR of 20 or less	2016 Title 24 Residential Reach Code Recommendations: Cost Effectiveness Analysis for All California Climate Zones (Page 1)
Option 2: Home is all electric, 20% more efficient than state code, and has at least 2.5 kw of solar	CALGreen All-Electric Cost Effectiveness Study (Page 13)
Option 3: Passive House Certified	*No study* – a cost-effective alternative is provided.
Requirements for new multifamily building that is 3 stories or less	
Option 1: 10% more efficient than state code if no solar is installed	2016 Title 24 Residential Reach Code Recommendations: Cost Effectiveness Analysis for All California Climate Zones (Page 1)
Option 2: 15% more efficient than state code if solar is installed	2016 Title 24 Residential Reach Code Recommendations: Cost Effectiveness Analysis for All California Climate Zones (Page 1)
Option 3: All-electric units at baseline	*No study* – does not exceed state standards, and a cost-effective alternative is provided.
Requirements for new multifamily building that is 4 stories or more	
Option 1: 10% more efficient than state code	Statewide Nonresidential Reach Code Cost Effectiveness Analysis (Page 1)
Option 2: All-electric units at baseline	*No study* – does not exceed state standards, and a cost-effective alternative is provided.
Requirements for new commercial buildings	
Option 1: 10% more efficient than state code	Statewide Nonresidential Reach Code Cost Effectiveness Analysis (Page 1)
Option 2: All-electric units at baseline	*No study* – does not exceed state standards, and a cost-effective alternative is provided.

[2] Details about all studies are located here: http://localenergycodes.com/content/performance-ordinances

CA Statewide Codes and Standards Program

Title 24, Part 11
Local Energy Efficiency Ordinances

CALGreen Cost Effectiveness Study

Prepared for:
Marshall Hunt
Codes and Standards Program
Pacific Gas and Electric Company

Prepared by:
Davis Energy Group, Inc.
Enercomp, Inc.
Misti Bruceri & Associates, LLC

Last Modified: November 16, 2016

LEGAL NOTICE

This report was prepared by Pacific Gas and Electric Company and funded by the California utility customers under the auspices of the California Public Utilities Commission.

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1 Introduction

The California Building Energy Efficiency Standards Title 24, Part 6 (Title 24) (CEC, 2016b) is maintained and updated every three years by two state agencies, the California Energy Commission (CEC) and the Building Standards Commission (BSC). In addition to enforcing the code, local jurisdictions have the authority to adopt local energy efficiency ordinances, or reach codes, that exceed the minimum standards defined by Title 24 (as established by Public Resources Code Section 25402.1(h)2 and Section 10-106 of the Building Energy Efficiency Standards). Local jurisdictions must demonstrate that the requirements of the proposed ordinance are cost effective and do not result in buildings consuming more energy than is permitted by Title 24. In addition, the jurisdiction must obtain approval from the CEC and file the ordinance with the BSC for the ordinance to be legally enforceable.

This report presents the results from analysis of the feasibility and cost-effectiveness of requiring new low-rise single family and multifamily residential construction to exceed the 2016 Building Energy Efficiency Standards, which become effective January 1, 2017. The analysis includes scenarios of compliance packages options and cost effectiveness analysis for all sixteen California climate zones. Four levels of building energy performance were examined:

(1) exceeding the minimum requirements by at least 15%, consistent with the voluntary Tier 1 Performance Standard in Title 24, Part 11 (CALGreen),

(2) exceeding minimum requirement by at least 30%, consistent with the voluntary Tier 2 Performance Standard in CALGreen,

(3) meeting minimum Title 24 efficiency performance targets plus on-site renewable energy generation sufficient to achieve an Energy Design Rating of zero (TDV-Zero), consistent with the voluntary Zero Net Energy Design tier in CALGreen,

(4) meeting minimum Title 24 efficiency performance targets plus on-site renewable energy generation sized to offset a portion of the total TDV loads of the building without risking sizing of the PV system larger than the estimated electrical energy use of the building.

This analysis uses a customer-based lifecycle cost (LCC) approach to evaluating cost effectiveness of the proposed ordinance, whereas the CEC LCC methodology uses Time Dependent Valuation (TDV) as the primary metric for energy savings. Both methodologies require estimating and quantifying the energy savings associated with energy efficiency measures, as well as quantifying the costs associated with the measures. The main difference between the methodologies is the manner in which they value energy and thus the cost savings of reduced or avoided energy use. The CEC LCC Methodology uses TDV, which is intended to capture the societal impact of energy savings, while the life cycle customer cost methodology uses utility rate schedules and applies net energy metering rules to estimate cost savings from onsite PV generation to the customer. TRC has completed a parallel analysis to this one for the City of Santa Monica on behalf of Southern California Edison that utilizes the CEC LCC Methodology (TRC, 2016).

2 Methodology and Assumptions

2.1 Building Prototypes

The CEC defines building prototypes which it uses to evaluate the cost-effectiveness of proposed changes to Title 24 requirements. There exist two single family prototypes and one multifamily prototype, all three of which are used in this analysis in development of the above-code efficiency packages. Table 1 describes the basic characteristics of each prototype. Additional details on the prototypes can be found in the ACM Approval Manual (CEC, 2016a).

Table 1: Prototype Characteristics

	Single Family One-Story	Single Family Two-Story	Multifamily
Conditioned Floor Area	2,100 ft^2	2,700 ft^2	6,960 ft^2: (4) 780 ft^2 & (4) 960 ft^2 units
Num. of Stories	1	2	2
Num. of Bedrooms	3	3	(4) 1-bed & (4) 2-bed units
Window-to-Floor Area Ratio	20%	20%	15%

Additionally, each prototype building has the following features:

- Slab-on-grade foundation
- Vented attic. High performance attic in climates where prescriptively assigned (CZ 4, 8-16) with insulation installed below roof deck. Refer to Table 150.1-A in Appendix A.
- Ductwork located in the attic for single family homes and in conditioned space for multifamily.
- Split-system gas furnace with air conditioner that meet the minimum federal guidelines for efficiency
- Tankless gas water heater that meets the minimum federal guidelines for efficiency; individual water heaters in each multifamily apartment.

Other features are defined consistent with the Standard Design in the Alternative Calculation Method Reference Manual (CEC, 2016d), designed to meet, but not exceed, the minimum requirements.

The CEC's standard protocol for the single family prototypes is to weight the simulated energy impacts by a factor that represents the distribution of single-story and two-story homes being built statewide, assuming 45% single-story homes and 55% two-story homes. Simulation results in this study are therefore characterized according to this ratio, which is approximately equivalent to a 2,430 ft^2 house[1].

2.2 Efficiency Measures & Package Development

The CBECC-RES 2016.2.0 ALPHA2[2] (833) compliance simulation tool was used to evaluate energy impacts using the 2016 prescriptive standards as the benchmark and the 2016 time dependent valuation (TDV) values. TDV is the energy metric used by the CEC since the 2005 Title 24 energy code to evaluate compliance with the Title 24 standards. TDV values energy use differently depending on the fuel source (gas, electricity, and propane), time of day, and season. TDV was developed to reflect the "societal value or cost" of energy including long-term projected costs of energy such as the cost of providing energy during peak periods of demand and other societal costs such as projected costs for carbon emissions. Electricity used (or saved) during peak periods of the summer has a much higher value than electricity used (or saved) during off-peak periods (Horii et al, 2014).

The methodology used in the analyses for each of the prototypical building types begins with a design that precisely meets the minimum 2016 prescriptive requirements (0% compliance margin). A table of

[1] 2,430 ft^2 = 45% * 2,100 ft^2 + 55% * 2,700 ft^2

[2] On June 14, 2016 the CEC approved CBECC-Res 2016.2.0 Version of the software. The version used for this study is nearly identical to the approved version with the exception of minor changes that do not affect the cost effective analysis of the measures evaluated.

prescriptive measures used in each base design by climate zone is located in Appendix A. Using the 2016 baseline as the starting point, prospective energy efficiency measures were identified and modeled in each of the prototypes to determine the projected energy (Therm and kWh) and compliance impacts. A large set of parametric runs[3] were conducted to develop packages of measures that exceed the minimum code performance level by 15% (CALGreen Tier 1), and 30% (Tier 2). The consultants authoring this study selected packages and measures based on decades of experience with residential architects, builders, and engineers along with general knowledge of the relative acceptance and preferences of many measures, as well as their incremental costs.

Evaluation results for the selected packages show that meeting the performance targets for both single family and multifamily prototypes is feasible in most climate zones. In climates where it was not feasible, targets were relaxed to an appropriate level. It is important to note that the packages contained in this report are examples only; any project meeting requirements of a local ordinance, both single family and multifamily, must independently evaluate and identify the most cost effective approach based on project-specific factors.

Following are descriptions of each of the efficiency measures applied in this analysis.

Quality Insulation Installation (QII): HERS rater verification of insulation quality according to the procedures outlined in the 2016 Reference Appendices RA3.5 (CEC, 2016c). QII is included in all cases since it is a pre-requisite for all the voluntary tiers in 2016 CALGreen.

Reduced Infiltration (ACH50): HERS rater field verification and diagnostic testing of building air leakage according to the procedures outlined in the 2016 Reference Appendices RA3.8 (CEC, 2016c). The default infiltration assumption for single family homes is 5 air changes per hour at 50 Pascals (ACH50)[4] and the reduced level applied in this analysis is 3 ACH50. This measure was not applied to multifamily homes because the modeling software does not allow this credit unless each unit is modeled individually, which is not typical in the compliance process for multifamily buildings.

Window Performance: Reduce window U-value from the prescriptive value of 0.32 to 0.30 in all climates and reduce the solar heat gain coefficient (SHGC) from the prescriptive value of 0.25 to 0.23 in climate zone 2, 4, 6 through 16. In climate zones 1, 3, and 5 there is no prescriptive SHGC requirement and the default value of 0.50 is left as is.

Door Performance: Install insulated doors that meet a U-value of 0.20 at the front entry and doors between the house and garage. It's assumed there is a single 3' x 6'8" entry door per single family home and multifamily unit as well as a second 3' x 6'8" door to the garage per single family home.

Cool Roof: Install a roofing product that's rated by the Cool Roof Rating Council to have an aged solar reflectance of 0.20. This measure only applies to climates zones where this is not already required prescriptively.

Exterior Wall Insulation: Increase wall cavity insulation from R-19 to R-21 in 2x6 walls.

High Performance Attics (HPA): For climates where HPA is not already prescriptive under the 2016 code (CZ 1-3, 5-7), increase attic ceiling insulation to R-38 and add insulation under the roof deck between framing (R-13 for roof with air space, R-18 for roof without air space).

High Efficiency Furnace: Upgrade furnace to a condensing unit with an efficiency of 92% AFUE.

[3] Using the "quick" simulation speed option.

[4] Whole house leakage tested at a pressure difference of 50 Pascals between indoors and outdoors.

High Efficiency Air Conditioner: Upgrade air conditioner efficiency beyond federal efficiency minimum to either SEER 15 / EER 12.5 or SEER 16 / EER 13.

High Efficacy Fan: Upgrade the fan in the furnace or air handler using an electronically commutated motor (ECM) that meets an efficacy of 0.3 Watts / cfm or lower operating at full speed. Fan watt draw is verified by a HERS rater according to the procedures outlined in the 2016 Reference Appendices RA3.3 (CEC, 2016c). New federal regulations that go into effect July 3, 2019 are expected to result in equivalent performance for all newly manufactured furnaces provided that the ducts are sized properly.

Refrigerant Charge Verification: HERS rater verification of proper air conditioner refrigerant charge according to the procedures outlined in the 2016 Reference Appendices RA3.2 (CEC, 2016c). This measure only applies to climates zones where this is not already required prescriptively.

R-8 Duct Insulation: Increase duct insulation to R-8. This measure only applies to climates zones where R-8 ducts are not already required prescriptively.

High Efficiency Water Heater: Upgrade tankless water heater to a condensing unit with a rated Energy Factor (EF) of either 0.94 or 0.96. Even though equipment costs for condensing tankless water heaters are higher than standard units, labor is less due to the lower installation costs. Non-condensing tankless water heaters require stainless steel venting while condensing units use PVC venting. Based on feedback from the field these cost differences are offset and the incremental cost have been found to be negligible.

Hot Water Pipe Insulation: Beginning in January 1, 2017 the 2016 California Plumbing Code will require pipe insulation levels that are close to that required if taking the Title-24 pipe insulation credit. This credit will be obsolete under the 2016 energy code, however, the HERS-Verified Pipe Insulation Credit, as defined in the 2016 Reference Appendices RA3.6.3 (CEC, 2016c), will remain. While CBECC-Res has not yet been updated to reflect this, for this analysis it was assumed that the revised HERS verified credit would be equivalent to the current credit for pipe insulation without HERS verification. This was determined based on simulations that demonstrated the HERS credit to be valued at roughly twice that for pipe insulation without verification in terms of TDV energy. This credit was only applied to single family residences. For costing purposes, 120 linear feet of 1/2in insulated pipe is assumed to be insulated.

Hot Water Compact Distribution: HERS rater verification of compact distribution system requirements according to the procedures outlined in the 2016 Reference Appendices RA3.6.5 (CEC, 2016c). This measure was applied to multifamily buildings only. Many multifamily buildings with individual water heaters are expected to easily meet this credit with little or no alteration to plumbing design. This measure also requires verification of pipe insulation per the HERS-Verified Pipe Insulation Credit. Assumption is 60 linear feet per dwelling unit of 1/2in insulated pipe.

Solar Ready: Under both the 2013 and 2106 Title 24 code, single family homes located in subdivisions with ten or more single family residences, and multifamily buildings are required to be solar ready. Solar ready for single family homes is defined as having:

- A solar zone with an area no less than 250 square feet
- Interconnection pathways shown on construction documents
- A main electric panel capable of serving a future solar electric installation

Where cost effective, solar ready definition was expanded in single family homes to include the following:

- All single family residential buildings shall install conduit to support the future installation of solar PV.
- The solar ready definition is expanded to include all single family residential buildings (including custom homes).

For costing purposes, 45 linear feet of 1 inch conduit is assumed between the proposed location of the inverter and the attic. Incremental costs assume both material and labor costs. There are no associated savings for this measure. Because of the additional cost for multiple units this measure was not considered for multifamily buildings.

PV and PV Compliance Credit: To be eligible for this compliance credit a PV system with a minimum capacity of 2 kW DC per single family home with no more than 2,000 ft^2 of conditioned floor area and 1 kW DC per multifamily unit with no more than 1,000 ft^2 of conditioned floor area is required. For the single family 2,430 ft^2 prototype the minimum capacity as calculated by CBECC-Res is 2.0 kW to 2.4 kW depending on the climate zone. The multifamily apartment units in the prototype are all under 1,000 ft^2 and therefore require a 1 kW system. The credit was developed to give builders an option with which to trade-off High Performance Attics and Walls, and to begin preparing for ZNE requirements. For costing, a micro inverter is assumed which is expected to be replaced at year 20.

Table 2 below summarizes the measures evaluated along with cost assumptions.

Table 2: Measure Descriptions & Cost Assumptions

Measure	Performance Level	Incremental Cost: Single Family	Incremental Cost: MF – Per Unit	Source & Notes
QII	Yes	$519	$133	City of Palo Alto 2016 Reach Code Ordinance: http://www.cityofpaloalto.org/civicax/filebank/documents/52054
ACH50	3.0	$379	n/a	NREL measure cost database ($0.115/ft^2 for sealing) + HERS rater verification ($100).
Wall Insulation	R-21	$391	n/a	Relative to R-19. 2016 CASE Report: Residential High Performance Walls and QII, 2016-RES-ENV2-F
Cool Roof	Aged Reflect = 0.20	$523	$131	$0-$0.50 / ft^2 of roof area per local industry expert at LBNL. Used average of $0.25/ft^2.
Window U-factor/ SHGC	0.30/0.23	$73	$20	EnerComp ($0.15/ft^2 of window area)
Doors	0.20 U-factor	$40	$20	EnerComp ($1.00/ft^2 for exterior doors)
High Performance Attics (HPA)	R-13 under roof deck	$878	$219	For climate zones 1-3, & 5-7 only where HPA is not prescriptive. 2016 CASE Report: Residential Ducts in Conditioned Space / High Performance Attics, 2016-RES-ENV1-F
Furnace	92%	$389	$351	HVAC contractor costs, MF reduction for smaller capacity.
Air Conditioning	15/12.5	$78	$46	HVAC contractor costs, MF reduction for smaller capacity.
	16/13	$839	$699	Average of local HVAC contractor & NREL database costs. MF reduction for smaller capacity.
Fan Efficacy	0.3 Watts/cfm	$143	$104	HVAC contractor costs, MF reduction for smaller capacity.
Refrigerant Charge	HERS verified	n/a	$75	Local HERS rater.
Duct Insulation	R-8	$164	n/a	For climate zones 3, 6, & 7 where not prescriptive. Cost is relative to R-6. 2016 CASE Report: Residential Ducts in Conditioned Space / High Performance Attics, 2016-RES-ENV1-F
Water heater	0.94 EF	$0	$0	Internet pricing and plumbing contractor input. Minimal incremental equip cost and lower cost to install PVC venting (condensing) vs stainless venting (standard). Slight premium going from 0.94 to 0.96.
	0.96 EF	$100	$100	
Hot water pipe insulation	HERS verified	$146	n/a	Roughly equivalent to code requirements effective Jan. 2017. 10% of $3.87 per ft (2013 SF DHW CASE study) for additional labor to pass HERS inspection. $100 for HERS verification per local HERS raters.
Hot water compact distribution	HERS verified	n/a	$112	Assume compact design already or easily achieved in MF units – no added cost. $100 HERS verification fee per local HERS rater. Pipe insulation cost per the pipe insulation measure assumptions.
Solar Ready	n/a	$257	n/a	RS Means: $5.70 per linear foot installed cost and 45 linear ft of 1" conduit.
PV System	System size varies	$3.35 / W DC	$3.03 / W DC	Avg. system cost for systems < 10kW (for the last 12 months) of $5.29/Watt for single family (http://www.gosolarcalifornia.ca.gov/). For multi-family systems, an average of the < 10 kW and > 10kW system cost ($4.37/Watt) was used; systems are expected to be typically greater than 10 kW, although not as large as some commercial systems reported on in the database. In both cases cost was reduced by $0.50/Watt for the NSHP incentive & 30% for the solar investment tax credit.
PV Inverter – Replacement	Micro inverter	$0.40 / W DC	$0.40 / W DC	Assumes inverter replacement at 20 years based on life of micro inverters. NREL cost study: $0.29/W based on new construction. (http://www.nrel.gov/docs/fy15osti/64746.pdf). Add labor cost of $275

2.3 Efficiency Packages

Three efficiency packages were developed for each climate zone where feasible, as described below.

1) **Envelope**: These packages focus on building envelope measures but also include efficient hot water pipe distribution and cooling fan efficiency measures that don't trigger federal preemption issues.
2) **Equipment**: Use of HVAC and water heating equipment that are more efficient than federal standards combined with efficient envelope measures if necessary.
3) **PV Credit**: Utilize the PV compliance credit (PVCC) available in all climate zones except 6 and 7. See Table 16 and Table 17 in Appendix B for minimum kW DC capacity requirements for the PVCC.

Since state and local governments are prohibited from adopting minimum efficiency standards for equipment and appliances that are federally regulated under the National Appliance Energy Conservation Act (NAECA), including heating, cooling, and water heating equipment, the focus of this study was to evaluate and identify cost effective packages that did not include high efficiency equipment measures. In climates where the PV Compliance Credit (PVCC) is available (all climates except 6 and 7) a package that includes the PVCC in addition to efficiency measures was evaluated to achieve Tier 2 performance levels. The Envelope (and the PV Credit) packages demonstrate that the requirements for the local ordinance can be met without the use of equipment that exceeds federal minimum efficiency requirements. While cost-effective, the Envelope package is not the only design choice. More often, builders use a combination of improvements to the envelope and high efficiency equipment to meet the performance requirements, as shown in the Equipment package, which usually results in a higher benefit to cost ratio. All measure packages are examples only, using a prototypical building, demonstrating that there are multiple options to cost-effectively meet the performance requirements.

2.4 PV Performance Packages

Using the Tier 2 efficiency package (or Tier 1 in cases where reaching Tier 2 wasn't feasible), the PV system was evaluated and sized to offset TDV loads for the following two conditions:

1) **PV-Plus**: Install a PV system sized to offset a portion of the total household energy use based on TDV energy. PV sizing is consistent with the methodology included in the California Energy Commission's proposed Solar PV Ordinance being developed by the CEC, and PV sizing calculations were developed such that PV size is to be equivalent to offsetting approximately 80% of total estimated building electricity use for a gas/electric home built to the 2016 Title 24. Table 3 summarizes the prescriptive PV sizing based on Climate Zone and home size.

2) **TDV-Zero**: Install a PV system sized to offset 100% of building energy use based on TDV energy, including appliances and plug loads. This is consistent with the requirements of the CALGreen Zero Net Energy Design tier.

In both these cases PV is evaluated in CBECC-Res according to the California Flexible Installation (CFI).

Table 3: Minimum PV System Size (kW_{DC}) required to meet Solar PV Ordinance by Climate Zone

Conditioned Space (ft2)	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Less than 1000	1.6	1.4	1.5	1.3	1.4	1.5	1.3	1.5	1.4	1.4	1.7	1.5	1.8	1.3	2.1	1.3
1000 - 1499	2.0	1.7	1.7	1.5	1.6	1.7	1.5	1.8	1.7	1.7	2.2	1.9	2.3	1.6	2.8	1.6
1500 - 1999	2.4	2.0	2.1	1.8	1.9	2.0	1.8	2.1	2.0	2.0	2.7	2.3	2.8	2.0	3.5	1.9
2000 - 2499	2.8	2.3	2.4	2.1	2.1	2.3	2.0	2.4	2.3	2.3	3.2	2.7	3.4	2.3	4.2	2.3
2500 - 2999	3.2	2.6	2.7	2.4	2.4	2.6	2.3	2.7	2.6	2.7	3.7	3.1	3.9	2.7	4.9	2.6
3000 - 3499	3.6	2.9	3.0	2.6	2.7	2.9	2.5	3.0	2.9	3.0	4.2	3.4	4.4	3.0	5.6	3.0
3500 - 3999	3.9	3.2	3.2	2.9	2.9	3.2	2.7	3.3	3.2	3.3	4.7	3.8	4.9	3.4	6.3	3.3
4000 - 4499	4.3	3.5	3.5	3.2	3.1	3.4	2.9	3.6	3.5	3.6	5.1	4.2	5.4	3.7	7.0	3.6

2.5 Cost Effectiveness

A customer based approach to evaluating cost effectiveness was used based on past experience with Reach Code adoption by local governments. The current residential utility rates at the time of the analysis were used to calculate utility costs for all cases and determine cost effectiveness for the proposed packages. Annual utility costs were calculated using hourly electricity and gas output from CBECC-Res and applying the utility tariffs summarized in Table 4. Appendix C includes the utility rate schedules used for this study. The standard residential rate (E1 in PG&E territory, D in SCE territory, & DR in SDG&E) was applied to the base case and all cases without PV systems. The applicable residential time-of-use (TOU) rate was applied to all cases with PV systems. [5] Any annual electricity production in excess of annual electricity consumption is credited to the utility account at the applicable wholesale rate based on the approved NEM tariffs for that utility. The net surplus compensation rates for the different utilities are as follows:

- PG&E: $0.043 / kWh
- SCE: $0.0298 / kWh[6]
- SDG&E: $0.0321 / kWh[7]

Table 4: IOU Utility Tariffs used based on Climate Zone

Climate Zones	Electric / Gas Utility	Electricity (Standard)	Electricity (Time-of-use)	Natural Gas
1-5, 11-13, 16	PG&E	E1	E-TOU, Option A	G1
6, 8-10, 14, 15	SCE / SoCal Gas	D	TOU-D-T	GR
7	SDG&E	DR	DR-SES	GR

[5] Under NEM rulings by the CPUC (D-16-01-144, 1/28/16), all new PV customers shall be in an approved TOU rate structure. As of March 2016, all new PG&E net energy metering (NEM) customers are enrolled in a time-of-use rate. (http://www.pge.com/en/myhome/saveenergymoney/plans/tou/index.page?).

[6] SCE net surplus compensation rate based on 1-year average September 2015 – August 2016.

[7] SDG&E net surplus compensation rate based on 1-year average August 2015 – July 2016.

Cost effectiveness was evaluated for all sixteen climate zones and is presented according to lifecycle customer benefit-to-cost ratio. The benefit-to-cost ratio is a metric which represents the cost effectiveness of energy efficiency over a 30-year lifetime taking into account discounting of future savings and financing of incremental costs. A value of one indicates the savings over the life of the measure are equivalent to the incremental cost of that measure. A value greater than one represents a positive return on investment. The ratio is calculated as follows:

Equation 1

$$Lifecycle\ Benefit\ Cost\ Ratio = \frac{(Annual\ utility\ cost\ savings\ *\ Lifecycle\ cost\ factor)}{(First\ incremental\ cost\ *\ Financing\ factor)}$$

The lifecycle cost factor is 19.6 and was calculated using Equation 2 as follows. No utility rate escalation is assumed (conservative assumption).

$$\boldsymbol{Lifecycle\ Cost\ Factor = \frac{1-(1+disc)^{-n}}{disc}} \quad \textbf{\textit{Equation 2}}$$

Where:

- n = analysis and financing term of 30-years
- $disc$ = real discount rate of 3%

The financing factor is calculated as follows:

$$\boldsymbol{Financing\ Factor = \frac{PV_{Mortgage\ Increase} - PV_{Tax\ Savings}}{L}} \quad \textbf{\textit{Equation 3}}$$

Where:

- L = first incremental cost ($)
- $PV_{Mortgage\ Increase}$ = Present value of increased mortgage costs
- $PV_{Tax\ Savings}$ = Present value of tax savings from additional interest payments due to increased mortgage

$PV_{Mortgage\ Increase}$ is calculated using Equations 4 and 5.

$$\boldsymbol{P = L\frac{\left[\frac{c}{12} * \left(1+\frac{c}{12}\right)^{n*12}\right]}{\left[\left(1+\frac{c}{12}\right)^{n*12} - 1\right]}} \quad \textbf{\textit{Equation 4}}$$

$$\boldsymbol{PV_{Mortgage\ Increase} = P * 12\,\frac{1-(1+disc)^{-n}}{disc}} \quad \textbf{\textit{Equation 5}}$$

Where:

- P = incremental monthly mortgage payment ($)
- c = loan interest rate of 4.5%

$PV_{Tax\ Savings}$ is calculated using Equations 6 and 7.

$$\boldsymbol{Annual\ Tax\ Savings = balance * c * taxrate} \qquad \textbf{\textit{Equation 6}}$$

$$\boldsymbol{PV_{Tax\ Savings} = \sum_{n=1}^{30} Annual\ Tax\ Savings * \frac{1}{(1+disc)^n}} \qquad \textbf{\textit{Equation 7}}$$

Where:

- *taxrate* = average tax rate of 20% (to account for tax savings due to loan interest deductions)
- *balance* = balance of incremental cost of mortgage at beginning of each year

The financing factor based on the above assumptions was 1.068 for this study.

Simple payback is also presented and is calculated using the equation below. Based on the terms described above the lifecycle cost-to-benefit ratio threshold of one is roughly equivalent to a simple payback of 18 years. Maintenance costs were not included because there are no incremental maintenance costs expected for any of these measures. There is no assumed maintenance on the envelope measures and for HVAC and DHW measures there should not be any additional maintenance cost for a more efficient version of the same system type as the baseline. Replacement costs for inverters were included for PV systems.

Simple payback = First incremental cost / Annual customer utility cost savings ***Equation 8***

2.6 Greenhouse Gas Emissions

Equivalent CO_2 emission savings were calculated using the following emission factors. Electricity factors are specific to California electricity production.

Table 5: Equivalent CO_2 Emissions Factors

		Source
Electricity	0.724 lb. CO_2-e / kWh	U.S. Environmental Protection agency's 2007 eGRID data.[8]
Natural Gas	11.7 lb. CO_2-e / Therm	Emission rates for natural gas combustion as reported by the U.S. Environmental Protection agency's GHG Equivalencies Calculator.[9]

[8] https://www.epa.gov/energy/ghg-equivalencies-calculator-calculations-and-references

[9] https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

3 Results

Cost effective analysis including evaluating three efficiency packages and two PV performance packages was completed for all sixteen climate zones. Evaluations looked to identify cost effective Tier 1 and Tier 2 packages for both single family and multifamily prototypes at the CALGreen performance targets of 15% and 30%. When initial proposed packages were found to not be cost effective, multiple iterations were conducted to identify a cost effective package. In certain climates it was not feasible, and targets were subsequently relaxed to something more appropriate. In other climates no cost effective package could be identified. In almost every climate there was no cost effective way to achieve Tier 2 efficiency levels without the PV compliance credit, therefore all Tier 2 packages include PV. Because the PVCC is not available in climate zones 6 and 7, no Tier 2 packages were developed for those climates.

Since the results from this analysis are intended to support mandatory energy efficiency requirements, the authors intentionally selected proven cost-effective measures with wide market acceptance in typical residential construction. Achieving greater performance is feasible using advanced design strategies and measures.

3.1 Single Family Results

3.1.1 Single Family Cost Effectiveness Analysis

A comparison of cost effectiveness for each climate zone and five cases is presented in Figure 1. Table 6 and Table 7 provide the results in tabular form along with energy and greenhouse gas (GHG) savings for each efficiency and PV performance tier. Cost effectiveness results are presented for all three efficiency packages described previously (Envelope, Equipment, and PV Credit) as well as for the two PV performance packages (PV-Plus and TDV-Zero). A summary of measures included in each package is listed in Appendix B.1. The lifecycle benefit-to-cost ratio threshold of one is roughly equivalent to a simple payback of 18 years. Shaded rows in the tables reflect those cases which are not cost effective. While using high efficiency equipment is shown to result in the highest return on investment in many climates, it was necessary to find cost effective packages that do not require specification of equipment with efficiencies better than federally mandated values to avoid federal preemption prohibitions.

Tier 1 Envelope packages were found to be cost effective in climate zones 1 through 5 and 9 through 16. The Tier 1 threshold in climate zone 4 was reduced to 10% to meet the cost effectiveness criteria without installing equipment more efficient than federally mandated. No cost effective Tier 1 efficiency packages were identified in climate zones 6 through 8. Additional solar ready requirements of installing electrical conduit are included in the Tier 1 Envelope packages for climate zones 1 through 3 and 11 through 16 while still remaining cost effective. Adding PV conduit to the Tier 1 packages was not cost effective in the other climate zones.

Table 7 presents results for the two PV performance packages including the PV capacity necessary to offset the specified TDV energy. The PV system capacity for the PV-Plus packages is sized based upon the values in Table 3 to provide approximately 80% of estimated annual kWh consumption. The required TDV-Zero PV capacity (as required to generate a TDV=0 compliance simulation result) ranges from 3.1 kW DC in the mild climates (CZ5 and 7) to 7.7 kW DC in hot climates (CZ15). In all cases the measures in these packages reflect those in the Tier 2 package, with the exception of climate zones 6 & 7 where they are based on the Tier 1 envelope package.

The PV-Plus cases demonstrate cost effectiveness with a benefit-to-cost ratio ranging from 1.06 to 1.55. Adding PV beyond the amount needed to offset electricity use reduces cost effectiveness in all cases. The Zero-TDV cases are cost effective in only four climate zones and benefit-cost ratios are consistently lower in all climates. This is impacted by the fact that the compliance model is based upon a home with natural gas space and water heating, thus when sizing PV to offset total house TDV, PV electricity generation is offsetting natural gas consumption. The customer is paid for excess electricity generation beyond what is consumed by the dwelling but only at the wholesale rate which is substantially lower than the retail rate.

Greenhouse gas (GHG) savings range from 4.1% to 12.7% for the envelope and equipment Tier 1 packages. Including the PV compliance credit increases GHG reductions to 39% on average. GHG reductions for the two PV packages average 50% and 77% for the PV-Plus and TDV-ZERO cases, respectively.

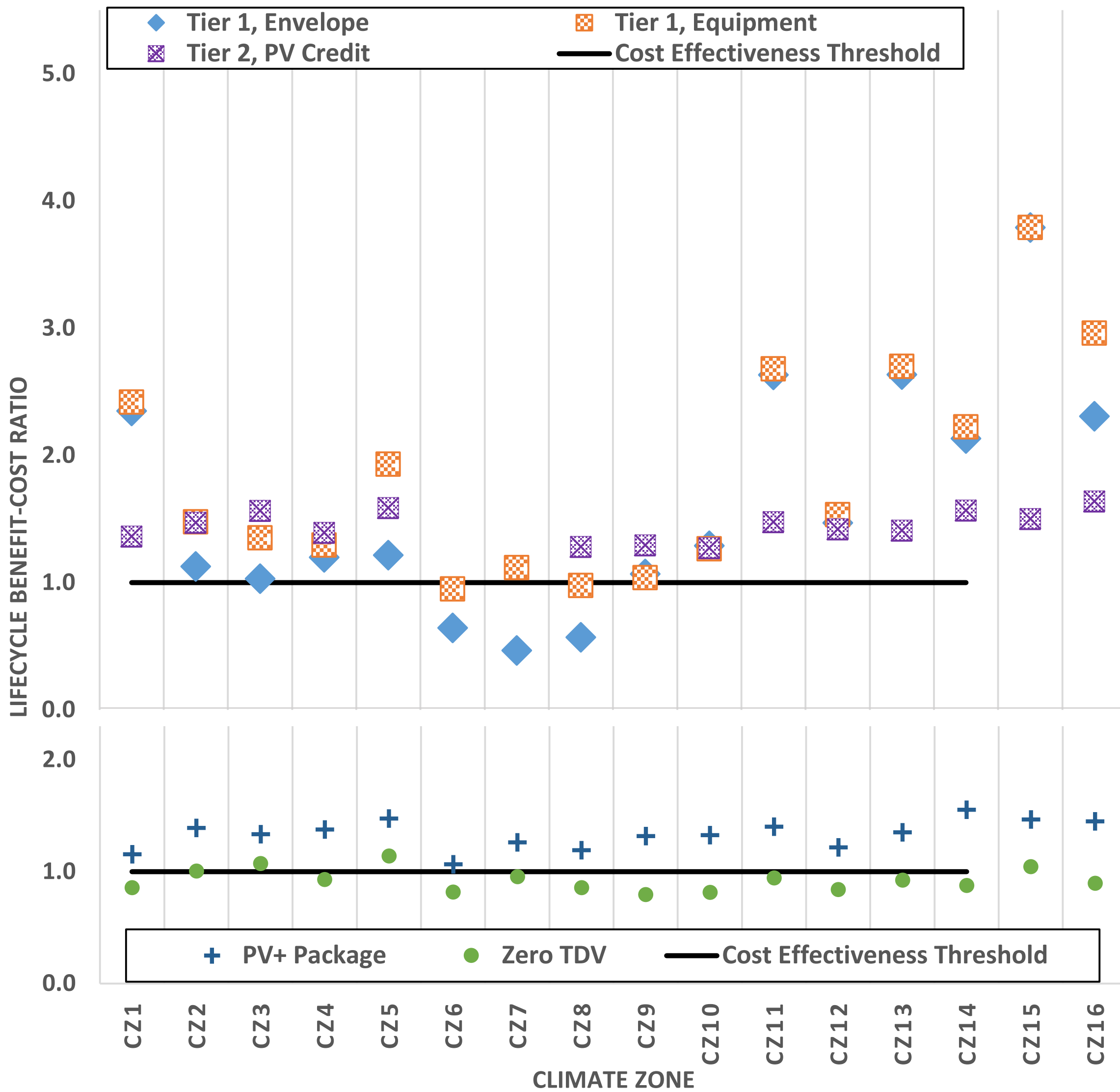

Figure 1: Single family cost effectiveness comparison

Table 6: Single Family Efficiency Package Cost Effectiveness Results[1]

Climate Zone	T-24 Comp. Margin	Elec Savings (kWh)	Gas Savings (therms)	% GHG Savings[2]	Package Cost[3]	Utility Cost Savings	Simple Payback	Lifecycle Benefit-Cost Ratio
Tier 1, Envelope Cases								
CZ1	16.1%	67	83.7	10.7%	$1,138	$146	7.8	2.35
CZ2	15.8%	146	49.1	8.2%	$1,712	$105	16.3	1.13
CZ3	15.5%	32	43.6	7.7%	$1,138	$64	17.8	1.03
CZ4	12.0%	114	18.8	4.1%	$808	$53	15.3	1.20
CZ5	15.2%	27	39.3	7.3%	$812	$54	15.1	1.22
CZ6	8.7%	20	17.1	3.6%	$571	$20	28.4	0.65
CZ7	7.0%	9	9.7	2.3%	$571	$15	39.3	0.47
CZ8	8.9%	37	10.2	2.6%	$571	$18	32.1	0.57
CZ9	17.2%	169	11.1	4.1%	$808	$47	17.2	1.07
CZ10	17.2%	213	12.9	4.7%	$808	$57	14.2	1.29
CZ11	16.9%	460	25.9	7.1%	$1,090	$156	7.0	2.63
CZ12	16.4%	222	24.2	5.4%	$1,090	$87	12.5	1.47
CZ13	17.4%	485	22.1	7.0%	$1,090	$157	7.0	2.64
CZ14	16.4%	441	24.4	6.9%	$1,090	$127	8.6	2.13
CZ15	15.2%	896	4.7	8.1%	$1,010	$209	4.8	3.79
CZ16	15.8%	296	80.4	9.8%	$1,551	$195	8.0	2.31
Tier 1, Equipment Cases								
CZ1	19.3%	47	101.7	12.7%	$1,281	$169	7.6	2.42
CZ2	16.8%	34	67.0	9.7%	$1,281	$103	12.4	1.48
CZ3	15.3%	23	45.4	8.0%	$853	$63	13.6	1.35
CZ4	17.0%	103	45.4	8.3%	$1,156	$82	14.2	1.30
CZ5	16.9%	22	46.0	8.4%	$571	$60	9.5	1.93
CZ6	15.5%	20	36.2	7.3%	$732	$38	19.3	0.95
CZ7	15.6%	9	25.7	5.8%	$571	$35	16.4	1.12
CZ8	17.4%	68	25.1	6.0%	$728	$39	18.8	0.98
CZ9	16.9%	159	12.2	4.2%	$813	$46	17.6	1.04
CZ10	16.6%	203	14.2	4.9%	$813	$56	14.5	1.26
CZ11	17.3%	473	26.0	7.2%	$1,096	$160	6.9	2.68
CZ12	16.0%	247	22.7	5.4%	$1,096	$92	12.0	1.54
CZ13	17.9%	507	21.5	7.1%	$1,096	$161	6.8	2.70
CZ14	17.1%	458	26.4	7.3%	$1,096	$133	8.2	2.23
CZ15	15.2%	896	4.7	8.1%	$1,010	$209	4.8	3.79
CZ16	17.6%	58	123.7	12.6%	$1,281	$207	6.2	2.96

Climate Zone	T-24 Comp. Margin	Elec Savings (kWh)	Gas Savings (therms)	% GHG Savings[2]	Package Cost[3]	Utility Cost Savings	Simple Payback	Lifecycle Benefit-Cost Ratio
Tier 2, Cases with PV Credit								
CZ1	32.2%	2,947	111.8	35.7%	$10,497	$781	13.4	1.37
CZ2	31.4%	3,227	132.7	46.9%	$10,079	$809	12.5	1.47
CZ3	21.8%	3,190	40.1	40.3%	$8,559	$731	11.7	1.57
CZ4	30.4%	3,353	21.8	36.6%	$8,908	$677	13.2	1.39
CZ5	22.0%	3,392	35.6	43.7%	$8,515	$737	11.6	1.59
CZ6	N/A - No PV Credit							
CZ7	N/A - No PV Credit							
CZ8	36.4%	3,290	10.2	44.0%	$8,828	$617	14.3	1.28
CZ9	35.0%	3,333	13.2	41.5%	$8,435	$595	14.2	1.29
CZ10	32.2%	3,517	15.4	42.3%	$8,828	$612	14.4	1.27
CZ11	31.2%	3,698	35.8	34.7%	$9,345	$752	12.4	1.48
CZ12	32.4%	3,386	27.9	33.8%	$8,828	$684	12.9	1.42
CZ13	31.3%	3,584	25.4	33.2%	$9,301	$715	13.0	1.41
CZ14	30.9%	4,366	26.4	39.4%	$9,378	$801	11.7	1.57
CZ15	32.2%	4,610	4.7	39.0%	$9,378	$767	12.2	1.50
CZ16	31.5%	3,881	80.4	31.8%	$9,526	$852	11.2	1.64

[1] Shaded rows reflect those cases which are not cost effective.

[2] Based on CA electricity production and equivalent CO_2 emission rates of 0.724 lbCO_2e / kWh & 11.7 lb-CO_2e / therm.

[3] Includes 10% markup for builder profit and overhead.

Table 7: Single Family PV Performance Package Cost Effectiveness Results[1]

Climate Zone	Compliance Margin	PV Capacity (kW)	Elec Savings (kWh)	Gas Savings (therms)	GHG % Savings[2]	Package Cost[3]	Utility Cost Savings	Simple Payback	Lifecycle Benefit-Cost Ratio
PV-Plus Package									
CZ1	32.2%	3.0	4,178	111.8	45.0%	$14,114	$889	15.9	1.16
CZ2	31.4%	2.5	3,798	132.7	51.9%	$11,514	$872	13.2	1.39
CZ3	21.8%	2.6	4,082	40.1	49.7%	$10,780	$784	13.8	1.33
CZ4	30.4%	2.3	3,619	21.8	39.2%	$9,557	$716	13.3	1.38
CZ5	22.0%	2.3	3,838	35.6	48.6%	$9,557	$768	12.4	1.48
CZ6	10.8%	2.5	3,912	17.1	48.9%	$10,420	$604	17.2	1.06
CZ7	10.6%	2.2	3,556	9.7	51.5%	$9,526	$655	14.5	1.26
CZ8	36.4%	2.6	4,026	10.2	53.4%	$10,656	$691	15.4	1.19
CZ9	35.0%	2.5	4,092	13.2	50.3%	$10,263	$737	13.9	1.32
CZ10	32.2%	2.5	4,202	15.4	50.0%	$10,479	$757	13.8	1.33
CZ11	31.2%	3.5	5,728	35.8	51.1%	$14,359	$1,097	13.1	1.40
CZ12	32.4%	2.9	4,673	27.9	45.2%	$12,052	$799	15.1	1.22
CZ13	31.3%	3.7	5,863	25.4	52.1%	$15,101	$1,111	13.6	1.35
CZ14	30.9%	2.5	4,941	26.4	44.1%	$10,636	$900	11.8	1.55
CZ15	32.2%	4.6	8,600	4.7	72.2%	$18,755	$1,497	12.5	1.46
CZ16	31.5%	2.5	4,501	80.4	35.6%	$10,961	$866	12.7	1.45
Zero-TDV Package									
CZ1	32.2%	4.8	6,560	111.8	62.9%	$21,113	$987	21.4	0.86
CZ2	31.4%	4.0	6,200	132.7	72.9%	$17,550	$960	18.3	1.00
CZ3	21.8%	3.5	5,557	40.1	65.2%	$14,457	$845	17.1	1.07
CZ4	30.4%	3.9	6,252	21.8	65.3%	$15,986	$808	19.8	0.93
CZ5	22.0%	3.2	5,411	35.6	65.9%	$13,233	$821	16.1	1.14
CZ6	10.8%	3.5	5,530	17.1	68.3%	$14,450	$644	22.4	0.82
CZ7	10.6%	3.1	5,083	9.7	72.4%	$13,192	$686	19.2	0.95
CZ8	36.4%	3.7	5,821	10.2	76.3%	$15,119	$705	21.4	0.86
CZ9	35.0%	4.3	7,090	13.2	85.4%	$17,478	$756	23.1	0.79
CZ10	32.2%	4.3	7,103	15.4	82.5%	$17,478	$776	22.5	0.81
CZ11	31.2%	6.1	9,908	35.8	85.0%	$24,680	$1,269	19.4	0.94
CZ12	32.4%	5.1	8,094	27.9	75.4%	$20,624	$944	21.9	0.84
CZ13	31.3%	6.4	10,075	25.4	87.1%	$25,815	$1,299	19.9	0.92
CZ14	30.9%	5.5	10,295	26.4	88.0%	$22,353	$1,068	20.9	0.88
CZ15	32.2%	7.7	13,811	4.7	115.5%	$31,003	$1,762	17.6	1.04
CZ16	31.5%	5.2	9,147	80.4	64.2%	$21,715	$1,061	20.5	0.90

[1] Shaded rows reflect those cases which are not cost effective.
[2] Based on CA electricity production and equivalent CO_2 emission rates of 0.724 lbCO_2e / kWh & 11.7 lb-CO_2e / therm.
[3] Includes 10% markup for builder profit and overhead.

3.1.2 Single Family Package Recommendations

Based on the single family cost effective analysis, two reach code packages were developed, an efficiency package and a PV package as described below. Table 8 and Table 9 summarize the measures used to cost effectively meet the performance targets for each package.

Tier 1 Efficiency only: Where cost effective packages were identified, the 15% compliance margin target, consistent with CALGreen Tier 1 were used. As stated earlier, a cost effective 15% package was not identified for climate zone 4, so a 10% compliance margin target was used. No cost effective efficiency only packages were identified for climate zones 6 through 8.

Table 8: Single Family Efficiency Only: Cost Effective Measures Summary

Climate Zone	Compliance Margin Target	QII	ACH50	Window U-value / SHGC	Door U-value	AH Fan W/cfm	HW Pipe Insul.	Solar Ready
CZ1	15%	Y		.30/.50	0.20		Y	Y
CZ2	15%	Y	3	.30/.23	0.20	0.30	Y	Y
CZ3	15%	Y		.30/.50	0.20		Y	Y
CZ4	10%	Y		.30/.23		0.30		
CZ5	15%	Y		.30/.50			Y	
CZ6	No package							
CZ7	No package							
CZ8	No package							
CZ9	15%	Y		.30/.23		0.30		
CZ10	15%	Y		.30/.23		0.30		
CZ11	15%	Y		.30/.23		0.30		Y
CZ12	15%	Y		.30/.23		0.30		Y
CZ13	15%	Y		.30/.23		0.30		Y
CZ14	15%	Y		.30/.23		0.30		Y
CZ15	15%	Y				0.30		Y
CZ16	15%	Y	3	.30/.23	0.20	0.30		Y

PV-Plus: Cost effective packages with efficiency and PV were identified in all 16 climate zones, but the compliance margin targets were lowered to 20% for climates 3 and 5, and to 10% for 6 and 7. Table 9 summarizes the measures used in each climate zone to cost effectively meet the targets. It is assumed that the PV compliance credit can be used to meet all these targets, except in climate zones 6 and 7. It is also assumed that a PV system is installed per the methodology described in Table 3 and consistent with the CEC Solar PV Ordinance.

Table 9: Single Family PV-Plus: Cost Effective Measures Summary

Climate Zone	Compliance Margin Target	QII	ACH50	Window U-value / SHGC	Door U-value	HPA	AH Fan W/cfm	HW Pipe Insul.	PV Capacity (kW)
CZ1	30%	Y	3	.30/.50	0.20	Y		Y	3.0
CZ2	30%	Y		.30/.50	0.20	Y		Y	2.5
CZ3	20%	Y		.30/.50	0.20				2.6
CZ4	30%	Y		.30/.23					2.3
CZ5	20%	Y		.30/.50					2.3
CZ6	10%	Y					0.30		2.5
CZ7	10%	Y		.30/.23	0.20		0.30	Y	2.2
CZ8	30%	Y							2.6
CZ9	30%	Y							2.5
CZ10	30%	Y							2.5
CZ11	30%	Y		.30/.23	0.20				3.5
CZ12	30%	Y							2.9
CZ13	30%	Y		.30/.23					3.7
CZ14	30%	Y					0.30		2.5
CZ15	30%	Y					0.30		4.6
CZ16	30%	Y	3	.30/.23	0.20		0.30		2.5

3.2 Multifamily Results

It is generally more challenging to achieve equivalent savings targets for the multifamily cases than for the single family cases. With less exterior surface area per floor area the impact of envelope measures is diminished in multifamily buildings. The PV credit is also much smaller because it is offsetting only high performance walls; high performance attic is not applied to the multifamily prescriptive design because ducts are already assumed to be within conditioned space. Shaded rows in the tables below indicate cases that don't meet the 15% target for Tier 1 or don't have feasible Tier 2 packages.

3.2.1 Multifamily Cost Effectiveness Analysis

A comparison of cost effectiveness for the multi-family prototype is presented in Figure 2. Table 10 and Table 11 provide the results in tabular form, along with energy and greenhouse gas savings for the efficiency and PV performance tiers, respectively. *All multifamily results are presented on a per dwelling unit basis.* Cost effectiveness results are presented for all of the three efficiency packages described previously (envelope, equipment, and PV compliance credit) as well as for the two PV performance packages (PV-Plus and TDV-Zero). A summary of measures included in each package is listed in Appendix B.2. The lifecycle benefit-to-cost ratio threshold of one is roughly equivalent to a simple payback of 18 years. Shaded rows in the tables reflect those cases which aren't cost effective. While using high efficiency equipment is shown to result in an improved return on investment in many climates, it was necessary to find cost effective packages that do not require specification of equipment with efficiencies better than federally mandated values. It can be noted that since rental rates are determined primarily by location, tenants may not experience increased rents due to the cost of efficiency measures. If this is the case, the tenants have no costs and only the benefit of lower energy utility costs.

Tier 1, Envelope packages were found to be cost effective in climate zones 1, and 10 through 16, although the threshold for climate zone 10 was lowered to 10% to meet the cost effectiveness criteria. QII alone was found to be cost effective in climate zone 2 but a cost effective 10% package requires using the PV compliance credit. No cost effective Tier 1, Envelope efficiency packages were identified in climate zones 3 through 9 without the addition of high efficiency equipment or PV.

Table 11 summarizes the cost effectiveness of the PV performance packages. PV capacity required to meet the required TDV energy offset for each case is also included. The PV capacity for the PV-Plus packages are sized the same as for the single family analysis and based upon the values in Table 3. The required TDV-Zero PV capacity per apartment ranges from 1.9 kW DC in the mild climates to 3.7 kW DC in hot climates (CZ15). For the multifamily prototype 8-unit apartment building, this is equivalent to 15.2 to 29.6 kW for the building. In all cases the measures in these packages reflect those in the Tier 2 package, with the exception of climate zones 6 & 7 where they are based on the Tier 1 envelope package.

The PV-Plus cases demonstrate cost effectiveness with a benefit-to-cost ratio ranging from 1.02 to 1. 68. Similar to the single family analysis, while PV is cost effective in offsetting electricity use, adding PV to meet a zero TDV design reduces cost effectiveness in all cases with only two climates having a value greater than 1.

Greenhouse gas (GHG) savings range from 2.2% to 8.6% for the envelope and equipment Tier 1 packages. Including the PV compliance credit increases GHG reductions to 34% on average. GHG reductions for the two PV packages average 49% and 78% for the PV-Plus and ZN-TDV cases, respectively.

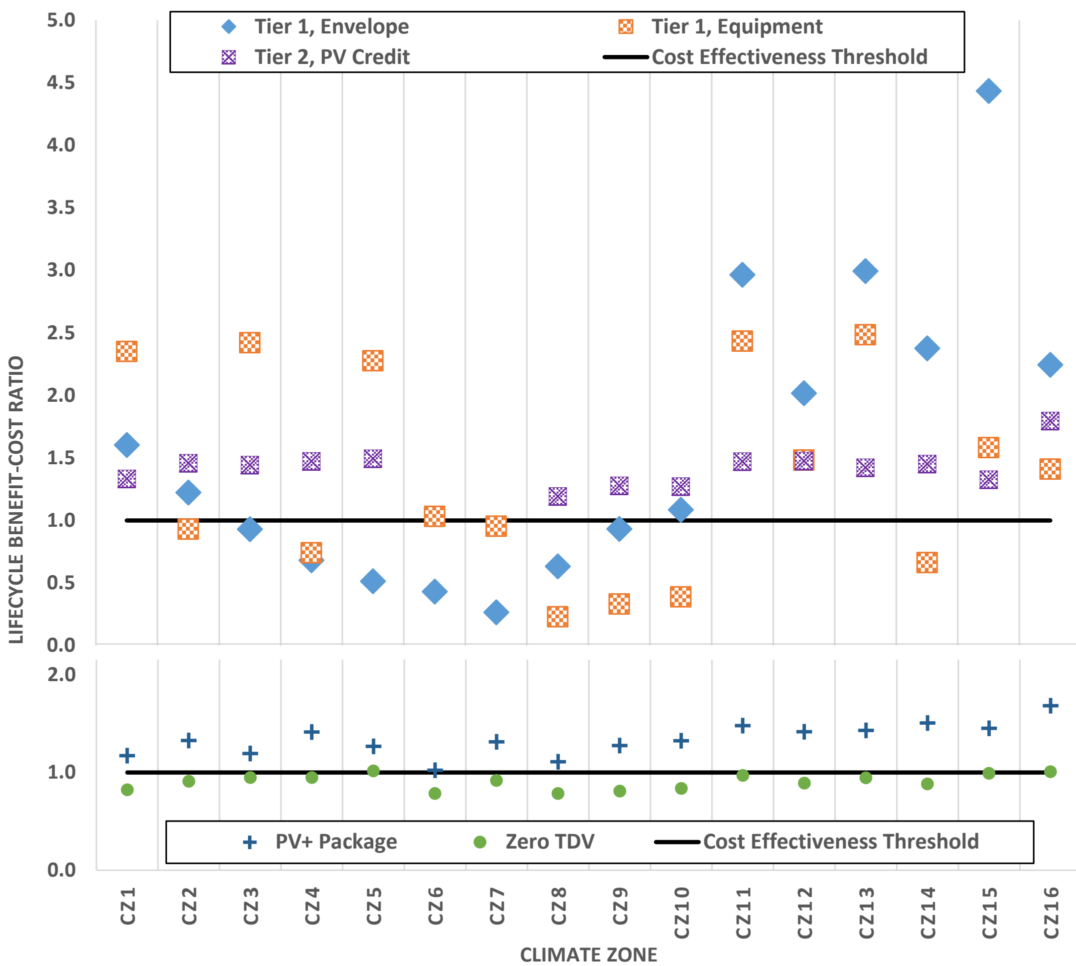

Figure 2: Multifamily cost effectiveness comparison

Table 10: Multifamily Efficiency Cost Effectiveness Results[1]

Climate Zone	T-24 Comp. Margin	Elec Savings (kWh)	Gas Savings (therms)	% GHG Savings[2]	Package Cost[3]	Utility Cost Savings	Simple Payback	Lifecycle Benefit-Cost Ratio
Tier 1, Envelope Cases								
CZ1	16.5%	31	28.0	8.0%	$427	$37	11.5	1.60
CZ2	4.8%	7	7.3	2.2%	$146	$10	15.0	1.22
CZ3	10.9%	-3	14.3	4.5%	$312	$16	19.8	0.93
CZ4	10.9%	45	4.6	2.3%	$364	$14	26.9	0.68
CZ5	10.2%	-4	13.3	4.2%	$509	$14	35.8	0.51
CZ6	11.7%	19	7.7	3.0%	$427	$10	42.6	0.43
CZ7	10.2%	10	4.3	1.7%	$509	$7	69.3	0.26
CZ8	10.5%	55	1.2	1.5%	$282	$10	29.0	0.63
CZ9	12.3%	79	2.0	2.2%	$282	$14	19.7	0.93
CZ10	10.1%	92	2.5	2.6%	$282	$17	16.9	1.08
CZ11	17.7%	186	13.2	6.5%	$304	$49	6.2	2.96
CZ12	17.1%	103	12.6	5.4%	$304	$33	9.1	2.02
CZ13	18.1%	200	11.3	6.3%	$304	$50	6.1	2.99
CZ14	17.8%	176	12.9	6.3%	$304	$39	7.7	2.38
CZ15	17.7%	426	0.6	6.8%	$304	$73	4.1	4.43
CZ16	16.3%	91	29.9	8.0%	$427	$52	8.2	2.24
Tier 1, Equipment Cases								
CZ1	16.7%	8	31.7	8.6%	$290	$37	7.8	2.35
CZ2	15.0%	7	27.3	8.0%	$642	$32	19.8	0.93
CZ3	12.4%	1	16.9	5.4%	$146	$19	7.6	2.42
CZ4	16.3%	11	25.5	8.0%	$765	$31	24.8	0.74
CZ5	11.8%	-3	16.6	5.3%	$146	$18	8.1	2.28
CZ6	12.1%	1	16.4	5.6%	$269	$15	17.8	1.03
CZ7	12.5%	-1	15.9	5.5%	$379	$20	19.3	0.95
CZ8	15.2%	83	1.2	2.1%	$1,133	$14	80.4	0.23
CZ9	15.7%	106	2.0	2.8%	$1,029	$19	55.4	0.33
CZ10	15.5%	124	2.5	3.2%	$1,029	$22	47.2	0.39
CZ11	16.5%	202	6.3	5.0%	$333	$44	7.5	2.43
CZ12	15.0%	109	6.1	3.6%	$333	$27	12.4	1.48
CZ13	15.4%	199	5.1	4.6%	$311	$42	7.4	2.48
CZ14	16.5%	201	6.1	4.9%	$1,029	$37	27.7	0.66
CZ15	20.4%	515	0.4	8.2%	$1,029	$89	11.6	1.58
CZ16	15.7%	86	29.8	7.9%	$668	$51	13.0	1.41

Climate Zone	T-24 Comp. Margin	Elec Savings (kWh)	Gas Savings (therms)	% GHG Savings[2]	Package Cost[3]	Utility Cost Savings	Simple Payback	Lifecycle Benefit-Cost Ratio
Tier 2, Cases with PV Credit								
CZ1	21.0%	1,370	28.0	30.2%	$4,004	$291	13.8	1.33
CZ2	20.4%	1,608	17.2	33.7%	$4,004	$318	12.6	1.46
CZ3	15.3%	1,585	14.1	35.7%	$4,004	$315	12.7	1.44
CZ4	26.9%	1,654	13.6	35.6%	$4,004	$321	12.5	1.47
CZ5	12.4%	1,677	13.3	37.7%	$4,004	$326	12.3	1.49
CZ6	N/A - No PV credit							
CZ7	N/A - No PV credit							
CZ8	21.0%	1,622	5.7	35.3%	$4,004	$260	15.4	1.19
CZ9	26.8%	1,719	4.0	35.4%	$3,882	$270	14.4	1.28
CZ10	26.2%	1,734	4.9	35.2%	$3,882	$269	14.4	1.27
CZ11	26.5%	1,778	13.2	32.6%	$3,882	$311	12.5	1.47
CZ12	26.5%	1,673	12.6	32.8%	$3,882	$312	12.4	1.47
CZ13	27.3%	1,746	11.3	31.8%	$3,882	$301	12.9	1.42
CZ14	26.0%	1,973	12.9	36.0%	$3,882	$307	12.7	1.45
CZ15	25.4%	2,100	0.6	33.0%	$3,882	$281	13.8	1.33
CZ16	25.7%	1,734	42.4	33.8%	$3,767	$369	10.2	1.80

[1] Shaded rows reflect those cases which are not cost effective.
[2] Based on CA electricity production and equivalent CO_2 emission rates of 0.724 lbCO_2e / kWh & 11.7 lb-CO_2e / therm.
[3] Includes 10% markup for builder profit and overhead.

***Table 11: Multifamily PV Performance Cost Effectiveness Results*[1]**

Climate Zone	Compliance Margin	PV Capacity (kW)	Elec Savings (kWh)	Gas Savings (therms)	GHG % Savings[2]	Package Cost[3]	Utility Cost Savings	Simple Payback	Lifecycle Benefit-Cost Ratio
PV-Plus Package									
CZ1	21.0%	1.6	2,172	28.0	43.5%	$6,151	$393	15.7	1.17
CZ2	20.4%	1.4	2,234	17.2	44.9%	$5,436	$393	13.8	1.33
CZ3	15.3%	1.5	2,374	14.1	51.2%	$5,793	$377	15.4	1.19
CZ4	26.9%	1.3	2,137	13.6	44.8%	$5,078	$391	13.0	1.41
CZ5	12.4%	1.4	2,350	13.3	51.1%	$5,436	$375	14.5	1.27
CZ6	11.7%	1.5	2,388	7.7	52.5%	$5,793	$322	18.0	1.02
CZ7	10.2%	1.3	2,139	4.3	48.0%	$5,160	$369	14.0	1.31
CZ8	21.0%	1.5	2,413	5.7	51.6%	$5,793	$350	16.5	1.11
CZ9	26.8%	1.4	2,372	4.0	48.4%	$5,313	$369	14.4	1.27
CZ10	26.2%	1.4	2,386	4.9	47.9%	$5,313	$383	13.9	1.32
CZ11	26.5%	1.7	2,893	13.2	50.8%	$6,386	$514	12.4	1.48
CZ12	26.5%	1.5	2,457	12.6	46.5%	$5,671	$437	13.0	1.42
CZ13	27.3%	1.8	2,982	11.3	52.2%	$6,744	$525	12.8	1.43
CZ14	26.0%	1.3	2,512	12.9	44.9%	$4,955	$406	12.2	1.51
CZ15	25.4%	2.1	3,940	0.6	61.8%	$7,817	$618	12.6	1.45
CZ16	25.7%	1.3	2,244	42.4	40.9%	$4,841	$444	10.9	1.68
Zero-TDV Package									
CZ1	21.0%	2.5	3,415	28.0	64.2%	$9,473	$424	22.3	0.82
CZ2	20.4%	2.3	3,674	17.2	70.7%	$8,728	$433	20.2	0.91
CZ3	15.3%	2.0	3,233	14.1	68.1%	$7,740	$400	19.4	0.95
CZ4	26.9%	2.2	3,587	13.6	72.4%	$8,300	$429	19.4	0.95
CZ5	12.4%	1.9	3,189	13.3	67.8%	$7,219	$399	18.1	1.02
CZ6	11.7%	2.1	3,356	8.0	72.7%	$7,987	$341	23.4	0.78
CZ7	10.2%	2.1	3,383	4.0	75.0%	$7,877	$394	20.0	0.92
CZ8	21.0%	2.4	3,768	5.7	79.6%	$8,858	$379	23.4	0.78
CZ9	26.8%	2.5	4,124	4.0	83.1%	$9,148	$403	22.7	0.81
CZ10	26.2%	2.5	4,115	4.9	81.5%	$9,109	$415	22.0	0.84
CZ11	26.5%	3.0	4,979	13.2	84.9%	$11,074	$586	18.9	0.97
CZ12	26.5%	2.8	4,509	12.6	82.3%	$10,347	$503	20.6	0.89
CZ13	27.3%	3.2	5,129	11.3	87.6%	$11,712	$603	19.4	0.94
CZ14	26.0%	2.7	5,056	12.9	86.8%	$10,021	$482	20.8	0.88
CZ15	25.4%	3.7	6,571	0.6	102.9%	$13,444	$726	18.5	0.99
CZ16	25.7%	2.6	4,398	42.4	71.0%	$9,378	$514	18.2	1.01

[1] Shaded rows reflect those cases which are not cost effective.

[2] Based on CA electricity production and equivalent CO_2 emission rates of 0.724 lbCO$_2$e / kWh & 11.7 lb-CO$_2$e / therm.

[3] Includes 10% markup for builder profit and overhead.

3.2.2 Multifamily Package Recommendations

Based on the multifamily cost effective analysis, two reach code packages were developed, similar to the single family packages. Table 12 and Table 13 summarize the measures used to cost effectively meet the performance targets for each multifamily package.

Tier 1 Efficiency only: Where cost effective packages were identified, the 15% compliance margin target, consistent with CALGreen Tier 1 were used. As stated earlier, a cost effective 15% package was not identified for climate zone 10, so a 10% compliance margin target was used, and only QII was cost effective in climate zone 2. Additionally, no cost effective efficiency only packages were identified for climate zones 3 through 9.

Table 12: Multifamily Efficiency Only: Cost Effective Measures Summary

Climate Zone	Compliance Margin Target	QII	Window U-value / SHGC	Door U-value	AH Fan W/cfm	Refrigerant Charge	HW Comp. Dist.
CZ1	15%	Y	0.30/0.50	0.20	0.3		Y
CZ2	QII Only	Y					
CZ3	No package						
CZ4	No package						
CZ5	No package						
CZ6	No package						
CZ7	No package						
CZ8	No package						
CZ9	No package						
CZ10	10%	Y	0.30/0.23		0.3		
CZ11	15%	Y	0.30/0.23	0.20	0.3		
CZ12	15%	Y	0.30/0.23	0.20	0.3		
CZ13	15%	Y	0.30/0.23	0.20	0.3		
CZ14	15%	Y	0.30/0.23	0.20	0.3		
CZ15	15%	Y	0.30/0.23	0.20	0.3		
CZ16	15%	Y	0.30/0.23	0.20	0.3		Y

PV-Plus: Cost effective packages with efficiency and PV were identified in all 16 climate zones, but the compliance margin targets in all climates were lowered below 30% in all cases to be cost effective. Table 13 summarizes the compliance margin targets in each climate zone and the measures used to cost effectively meet the targets. As with the single family packages, with the exception of climate zones 6 and 7, it is assumed that the PV compliance credit can be used to meet these targets. It is also assumed that a PV system is installed per the methodology developed for the proposed Solar PV ordinance (Table 3).

Table 13: Multifamily PV-Plus: Cost Effective Measures Summary

Climate Zone	Compliance Margin Target	QII	Window U-value / SHGC	Door U-value	AH Fan W/cfm	HW Comp. Dist.	PV Capacity (kW)
CZ1	20%	Y	0.30/0.50	0.20	0.3	Y	1.6
CZ2	20%	Y	0.30/0.23	0.20	0.3	Y	1.4
CZ3	15%	Y	0.30/0.50	0.20	0.3	Y	1.5
CZ4	25%	Y	0.30/0.23	0.20	0.3	Y	1.3
CZ5	10%	Y	0.30/0.50	0.20	0.3	Y	1.4
CZ6	10%	Y	0.30/0.23	0.20			1.5
CZ7	10%	Y	0.30/0.23	0.20			1.3
CZ8	20%	Y	0.30/0.23	0.20	0.3	Y	1.5
CZ9	25%	Y	0.30/0.23	0.20	0.3		1.4
CZ10	25%	Y	0.30/0.23	0.20	0.3		1.4
CZ11	25%	Y	0.30/0.23	0.20	0.3		1.7
CZ12	25%	Y	0.30/0.23	0.20	0.3		1.5
CZ13	25%	Y	0.30/0.23	0.20	0.3		1.8
CZ14	25%	Y	0.30/0.23	0.20	0.3		1.3
CZ15	25%	Y	0.30/0.23	0.20	0.3		2.1
CZ16	25%	Y	0.30/0.23	0.20			1.3

4 Conclusions & Summary

This report evaluated the feasibility and cost effectiveness of "above code" ordinance performance tiers through the application of both efficiency measures and PV in all 16 California climates zones. For this analysis, PG&E rates were used for gas and electricity in climate zones 1 through 5, 11 through 13, and 16. SCE electricity rates and Southern California Gas rates were used for climate zones 6, 8 through 10, 14 and 15. SDG&E rates were used for electricity and gas for climate zone 7.

The following describes the recommended performance levels for the above-code ordinance packages. The original intent was to develop packages that align with the tiers as defined in the 2016 CALGreen code. Based on the analysis results, performance thresholds were reduced in some climates and eliminated altogether in other climates. Identifying cost effective efficiency (only) packages was particularly challenging in multifamily buildings. Table 14 and Table 15 summarize recommended cost effective ordinance criteria by climate zone for single family and multifamily buildings, respectively. Where cost effective packages exist, there is both a Tier 1 efficiency only package and the efficiency with PV (PV-Plus) package. The tables include the Title 24 compliance target needed to meet the criteria for each package. Tier 1 compliance targets are compliance margins for efficiency measures only and are designed to be met without using the PV Compliance Credit. The PV-Plus compliance targets are for projects that include PV. The efficiency targets are set higher, but assume that the PV compliance credit (PVCC) is used to meet the performance targets. The efficiency targets are set lower for climate zones 6 and 7 because projects built in these climate zones are not eligible to take the PVCC.

Following is a summary of the differences between the two packages defined in this analysis and the tiers defined in CALGreen.

Tier 1 Packages: CALGreen defines Tier 1 as showing a 15% or greater Title 24 compliance margin compared to the Standard Design. The intent of the Efficiency tier in this study was to find cost effective packages of measures that meet the CALGreen Tier 1 criteria without mandating the installation of PV or high efficiency equipment that exceed federal minimum levels. To encourage adoption of efficiency measures in preparation for the 2019 Title-24 code, the authors recommend that PV not be allowed as a means to meet the Tier 1 compliance requirements. Based on the lifecycle benefit-to-cost ratio metric applied in this analysis, cost effectiveness results for the single family and low-rise multifamily homes show that there exist multiple cost effective packages to meet Tier 1. There are several climates where the compliance margin targets are lowered to maintain the cost effectiveness criteria and other climates where no cost effective efficiency packages were identified. To facilitate future PV installations in single family, solar ready requirements beyond those in the Title-24 code have been included where cost effective.

PV-Plus Packages: CALGreen defines both Tier 2 and ZNE Tier performance levels. The ZNE Tier requires that the building meet the required efficiency targets as defined in Section A4.203.1.2.3 of 2016 CALGreen and size a PV system to offset 100% of the TDV energy of the building (achieve an Energy Design Rating of 0). The results of this work, based on dwellings with gas and electricity, found that sizing the PV system to meet the ZNE Tier criteria was generally not cost effective or in some limited cases, marginally cost effective. Instead a PV and efficiency package (PV-Plus) was developed that limited the size of the PV system to no larger than the annual estimated electricity use of the building and combine it with efficiency measures that are cost effective in all climate zones. Lifecycle benefit-to-cost ratio for the PV-Plus cases for both the single family and multifamily prototypes are all above one. In cases where PV capacity in the PV-Plus package is less than the minimum to meet the PV compliance credit, it's recommended that jurisdictions allow the smaller PV capacity be installed and still qualify for the PVCC to avoid sizing the PV systems larger than the estimated electricity use.

Table 14: Single Family Reach Code Package Recommendations

Packages	Climate Zones	T-24 Compliance Target	QII	PVCC Allowed	PV	Solar Ready
Tier 1 Efficiency Only Package	1-3, 11-16	15%	Yes	No	n/a	Yes
	5, 9-10	15%	Yes	No	n/a	No
	4	10%	Yes	No	n/a	No
PV-Plus Package	1,2,4, 8-16	30%	Yes	Yes	Yes	n/a
	3,5	20%	Yes	Yes	Yes	n/a
	6-7	10%	Yes	n/a	Yes	n/a

Table 15: Multifamily Reach Code Package Recommendations

Packages	Climate Zones	T-24 Compliance Target	QII	PVCC Allowed	PV
Tier 1 Efficiency Only Package	1, 11-16	15%	Yes	No	n/a
	10	10%	Yes	No	n/a
	2	QII	Yes	No	n/a
PV-Plus Package	4, 9-16	25%	Yes	Yes	Yes
	1-2, 8	20%	Yes	Yes	Yes
	3	15%	Yes	Yes	Yes
	5	10%	Yes	Yes	Yes
	6-7	10%	Yes	n/a	Yes

Consistent with CALGreen, a pre-requisite for all packages includes HERS verification of Quality Insulation Installation (QII).

The recommended packages do not include a TDV-Zero option because these packages were generally not found to be cost effective. Lifecycle benefit-to-cost ratios for the single family TDV-Zero packages are 0.78 to 1.07. Limited cost effectiveness is largely a result of oversizing the PV systems relative to the house electricity load. With mixed fuel homes, PV electricity generation offsets natural gas consumption when sizing relative to zero TDV. The consumer is compensated by the utility for electricity generation in excess of annual consumption, but only at the wholesale rate which is substantially lower than the retail rate. Consideration of dwellings without gas was not in the scope of this study.

This analysis uses a customer-based lifecycle cost (LCC) approach to evaluating cost effectiveness of the proposed ordinance, whereas the CEC LCC methodology uses Time Dependent Valuation (TDV) as the primary metric for energy savings. Both methodologies require estimating and quantifying the energy savings associated with energy efficiency measures, as well as quantifying the costs associated with the measures. The main difference between the methodologies is the manner in which they value energy and thus the cost savings of reduced or avoided energy use. The CEC LCC Methodology uses TDV, which is intended to capture the societal impact of energy savings, while the life cycle customer cost methodology uses utility rate schedules and applies net energy metering rules to estimate cost savings to the customer from onsite PV generation. If evaluated under the CEC's TDV methodology, all of the PV performance packages, including Zero-TDV, would be cost effective.

In conclusion, this report has identified cost effective options to meet above-code performance levels for dwellings using natural gas and electricity which can be adopted by cities and counties within investor-owned utility territories across California. Including PV to the level of offsetting electricity loads was found to be cost effective in all sixteen climate zones evaluated as summarized above.

5 References

CEC. 2016a. 2016 Alternative Calculation Method Approval Manual. CEC-400-2015-039-CMF. June 2015. California Energy Commission. http://www.energy.ca.gov/2015publications/CEC-400-2015-039/CEC-400-2015-039-CMF.pdf

CEC. 2016b. 2016 Building Energy Efficiency Standards for Residential and Nonresidential Buildings. CEC-400-2015-037-CMF. June 2015. California Energy Commission. http://www.energy.ca.gov/2015publications/CEC-400-2015-037/CEC-400-2015-037-CMF.pdf

CEC. 2016c. 2016 Reference Appendices. CEC-400-2015-038-CMF. June 2015. California Energy Commission. http://www.energy.ca.gov/2015publications/CEC-400-2015-038/CEC-400-2015-038-CMF.pdf

CEC. 2016d. 2016 Residential Alternative Calculation Method Reference Manual. CEC-400-2015-024-CMF-REV. June 2017. California Energy Commission. http://www.energy.ca.gov/2015publications/CEC-400-2015-024/CEC-400-2015-024-CMF-REV.pdf

Horii, B., E. Cutter, N. Kapur, J. Arent, and D. Conotyannis. 2014. "Time Dependent Valuation of Energy for Developing Building Energy Efficiency Standards." http://www.energy.ca.gov/title24/2016standards/prerulemaking/documents/2014-07-09_workshop/2017_TDV_Documents/

TRC. 2016. "City of Santa Monica 2016 Building Energy Efficiency Reach Code Cost Effectiveness Study." Prepared for Javier Mariscal, Codes and Standards Program Southern California Edison. November, 16, 2016.

Appendix A – Prescriptive Package

The following presents the residential prescriptive package as printed in the 2016 Building Energy Efficiency Standards (CEC, 2016b).

TABLE 150.1-A COMPONENT PACKAGE-A STANDARD BUILDING DESIGN

						C															
						1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Building Envelope Insulation	**Roofs/ Ceilings**	**Option A (meets §150.1(c)9A)**	Continuous Insulation Above Roof Rafter	Roofing Type	No Air Space[1]	NR	NR	NR	R 8	NR	NR	NR	R 8	R 8	R 8	R 8	R 8	R 8	R 8	R 8	R 8
					With Air Space[2]	NR	NR	NR	R 6	NR	NR	NR	R 6	R 6	R 6	R 6	R 6	R 6	R 6	R 6	R 6
			Ceiling Insulation			R 38	R 38	R 30	R 38	R 30	R 30	R 30	R 38	R 38	R 38	R 38	R 38	R 38	R 38	R 38	R 38
			Radiant Barrier			NR	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	NR
		Option B (meets §150.1(c)9A)	Below Roof Deck Insulation	Roofin g Type	No Air Space	NR	NR	NR	R 18	NR	NR	NR	R 18	R 18	R 18	R 18	R 18	R 18	R 18	R 18	R 18
					With Air	NR	NR	NR	R 13	NR	NR	NR	R 13	R 13	R 13	R 13	R 13	R 13	R 13	R 13	R 13
			Ceiling Insulation			R 38	R 38	R 30	R 38	R 30	R 30	R 30	R 38	R 38	R 38	R 38	R 38	R 38	R 38	R 38	R 38
			Radiant Barrier			NR	REQ	REQ	NR	REQ	REQ	REQ	NR	NR	NR	NR	NR	NR	NR	NR	NR
		Option C (meets	Ceiling Insulation			R 38	R 30	R 30	R 30	R 30	R 30	R 30	R 30	R 30	R 30	R 38	R 38	R 38	R 38	R 38	R 38
			Radiant			NR	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	NR

TABLE 150.1-A COMPONENT PACKAGE-A STANDARD BUILDING DESIGN (CONTINUED)

				Climate Zone															
				1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Building Envelope Insulation	**Walls**	Above Grade	Framed[4]	U 0.051	U 0.051	U 0.051	U 0.051	U 0.051	U 0.065	U 0.065	U 0.051	U 0.051	U 0.051	U 0.051	U 0.051	U 0.051	U 0.051	U 0.051	U 0.051
			Mass Wall Interior[5]	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.059 R 17
			Mass Wall Exterior[6]	U 0.125 R 8.0	U 0.125 R 8.0	U 0.125 R 8.0	U 0.125 R 8.0	U 0.125 R 8.0	U 0.125 R 8.0	U 0.125 R 8.0	U 0.125 R 8.0	U 0.125 R 8.0	U 0.125 R 8.0	U 0.125 R 8.0	U 0.125 R 8.0	U 0.125 R 8.0	U 0.1025 R 8.0	U 0.125 R 8.0	U 0.070 R 13
		Below Grade	Below Grade Interior[7]	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.066 R 15
			Below Grade Exterior	U 0.200 R 5.0	U 0.200 R 5.0	U 0.200 R 5.0	U 0.200 R 5.0	U 0.200 R 5.0	U 0.200 R 5.0	U 0.200 R 5.0	U 0.200 R 5.0	U 0.200 R 5.0	U 0.200 R 5.0	U 0.200 R 5.0	U 0.200 R 5.0	U 0.200 R 5.0	U 0.100 R 10	U 0.100 R 10	U 0.053 R 19
	Floors	Slab Perimeter		NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	U 0.58 R 7.0
		Raised		U 0.037 R 19	U 0.037 R 19	U 0.037 R 19	U 0.037 R 19	U 0.037 R 19	U 0.037 R 19	U 0.037 R 19	U 0.037 R 19	U 0.037 R 19	U 0.037 R 19	U 0.037 R 19	U 0.037 R 19	U 0.037 R 19	U 0.037 R 19	U 0.037 R 19	U 0.037 R 19
		Concrete Raised		U 0.092 R 8.0	U 0.092 R 8.0	U 0.269 R 0	U 0.269 R 0	U0.269 R 0	U 0.269 R 0	U 0.269 R 0	U 0.269 R 0	U 0.269 R 0	U 0.269 R 0	U 0.092 R 8.0	U 0.138 R 4.0	U 0.092 R 8.0	U 0.092 R 8.0	U 0.138 R 4.0	U 0.092 R 8.0
Building Envelope	**Roofing Products**	**Low-sloped**	Aged Solar Reflectance	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0.63	NR	0.63	NR
			Thermal Emittance	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0.75	NR	0.75	NR
		Steep Sloped	Aged Solar Reflectance	NR	NR	NR	NR	NR	NR	NR	NR	NR	0.20	0.20	0.20	0.20	0.20	0.20	NR
			Thermal Emittance	NR	NR	NR	NR	NR	NR	NR	NR	NR	0. 75	0.75	0.75	0.75	0.75	0.75	NR
Building Envelope	**Fenestration**	Maximum U-factor		0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
		Maximum SHGC		NR	0.25	NR	0.25	NR	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
		Maximum Total Area		20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
		Maximum West Facing Area		NR	5%	NR	5%	NR	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%

TABLE 150.1-A COMPONENT PACKAGE-A STANDARD BUILDING DESIGN (CONTINUED)

				Climate Zone															
				1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
HVAC SYSTEM	**Space Heating** [11]	**Electric-Resistance Allowed**		No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
		If gas, AFUE		MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN
		If Heat Pump, HSPF [9]		MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN
	Space cooling	**SEER**		MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN
		Refrigerant Charge Verification or Fault Indicator Display		NR	REQ	NR	NR	NR	NR	NR	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	NR
		Whole House Fan [10]		NR	NR	NR	NR	NR	NR	NR	REQ	REQ	REQ	REQ	REQ	REQ	REQ	NR	NR
	Central System Air Handlers	**Central Fan Integrated Ventilation System Fan Efficacy**		REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ
	Ducts [12]	**Roof/Ceiling Options A & B**	Duct Insulation	R-8	R-8	R-6	R-8	R-6	R-6	R-6	R-8	R-8	R-8	R-8	R-8	R-8	R-8	R-8	R-8
			§150.1(c)9A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Roof/Ceiling	Duct Insulation	R-6	R-6	R-6	R-6	R-6	R-6	R-6	R-6	R-6	R-6	R-6	R-6	R-6	R-6	R-6	R-6
			§150.1(c)9B	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ
Water Heating	**All Buildings**			System Shall meet Section 150.1(c)8															

Footnote requirements to TABLE 150.1-A:[10]

1. Install the specified R-value with no air space present between the roofing and the roof deck.
2. Install the specified R-value with an air space present between the roofing and the roof deck. Such as standard installation of concrete or clay tile.
3. R-values shown for below roof deck insulation are for wood-frame construction with insulation installed between the framing members.
4. Assembly U-factors can be met with cavity insulation alone or with continuous insulation alone, or with both cavity and continuous insulation that results in an assembly U-factor equal to or less than the U-factor shown. Use Reference Joint Appendices JA4 Table 4.3.1, 4.3.1(a), or Table 4.3.4 to determine alternative insulation products to meet the required maximum U-factor.
5. Mass wall has a thermal heat capacity greater than or equal to 7.0 Btu/h-ft^2. "Interior" denotes insulation installed on the inside surface of the wall.
6. Mass wall has a thermal heat capacity greater than or equal to 7.0 Btu/h-ft^2. "Exterior" denotes insulation installed on the exterior surface of the wall.
7. Below grade "interior" denotes insulation installed on the inside surface of the wall.
8. Below grade "exterior" denotes insulation installed on the outside surface of the wall.
9. HSPF means "heating seasonal performance factor."
10. When whole house fans are required (REQ), only those whole house fans that are listed in the Appliance Efficiency Directory may be installed. Compliance requires installation of one or more WHFs whose total airflow CFM is capable of meeting or exceeding a minimum 1.5 cfm/square foot of conditioned floor area as specified by Section 150.1(c)12.
11. A supplemental heating unit may be installed in a space served directly or indirectly by a primary heating system, provided that the unit thermal capacity does not exceed 2 kilowatts or 7,000 Btu/hr and is controlled by a timelimiting device not exceeding 30 minutes.
12. For duct and air handler location: REQ denotes location in conditioned space. When the table indicates ducts and air handlers are in conditioned space, a HERS verification is required as specified by Reference Residential Appendix RA3.1.4.3.8.

[10] Single family buildings are modeled with Option B and multifamily buildings are modeled with Option C.

Appendix B.1 – Single Family Package Summaries

Table 16: Single Family Tier Packages

Climate Zone	QII	ACH50	Window U-value / SHGC	Door U-value	HPA	Furnace AFUE	AC SEER/EER	AH Fan W/cfm	DHW EF	HW Pipe Insul.	Solar Ready	PV Credit Size (kW)	T-24 Comp. Margin
Tier 1, Envelope Cases													
CZ1	Y		.30/.50	0.20						Y	Y		16.1%
CZ2	Y	3	.30/.23	0.20				0.30		Y	Y		15.8%
CZ3	Y		.30/.50	0.20						Y	Y		15.5%
CZ4	Y		.30/.23					0.30					12.0%
CZ5	Y		.30/.50							Y			15.2%
CZ6	Y												8.7%
CZ7	Y												7.0%
CZ8	Y												8.9%
CZ9	Y		.30/.23					0.30					17.2%
CZ10	Y		.30/.23					0.30					17.2%
CZ11	Y		.30/.23					0.30			Y		16.9%
CZ12	Y		.30/.23					0.30			Y		16.4%
CZ13	Y		.30/.23					0.30			Y		17.4%
CZ14	Y		.30/.23					0.30			Y		16.4%
CZ15	Y							0.30			Y		15.2%
CZ16	Y	3	.30/.23	0.20				0.30			Y		15.8%
Tier 1, Equipment Cases													
CZ1	Y					0.92					Y		19.3%
CZ2	Y					0.92					Y		16.8%
CZ3	Y								0.94		Y		15.3%
CZ4	Y					0.92		0.30					17.0%
CZ5	Y								0.94				16.9%
CZ6	Y								0.94	Y			15.5%
CZ7	Y								0.94				15.6%
CZ8	Y							0.30	0.94				17.4%
CZ9	Y						15/12.5	0.30					16.9%
CZ10	Y						15/12.5	0.30					16.6%
CZ11	Y						15/12.5	0.30			Y		17.3%
CZ12	Y						15/12.5	0.30			Y		16.0%
CZ13	Y						15/12.5	0.30			Y		17.9%
CZ14	Y						15/12.5	0.30			Y		17.1%
CZ15	Y							0.30			Y		15.2%
CZ16	Y					0.92					Y		17.6%

Climate Zone	QII	ACH50	Window U-value / SHGC	Door U-value	HPA	Furnace AFUE	AC SEER/EER	AH Fan W/cfm	DHW EF	HW Pipe Insul.	Solar Ready	PV Credit Size (kW)	T-24 Comp. Margin
Tier 2, Cases with PV Credit													
CZ1	Y	3	.30/.50	0.20	Y					Y		2.1	32.2%
CZ2	Y		.30/.50	0.20	Y					Y		2.1	31.4%
CZ3	Y		.30/.50	0.20								2.0	21.8%
CZ4	Y		.30/.23									2.1	30.4%
CZ5	Y		.30/.50									2.0	22.0%
CZ6							N/A – No PV Credit						
CZ7							N/A – No PV Credit						
CZ8	Y											2.1	36.4%
CZ9	Y											2.0	35.0%
CZ10	Y											2.1	32.2%
CZ11	Y		.30/.23	0.20								2.2	31.2%
CZ12	Y											2.1	32.4%
CZ13	Y		.30/.23									2.2	31.3%
CZ14	Y							0.30				2.2	30.9%
CZ15	Y							0.30				2.2	32.2%
CZ16	Y	3	.30/.23	0.20				0.30				2.1	31.5%

Appendix B.2 – Multifamily Package Summaries

Table 17: Multifamily Tier 1 Packages

Climate Zone	QII	Window U-value / SHGC	Door U-value	Furnace AFUE	AC SEER/EER	AH Fan W/cfm	Refrigerant Charge	DHW EF	HW Comp. Dist.	PV Credit Size (kW)	T-24 Comp. Margin
Tier 1, Envelope Cases											
CZ1	Y	0.30/0.50	0.20			0.3			Y		16.5%
CZ2	Y										4.8%
CZ3	Y	0.30/0.50	0.20						Y		10.9%
CZ4	Y	0.30/0.23				0.3	Y				10.9%
CZ5	Y	0.30/0.50	0.20			0.3	Y		Y		10.2%
CZ6	Y	0.30/0.23	0.20			0.3			Y		11.7%
CZ7	Y	0.30/0.23	0.20			0.3	Y		Y		10.2%
CZ8	Y	0.30/0.23				0.3					10.5%
CZ9	Y	0.30/0.23				0.3					12.3%
CZ10	Y	0.30/0.23				0.3					10.1%
CZ11	Y	0.30/0.23	0.20			0.3					17.7%
CZ12	Y	0.30/0.23	0.20			0.3					17.1%
CZ13	Y	0.30/0.23	0.20			0.3					18.1%
CZ14	Y	0.30/0.23	0.20			0.3					17.8%
CZ15	Y	0.30/0.23	0.20			0.3					17.7%
CZ16	Y	0.30/0.23	0.20			0.3			Y		16.3%
Tier 1, Equipment Cases											
CZ1	Y	0.30/0.50						94	Y		16.7%
CZ2	Y			92				96			15.0%
CZ3	Y							94			12.4%
CZ4	Y			92				96	Y		16.3%
CZ5	Y							94			11.8%
CZ6	Y							94	Y		12.1%
CZ7	Y							96	Y		12.5%
CZ8	Y	0.30/0.23			16/13	0.3	Y				15.2%
CZ9	Y				16/13	0.3					15.7%
CZ10	Y				16/13	0.3					15.5%
CZ11	Y	0.30/0.23			15/12.5	0.3					16.5%
CZ12	Y	0.30/0.23			15/12.5	0.3					15.0%
CZ13	Y				15/12.5	0.3					15.4%
CZ14	Y				16/13	0.3					16.5%
CZ15	Y				16/13	0.3					20.4%
CZ16	Y	0.30/0.23		92		0.3					15.7%

Climate Zone	QII	Window U-value / SHGC	Door U-value	Furnace AFUE	AC SEER/EER	AH Fan W/cfm	Refrigerant Charge	DHW EF	HW Comp. Dist.	PV Credit Size (kW)	T-24 Comp. Margin
Tier 2, Cases with PV Credit											
CZ1	Y	0.30/0.50	0.20			0.3			Y	1.0	21.0%
CZ2	Y	0.30/0.23	0.20			0.3			Y	1.0	20.4%
CZ3	Y	0.30/0.50	0.20			0.3			Y	1.0	15.3%
CZ4	Y	0.30/0.23	0.20			0.3			Y	1.0	26.9%
CZ5	Y	0.30/0.50	0.20			0.3			Y	1.0	12.4%
CZ6	N/A – No PV Credit										
CZ7	N/A – No PV Credit										
CZ8	Y	0.30/0.23	0.20			0.3			Y	1.0	21.0%
CZ9	Y	0.30/0.23	0.20			0.3				1.0	26.8%
CZ10	Y	0.30/0.23	0.20			0.3				1.0	26.2%
CZ11	Y	0.30/0.23	0.20			0.3				1.0	26.5%
CZ12	Y	0.30/0.23	0.20			0.3				1.0	26.5%
CZ13	Y	0.30/0.23	0.20			0.3				1.0	27.3%
CZ14	Y	0.30/0.23	0.20			0.3				1.0	26.0%
CZ15	Y	0.30/0.23	0.20			0.3				1.0	25.4%
CZ16	Y	0.30/0.23	0.20							1.0	25.7%

Appendix C - Utility Rate Tariffs

Following are the PG&E electricity, both standard and time-of-use, and natural gas tariffs applied in this study. The PG&E monthly gas rate in $/therm was applied on a monthly basis for the 12-month period ending March 2016.

Pacific Gas and Electric Company		Revised	Cal. P.U.C. Sheet No.	36706-E
San Francisco, California	Cancelling	Revised	Cal. P.U.C. Sheet No.	36470-E
U 39				

ELECTRIC SCHEDULE E-1
RESIDENTIAL SERVICES

Sheet 1

APPLICABILITY: This schedule is applicable to single-phase and polyphase residential service in single-family dwellings and in flats and apartments separately metered by PG&E; to single-phase and polyphase service in common areas in a multifamily complex (see Special Condition 8); and to all single-phase and polyphase farm service on the premises operated by the person whose residence is supplied through the same meter.

The provisions of Schedule S—Standby Service Special Conditions 1 through 6 shall also apply to customers whose premises are regularly supplied in part (but not in whole) by electric energy from a nonutility source of supply. These customers will pay monthly reservation charges as specified under Section 1 of Schedule S, in addition to all applicable Schedule E-1 charges. See Special Conditions 11 and 12 of this rate schedule for exemptions to standby charges.

TERRITORY: This rate schedule applies everywhere PG&E provides electric service.

RATES: Total bundled service charges are calculated using the total rates below. Customers on this schedule are subject to the delivery minimum bill amount shown below applied to the delivery portion of the bill (i.e. to all rate components other than the generation rate). In addition, total bundled charges will include applicable generation charges per kWh for all kWh usage.

Customers receiving a medical baseline allowance shall pay for all usage in excess of 200 percent of baseline at a rate $0.04000 per kWh less than the applicable rate for usage in excess of 200 percent of baseline. No portion of the rates paid by customers that receive a Medical Baseline allowance shall be used to pay the DWR Bond charge. For these customers, the Conservation Incentive Adjustment is calculated residually based on the total rate less the sum of: Transmission, Transmission Rate Adjustments, Reliability Services, Distribution, Generation, Public Purpose Programs, Nuclear Decommissioning, Competition Transition Charges (CTC), New System Generation Charges,[1] and Energy Cost Recovery Amount. Customers receiving a medical baseline allowance shall also receive a 50 percent discount on the delivery minimum bill amount shown below.

Direct Access (DA) and Community Choice Aggregation (CCA) charges shall be calculated in accordance with the paragraph in this rate schedule titled Billing.

TOTAL RATES

Total Energy Rates ($ per kWh)	
Baseline Usage	$0.18212
101% - 130% of Baseline	$0.24090 (I)
131% - 200% of Baseline	$0.24090 (R)
201% - 300% of Baseline	$0.39999 (I)
Over 300% of Baseline	$0.39999 (I)
Delivery Minimum Bill Amount ($ per meter per day)	$0.32854
California Climate Credit (per household, per semi-annual payment occurring in the April and October bill cycles)	($28.14)

[1] Per Decision 11-12-031, New System Generation Charges are effective 1/1/2012.

(Continued)

Advice Letter No:	4810-E-A	Issued by	Date Filed	May 31, 2016
Decision No.	15-07-001 and E-4782	**Steven Malnight**	Effective	June 1, 2016
		Senior Vice President	Resolution No.	
1C8		Regulatory Affairs		

Pacific Gas and Electric Company San Francisco, California U 39		Revised	Cal. P.U.C. Sheet No.	36713-E
	Cancelling	Revised	Cal. P.U.C. Sheet No.	36500-E

ELECTRIC SCHEDULE E-TOU
RESIDENTIAL TIME-OF-USE SERVICE

Sheet 2

RATES
(Cont'd.):

OPTION A TOTAL RATES

Total Energy Rates ($ per kWh)	PEAK		OFF-PEAK	
Summer				
Total Usage	$0.40327	(I)	$0.32769	(I)
Baseline Credit (Applied to Baseline Usage Only)	($0.11709)	(R)	($0.11709)	(R)
Winter				
Total Usage	$0.28530	(I)	$0.27100	(I)
Baseline Credit (Applied to Baseline Usage Only)	($0.11709)	(R)	($0.11709)	(R)
Delivery Minimum Bill Amount ($ per meter per day)	$0.32854			
California Climate Credit (per household, per semi-annual payment occurring in the April and October bill cycles)	($28.14)			

Total bundled service charges shown on customer's bills are unbundled according to the compo nt rates shown below. Where the delivery minimum bill amount applies, the customer's bill will equal the sum of (1) the delivery minimum bill amount plus (2) for bundled service, the generation rate times the number of kWh used. For revenue accounting purposes, the revenues from the delivery minimum bill amount will be assigned to the Transmission, Transmission Rate Adjustments, Reliability Services, Public Purpose Programs, Nuclear Decommissioning, Competition Transition Charges, Energy Cost Recovery Amount, DWR Bond, and New System Generation Charges[1] based on kWh usage times the corresponding unbundled rate component per kWh, with any residual revenue assigned to Distribution.*

[1] Per Decision 11-12-031, New System Generation Charges are effective 1/1/2012.
* This same assignment of revenues applies to direct access and community choice aggregation customers.

(Continued)

Advice Letter No:	4810-E-A	*Issued by*	*Date Filed*	May 31, 2016
Decision No.	15-07-001 and E-4782	***Steven Malnight***	*Effective*	June 1, 2016
		Senior Vice President	*Resolution No.*	
2C9		*Regulatory Affairs*		

Pacific Gas and Electric Company *San Francisco, California* U 39	*Cancelling*	Revised Revised	*Cal. P.U.C. Sheet No.* *Cal. P.U.C. Sheet No.*	32682-G 32620-G

GAS SCHEDULE G-1
RESIDENTIAL SERVICE

Sheet 1

APPLICABILITY: This rate schedule* applies to natural gas service to Core End-Use Customers on PG&E's Transmission and/or Distribution Systems. To qualify, service must be to individually-metered single family premises for residential use, including those in a multifamily complex, and to separately-metered common areas in a multifamily complex where Schedules GM, GS, or GT are not applicable. Common area accounts that are separately metered by PG&E have an option of switching to a core commercial rate schedule. Common area accounts are those accounts that provide gas service to common use areas as defined in Rule 1.

TERRITORY: Schedule G-1 applies everywhere within PG&E's natural gas Service Territory.

RATES: Customers on this schedule pay a Procurement Charge and a Transportation Charge, per meter, as shown below. The Transportation Charge will be no less than the Minimum Transportation Charge, as follows:

Minimum Transportation Charge:**	Per Day
	$0.09863

	Per Therm Baseline		Per Therm Excess	
Procurement:	$0.20960	(R)	$0.20960	(R)
Transportation Charge:	$0.81592		$1.30547	
Total:	$1.02552	(R)	$1.51507	(R)

Public Purpose Program Surcharge:

Customers served under this schedule are subject to a gas Public Purpose Program (PPP) Surcharge under Schedule G-PPPS.

See Preliminary Statement, Part B for the Default Tariff Rate Components.

The Procurement Charge on this schedule is equivalent to the rate shown on informational Schedule G-CP—Gas Procurement Service to Core End-Use Customers.

BASELINE QUANTITIES: The delivered quantities of gas shown below are billed at the rates for baseline use.

BASELINE QUANTITIES (Therms Per Day Per Dwelling Unit)

Baseline Territories***	Summer Effective Apr. 1, 2016	Winter Effective Nov. 1, 2015
P	0.46	2.15
Q	0.69	1.98
R	0.46	1.79
S	0.46	1.92
T	0.69	1.79
V	0.69	1.79
W	0.46	1.69
X	0.59	1.98
Y	0.85	2.55

* PG&E's gas tariffs are available online at www.pge.com.
** The Minimum Transportation charge does not apply to submetered tenants of master-metered customers served under gas rate Schedules GS and GT.
*** The applicable baseline territory is described in Preliminary Statement, Part A.

(Continued)

Advice Letter No: 3715-G	*Issued by*	*Date Filed* May 24, 2016
Decision No. 97-10-065 & 98-07-025	***Steven Malnight***	*Effective* June 1, 2016
	Senior Vice President	*Resolution No.*
1C6	*Regulatory Affairs*	

Following are the SCE electricity tariffs, both standard and time-of-use, and SoCalGas natural gas tariffs applied in this study.

EDISON

Southern California Edison — Revised — Cal. PUC Sheet No. 59026-E

Rosemead, California (U 338-E) — Cancelling Revised — Cal. PUC Sheet No. 58237-E

Schedule D

DOMESTIC SERVICE

Sheet 2

(Continued)

RATES

	Delivery Service Total[1]	Generation[2] UG***	Generation[2] DWREC[3]
Energy Charge- $/kWh/Meter/Day			
Baseline Service			
Summer	0.06799 (I)	0.06919 (I)	(0.00022)
Winter	0.06799 (I)	0.06919 (I)	(0.00022)
Nonbaseline Service*			
101% - 200% of Baseline - Summer	0.15997 (I)	0.06919 (I)	(0.00022)
Winter	0.15997 (I)	0.06919 (I)	(0.00022)
Over 200% of Baseline - Summer	0.22306 (R)	0.06919 (I)	(0.00022)
Winter	0.22306 (R)	0.06919 (I)	(0.00022)
Basic Charge - $/Meter/Day			
Single-Family Accommodation	0.031		
Multi-Family Accommodation	0.024		
Minimum Charge** - $/Meter/Day			
Single-Family Accommodation	0.329		
Multi-Family Accommodation	0.329		
Minimum Charge (Medical Baseline)** - $/Meter/Day			
Single-Family Accommodation	0.164		
Multi-Family Accommodation	0.164		
California Climate Credit[4]	(38.00)		
Peak Time Rebate - $kWh		(0.75)	
Peak Time Rebate w/enabling technology - $/kWh		(1.25)	

* Nonbaseline Service includes all kWh in excess of applicable Baseline allocations as described in Preliminary Statement, Part H, Baseline Service.

** The Minimum Charge is applicable when the Delivery Service Energy Charge, plus the applicable Basic Charge is less than the Minimum Charge.

*** The ongoing Competition Transition Charge (CTC) of $(0.00015) per kWh is recovered in the UG component of Generation.

1 Total = Total Delivery Service rates are applicable to Bundled Service, Direct Access (DA) and Community Choice Aggregation Service (CCA Service) Customers, except DA and CCA Service Customers are not subject to the DWRBC rate component of this Schedule but instead pay the DWRBC as provided by Schedule DA-CRS or Schedule CCA-CRS.

2 Generation = The Generation rates are applicable only to Bundled Service Customers.

3\. DWREC = Department of Water Resources (DWR) Energy Credit - For more information on the DWR Energy Credit, see the Billing Calculation Special Condition of this Schedule.

4\. Applied on an equal basis, per household, semi-annually. See the Special Conditions of this Schedule for more information.

(Continued)

(To be inserted by utility)	Issued by	(To be inserted by Cal. PUC)
Advice 3401-E	R. O. Nichols	Date Filed May 2, 2016
Decision 16-03-030	Senior Vice President	Effective Jun 1, 2016
2C11		Resolution

EDISON

Southern California Edison — Revised Cal. PUC Sheet No. 59059-E
Rosemead, California (U 338-E) — Cancelling Revised Cal. PUC Sheet No. 58249-E

Schedule TOU-D-T
TIME-OF-USE TIERED DOMESTIC

Sheet 2

(Continued)

RATES

	Delivery Service Total[1]	Generation[2] UG***	Generation[2] DWREC[3]
Energy Charge - $/kWh/Meter/Day			
Summer Season - On-Peak			
Level I (up to 130% of Baseline)	0.10523 (I)	0.21660 (R)	(0.00022)
Level II (More than 130% of Baseline)	0.18352 (R)	0.21660 (R)	(0.00022)
Summer Season - Off-Peak			
Level I (up to 130% of Baseline)	0.10523 (I)	0.05311 (I)	(0.00022)
Level II (More than 130% of Baseline)	0.18352 (R)	0.05311 (I)	(0.00022)
Winter Season - On-Peak			
Level I (up to 130% of Baseline)	0.10523 (I)	0.09660 (R)	(0.00022)
Level II (More than 130% of Baseline)	0.18352 (R)	0.09660 (R)	(0.00022)
Winter Season - Off-Peak			
Level I (up to 130% of Baseline)	0.10523 (I)	0.04749 (I)	(0.00022)
Level II (More than 130% of Baseline)	0.18352 (R)	0.04749 (I)	(0.00022)
Basic Charge - $/Meter/Day			
Single-Family Accommodation	0.031		
Multi-Family Accommodation	0.024		
Minimum Charge* - $/Meter/Day			
Single-Family Accommodation	0.329		
Multi-Family Accommodation	0.329		
Minimum Charge (Medical Baseline)** - $/Meter/Day			
Single-Family Accommodation	0.164		
Multi-Family Accommodation	0.164		
California Climate Credit[4]	(36.00)		
California Alternate Rates for Energy Discount - %	100.00*		
Peak Time Rebate - $kWh		(0.75)	
Peak Time Rebate w/enabling technology - $/kWh		(1.25)	

* The Minimum Charge is applicable when the Delivery Service Energy Charge, plus the applicable Basic Charge is less than the Minimum Charge.
** Represents 100% of the discount percentage as shown in the applicable Special Condition of this Schedule.
*** The ongoing Competition Transition Charge (CTC) of $(0.00015) per kWh is recovered in the UG component of Generation.
1 Total = Total Delivery Service rates are applicable to Bundled Service, Direct Access (DA) and Community Choice Aggregation Service (CCA Service) Customers, except DA and CCA Service Customers are not subject to the DWRBC rate component of this Schedule but instead pay the DWRBC as provided by Schedule DA-CRS or Schedule CCA-CRS
2 Generation = The Gen rates are applicable only to Bundled Service Customers.
3 DWREC = Department of Water Resources (DWR) Energy Credit – For more information on the DWR Energy Credit, see the Billing Calculation Special Condition of this Schedule.
4 Applied on an equal basis, per household, semi-annually. See the Special Conditions of this Schedule for more information.

(Continued)

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Advice 3401-E	R. O. Nichols	Date Filed May 2, 2016
Decision 16-03-030	Senior Vice President	Effective Jun 1, 2016
2C19		Resolution

SOUTHERN CALIFORNIA GAS COMPANY Revised CAL. P.U.C. SHEET NO. 52782-G
LOS ANGELES, CALIFORNIA CANCELING Revised CAL. P.U.C. SHEET NO. 52751-G

Schedule No. GR
RESIDENTIAL SERVICE
(Includes GR, GR-C and GT-R Rates)

Sheet 1

APPLICABILITY

The GR rate is applicable to natural gas procurement service to individually metered residential customers.

The GR-C, cross-over rate, is a core procurement option for individually metered residential core transportation customers with annual consumption over 50,000 therms, as set forth in Special Condition 10.

The GT-R rate is applicable to Core Aggregation Transportation (CAT) service to individually metered residential customers, as set forth in Special Condition 11.

The California Alternate Rates for Energy (CARE) discount of 20%, reflected as a separate line item on the bill, is applicable to income-qualified households that meet the requirements for the CARE program as set forth in Schedule No. G-CARE.

TERRITORY

Applicable throughout the service territory.

RATES	GR	GR-C	GT-R	
Customer Charge, per meter per day:	16.438¢	16.438¢	16.438¢	
For "Space Heating Only" customers, a daily Customer Charge applies during the winter period from November 1 through April 30[1]:	33.149¢	33.149¢	33.149¢	
Baseline Rate, per therm (baseline usage defined in Special Conditions 3 and 4):				
Procurement Charge: [2]	34.536¢	34.536¢	N/A	I
Transmission Charge: [3]	56.280¢	56.280¢	55.758¢	
Total Baseline Charge:	90.816¢	90.816¢	55.758¢	I
Non-Baseline Rate, per therm (usage in excess of baseline usage):				
Procurement Charge: [2]	34.536¢	34.536¢	N/A	I
Transmission Charge: [3]	82.280¢	82.280¢	81.758¢	
Total Non-Baseline Charge:	116.816¢	116.816¢	81.758¢	I

[1] For the summer period beginning May 1 through October 31, with some exceptions, usage will be accumulated to at least 20 Ccf (100 cubic feet) before billing.

(Footnotes continue next page.)

(Continued)

(TO BE INSERTED BY UTILITY)
ADVICE LETTER NO. 4989
DECISION NO.

ISSUED BY
Dan Skopec
Vice President
Regulatory Affairs

(TO BE INSERTED BY CAL. PUC)
DATE FILED Jul 7, 2016
EFFECTIVE Jul 10, 2016
RESOLUTION NO. G-3351

Following are the SDG&E electricity, both standard and time-of-use, and natural gas tariffs applied in this study.

San Diego Gas & Electric Company
San Diego, California

Revised Cal. P.U.C. Sheet No. 27650-E

Canceling Revised Cal. P.U.C. Sheet No. 26948-E

Sheet 1

SCHEDULE DR

RESIDENTIAL SERVICE

(Includes Rates for DR-LI)

APPLICABILITY

Applicable to domestic service for lighting, heating, cooking, water heating, and power, or combination thereof, in single family dwellings, flats, and apartments, separately metered by the utility; to service used in common for residential purposes by tenants in multi-family dwellings under Special Condition 8; to any approved combination of residential and nonresidential service on the same meter; and to incidental farm service under Special Condition 7.

This schedule is also applicable to customers qualifying for the California Alternate Rates for Energy (CARE) Program and/or Medical Baseline, residing in single-family accommodations, separately metered by the Utility, and may include Non-profit Group Living Facilities and Qualified Agricultural Employee Housing Facilities, if such facilities qualify to receive service under the terms and conditions of Schedule E-CARE. The rates for CARE and Medical Baseline customers are identified in the rates tables below as DR-LI and DR-MB rates, respectively.

Customers on this schedule may also qualify for a semi-annual California Climate Credit $(17.44) per Schedule GHG-ARR.

TERRITORY

Within the entire territory served by the Utility.

RATES

Total Rates:

Description - DR Rates	UDC Total Rate		DWR-BC Rate	EECC Rate + DWR Credit	Total Rate		
Summer:							
Baseline Energy ($/kWh)	0.05480	I	0.00539	0.12965	0.18984	I	D
Above 130% of Baseline	0.25645	R	0.00539	0.12965	0.39149	R	
Winter:							
Baseline Energy ($/kWh)	0.10256	I	0.00539	0.06604	0.17399	I	D
Above 130% of Baseline	0.28737	R	0.00539	0.06604	0.35880	R	
Minimum Bill ($/day)	0.329				0.329		

Description -DR-LI Rates	UDC Total Rate		DWR-BC Rate	EECC Rate + DWR Credit	Total Rate		
Summer – CARE Rates:							
Baseline Energy ($/kWh)	0.05225	I	0.00000	0.12965	0.18190	I	D
Above 130% of Baseline	0.25390	R	0.00000	0.12965	0.38355	R	
Winter – CARE Rates:							
Baseline Energy ($/kWh)	0.10001	I	0.00000	0.06604	0.16605	I	D
Above 130% of Baseline	0.28482	R	0.00000	0.06604	0.35086	R	
Minimum Bill ($/day)	0.164				0.164		

(Continued)

1C10

Advice Ltr. No. 2861-E-A

Decision No. 15-07-001

Issued by
Dan Skopec
Vice President
Regulatory Affairs

Date Filed Jun 29, 2016

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Resolution No. E-4787

San Diego Gas & Electric Company
San Diego, California

Revised Cal. P.U.C. Sheet No. 26962-E

Canceling Revised Cal. P.U.C. Sheet No. 26908-E

Sheet 1

SCHEDULE DR-SES

DOMESTIC TIME-OF-USE FOR HOUSEHOLDS WITH A SOLAR ENERGY SYSTEM

APPLICABILITY

Service under this schedule is available on a voluntary basis for individually metered residential customers with Solar Energy Systems. Service is limited to individually metered residential customers with a Solar Energy System with domestic service for lighting, heating, cooking, water heating, and power, or combination thereof, in single family dwellings and flats. Qualifying California Alternative Rates for Energy (CARE) customers are eligible for service on this schedule, as further described under Special Condition 8 of this schedule.

Customers on this schedule may also qualify for a semi-annual California Climate Credit $(17.44) per Schedule GHG-ARR. I

TERRITORY

Within the entire territory served by the Utility.

RATES

Total Rates:

Description – DR-SES Rates	UDC Total Rate	DWR-BC Rate	EECC Rate + DWR Credit	Total Rate
Energy Charges ($/kWh)				
On-Peak – Summer	0.12835 I	0.00539 I	0.33023 R	0.46397 R
Semi-Peak– Summer	0.12835 I	0.00539 I	0.09530 R	0.22904 R
Off-Peak – Summer	0.12835 I	0.00539 I	0.07332 R	0.20706 R
Semi-Peak – Winter	0.12835 I	0.00539 I	0.08159 R	0.21533 R
Off-Peak – Winter	0.12835 I	0.00539 I	0.06826 R	0.20200 R
Minimum Bill ($/day)	0.329			0.329

(1) Total Rates consist of UDC, Schedule DWR-BC (Department of Water Resources Bond Charge), and Schedule EECC (Electric Energy Commodity Cost) rates, with the EECC rates reflecting a DWR Credit of $(0.00021) that customers receive on their monthly bills.

(2) Total Rates presented are for customers that receive commodity supply and delivery service from Utility. Differences in total rates paid by Direct Access (DA) and Community Choice Aggregation (CCA) customers are identified in Schedule DA-CRS and CCA-CRS, respectively. I

(3) DWR-BC charges do not apply to CARE or Medical Baseline customers.

UDC Rates

Description-DR-SES	Transm	Distr	PPP	ND	CTC	LGC	RS	TRAC	UDC Total
Energy Charges ($/kWh)									
On-Peak – Summer	0.02943 I	0.08367 R	0.01241 I	0.00052 I	0.00180 I	0.00039 I	0.00013 R	0.00000 I	0.12835 I
Semi-Peak – Summer	0.02943 I	0.08367 R	0.01241 I	0.00052 I	0.00180 I	0.00039 I	0.00013 R	0.00000 I	0.12835 I
Off-Peak - Summer	0.02943 I	0.08367 R	0.01241 I	0.00052 I	0.00180 I	0.00039 I	0.00013 R	0.00000 I	0.12835 I
Semi-Peak - Winter	0.02943 I	0.08367 R	0.01241 I	0.00052 I	0.00180 I	0.00039 I	0.00013 R	0.00000 I	0.12835 I
Off-Peak - Winter	0.02943 I	0.08367 R	0.01241 I	0.00052 I	0.00180 I	0.00039 I	0.00013 R	0.00000 I	0.12835 I
Minimum Bill ($/day)		0.329							0.329

(Continued)

1C9

Advice Ltr. No. 2840-E

Decision No.

Issued by
Dan Skopec
Vice President
Regulatory Affairs

Date Filed Dec 29, 2015

Effective Jan 1, 2016

Resolution No.

SDGE
San Diego Gas & Electric Company
San Diego, California

	Revised	Cal. P.U.C. Sheet No.	21921-G
Canceling	Revised	Cal. P.U.C. Sheet No.	21908-G

SCHEDULE GR

Sheet 1

RESIDENTIAL NATURAL GAS SERVICE
(Includes Rates for GR, GR-C, GTC/GTCA)

APPLICABILITY

The GR rate is applicable to natural gas procurement service for individually metered residential customers.

The GR-C, cross-over rate, is a core procurement option for individually metered residential core transportation customers with annual consumption over 50,000 therms, as set forth in Special Condition 10.

The GTC/GTCA rate is applicable to intrastate gas transportation-only services to individually metered residential customers, as set forth in Special Condition 11.

Customers taking service under this schedule may be eligible for a 20% California Alternate Rate for Energy (CARE) program discount, reflected as a separate line item on the bill, if they qualify to receive service under the terms and conditions of Schedule G-CARE.

TERRITORY

Within the entire territory served natural gas by the utility.

RATES

	GR	GR-C		GTC/GTCA[1/]
Baseline Rate, per therm (baseline usage defined in Special Conditions 3 and 4):				
Procurement Charge:[2/]	$0.34561	$0.34561	I	N/A
Transmission Charge:	$0.90805	$0.90805		$0.90805
Total Baseline Charge:	$1.25366	$1.25366	I	$0.90805
Non-Baseline Rate, per therm (usage in excess of baseline usage):				
Procurement Charge:[2/]	$0.34561	$0.34561	I	N/A
Transmission Charge:	$1.08354	$1.08354		$1.08354
Total Non-Baseline Charge:	$1.42915	$1.42915	I	$1.08354

[1/] The rates for core transportation-only customers, with the exception of customers taking service under Schedule GT-NGV, include any FERC Settlement Proceeds Memorandum Account (FSPMA) credit adjustments.

[2/] This charge is applicable to Utility Procurement Customers and includes the GPC and GPC-A Procurement Charges shown in Schedule GPC which are subject to change monthly as set forth in Special Condition 7.

(Continued)

1C5

Advice Ltr. No. 2489-G	Issued by **Dan Skopec** Vice President Regulatory Affairs	Date Filed	Jul 7, 2016
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Decision No.		Resolution No.	

2016 Title 24 Residential Reach Code Recommendations: Cost Effectiveness Analysis for All California Climate Zones

August 2017

This report was prepared by the California Statewide Codes and Standards Enhancement (CASE) Program that is funded, in part, by California utility customers under the auspices of the California Public Utilities Commission.

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Southern California Edison (SCE) engaged TRC Energy Services (TRC) to provide a cost effectiveness study to support low-rise residential new construction reach code requirements above 2016 Title 24 Building Energy Efficiency Standards (T24), in all 16 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. TRC developed high-performance reach code measure packages for each climate zone that represent possible ways to exceed T24, and are not intended to represent a mandatory or prescriptive set of measures.

TRC simulated measures in CBECC-Res 2016 v3.0 to inform energy impacts, and their corresponding costs were attained through expert interviews and online research. TRC tested various measure packages for cost effectiveness to maximize the compliance margin achieved solely through energy efficiency. In alignment with the goals of 2019 Title 24, TRC then sized solar photovoltaic (PV) generation to offset the annual electricity kWh required by the building after maximizing efficiency, referred to as the Efficiency + PV package.

TRC determined cost effectiveness by comparing the incremental cost of each measure package to the net present value (NPV) of energy cost savings over the 30-year period. Energy cost savings were estimated both in time dependent valuation (TDV) as well as on-bill savings determined through utility rates. The PV compliance credit is added to the efficiency-only packages to present the maximum compliance margin TRC found to be cost effective. Based on cost effectiveness results, TRC recommends that jurisdictions adopt ordinances with requirements and 2016 Energy Design Rating targets achieved through both energy efficiency and solar PV, as per Figure 1.

Figure 1. Summary of Cost Effectiveness Results

CZ	Single Family			Low-rise Multifamily		
	Compliance Margin Efficiency-Only	Compliance Margin Efficiency + PV	2016 Energy Design Rating Efficiency + PV	Compliance Margin Efficiency-Only	Compliance Margin Efficiency + PV	2016 Energy Design Rating Efficiency + PV
1	40%	45%	20	20%	25%	15
2	30%	35%	20	20%	25%	20
3	30%	35%	15	10%	15%	15
4	25%	45%	20	20%	30%	15
5	30%	40%	15	10%	10%	15
6	15%	15%	20	15%	15%	15
7	None	15%	15	None	10%	20
8	25%	55%	15	15%	25%	20
9	30%	55%	15	20%	30%	20
10	30%	55%	15	20%	30%	15
11	30%	50%	20	20%	30%	20
12	35%	55%	20	20%	30%	20
13	30%	50%	20	25%	30%	20
14	30%	50%	20	20%	30%	20
15	30%	45%	15	25%	30%	20
16	30%	45%	25	20%	30%	25

1. Introduction

Southern California Edison (SCE) engaged TRC Energy Services (TRC) to provide a cost effectiveness study to support low-rise residential new construction reach code requirements above 2016 Title 24 Building Energy Efficiency Standards (T24), in all 16 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.

The reach code energy efficiency targets for single family and low-rise multifamily are based on the CALGreen Tier 3 definition:

- Single Family: 30% in CZs 1-5 and 8-16; 15% in CZs 6 and 7
- Low-rise Multifamily: 30% in CZs 1, 2, 4, and 8-16; 15% in CZs 3 and 5-7

While TRC targeted these efficiency levels, the CALGreen Tier 3 requirement for an Energy Design Rating (EDR) = 0 was not targeted. Based on coordination with the CEC, TRC sized solar photovoltaic (PV) generation to offset the annual electricity kWh demanded by the buildings after maximizing efficiency, which results in an EDR > 0.

1.1 Scope

TRC researched measures drawn from multiple sources in an effort to develop cost effective packages that achieve the compliance margin targets above. Compliance margin improvement is measured in terms of Time Dependent Valuation (TDV), described further in Section 2.2.1. Measures were simulated in CEC-approved 2016 T24 compliance software to inform energy impacts, and their corresponding 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**.

1.1.1 Prototype

TRC used two single family prototypes and one low-rise multifamily prototype to estimate energy savings and cost effectiveness, further described in *Section 2.1*. These CEC developed prototypes are commonly used in Title 24 Code and Standards Enhancement (CASE) studies and local reach code analysis, and are meant to be representative of the types of buildings constructed in California.[1] Nonetheless, local jurisdictions can choose to analyze other prototypes during the reach code adoption process.

1.1.2 Cost Data

When available, TRC used existing cost data collected through 2019 Draft CASE Reports and other studies. TRC also conducted additional supplier, distributor, and contractor interviews in multiple locations throughout the state. TRC also researched online sources including RSMeans, Grainger, and Home Depot. Measure costs represent the incremental changes beyond the 2016 T24 Standards prescriptive requirements.

1.1.3 Cost Effectiveness

TRC determined cost effectiveness by comparing the incremental cost of each measure package to the NPV of energy cost savings over the 30-year period. Results include measure compliance margin, present value of energy savings, costs, and benefit to cost (B/C) ratio.

[1] Davis Energy Group (September 2016) CALGreen Cost Effectiveness Study. CA Statewide Codes and Standards Program.

TRC analyzed cost effectiveness for two scenarios:

- **Energy Efficiency Only:** The efficiency package energy savings benefits are measured in terms of TDV, in accordance with CEC Life Cycle Cost methodology typically used in CASE studies.
- **Energy Efficiency + PV (EE + PV):** The EE + PV package adds enough solar PV to the energy efficiency package to offset annual kWh load. Energy savings benefits are measured in terms of on-bill savings, in accordance with CEC cost effectiveness analysis for solar PV. TRC used life cycle customer cost methodology using residential retail rates for electricity and natural gas for each of the four major investor owned utilities - Pacific Gas & Electric Company (PG&E), Southern California Edison (SCE), Southern California Gas Company (SCG), and San Diego Gas and Electric (SDG&E).

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 2.3 for further detail.

1.2 Limitations

The study has the following scope limitations:

- **Federal Preemption:** The Department of Energy (DOE) regulates the minimum efficiencies required for all appliances, such as space conditioning and 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 preemption, 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 Title 24-2016 compliance software, CBECC-Res, to ensure that a free and readily available software program could be used by permit applicants to show compliance with the reach code. CEC-approved compliance software does not yet have the capability to model the energy performance of some measures typically associated with energy savings, such as drain water heat recovery, and reduced infiltration in low-rise multifamily. When necessary, TRC used spreadsheet analysis to estimate the energy performance of measures that could not be modeled in compliance software and added the impact to the compliance margin (including interactive effects).
- **Plug and Lighting Loads:** Plug and lighting loads (e.g., kitchen appliances and indoor lighting), 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.

2. Methodology

TRC developed 0% compliant residential prototypes for all 16 climate zones representing buildings that exactly meet the 2016 Title 24 code requirements to create the baseline model. TRC then used CBECC-Res to simulate energy efficiency measures and photovoltaics to evaluate the energy savings and corresponding compliance percentage over the baseline model.

TRC assessed the cost effectiveness of 2016 reach code packages by analyzing several energy efficiency measures applied to the prototype buildings. TRC used the on-bill cost savings to evaluate customer cost effectiveness. This methodology requires estimating and quantifying the value of the energy impact associated with measures as compared to the baseline prototypes using utility rate schedules over a life of 30 years. The methodology also includes quantifying the incremental costs for the construction, maintenance, and replacement of the proposed measure relative to the 2016 Title 24 prescriptive requirements. The methodology to attain incremental costs is described in *Section 2.2.2*.

2.1 Prototypes

TRC used CEC developed residential prototypes to run simulations for all California CZs:

- 2,100 ft^2 single family one-story home
- 2,700 ft^2 single family two-story home
- 6,960 ft^2 low-rise multifamily residential building with two stories and eight dwelling units

The CEC prototypes are fully defined in the Residential Alternative Calculation Method (ACM) reference manual.[2] The prototypes have equal geometry facing north, east, south, and west orientations, to ensure that results are applicable regardless of the orientation of a building.

TRC initialized the three prototypes to be exactly compliant with the prescriptive minimum 2016 T24 requirements (0% compliance margin) in each climate zone, summarized in Figure 2. The TDV of energy savings for energy efficiency measures were derived by applying measure packages to the minimally code compliant prototype as described in *Section 2.2*.

[2] 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

Figure 2: Parameters of Residential Prototypes

Parameters	Single Family Building		
	2100 SF	2700 SF	6960 MF
Floor Area (ft2)	2100	2700	6960
# of floors	1	2	2
Window-to-Floor Area Ratio	20%	20%	15%
HVAC Distribution System	Ducts located in ventilated attic		Ducts located entirely in conditioned space
Cooling System	Split AC: SEER 14 & EER 11.7		
Heating System	Gas furnace, 78% AFUE		
Conditioned Thermal Zones	1	1	8
Domestic Water Heating	Natural Gas instantaneous water heater; EF 0.82		
Ceiling Insulation (Option B, Table 150.1-A)	R-30 in CZ3 and 5-7; R-38 in CZ1, 2, 4 and 8-16		
Roof Insulation (Option B, Table 150.1-A)	No Requirement in CZ1-3 and 5-7 R13 in CZ4 and 8-16		
Steep-sloped Roof Solar Reflectance	0.10 in CZs 1-9 and CZ16 0.20 in other CZs		
Wood-framed Wall Insulation (U-factor)	0.065 for CZ6 & CZ7; 0.051 for other CZs		
Fenestration U-factor	0.32		
Fenestration Solar Heat Gain Coefficient (SHGC)	0.50 for CZ1, CZ3 & CZ5; 0.25 for other CZs		
Door U-factor	0.50		

2.2 Measure Analysis

TRC investigated measures for single family and low-rise multifamily prototypes with the goal of establishing cost effective packages of measures above 2016 Title 24, Part 6. TRC used CBECC-Res 2016.3.0 (build 954) to simulate the residential prototypes. CBECC is a free public-domain software developed by the CEC for use in complying with Title 24 Standards. Software algorithms are updated continuously, and new versions of the software are released periodically.

2.2.1 Energy Savings

Compliance software outputs energy performance in terms of TDV, kWh, therms, and EDR totals for both the proposed building and the standard building meeting prescriptive Title 24 requirements. The EDR uses a scale of 1 – 100, where 100 is a prescriptive residential building meeting the prescriptive requirements of the 2006 International Energy Conservation Code.

The compliance margin of the proposed building is determined by comparing the proposed building TDV energy usage for regulated loads to the standard building TDV energy usage. This study targets that the proposed buildings use 15-30% less energy than the standard building's TDV energy usage before PV is added, consistent with CALGreen Tier 3 energy efficiency goals. Note that CBECC-Res allows a compliance credit when a minimum PV system size is installed (see Figure 3). TRC added these compliance credits after determining cost effective, efficiency-only packages.

Figure 3. PV Compliance Credit by Climate Zone

Climate Zone	Maximum PV Credit for Single Family	Maximum PV Credit for Multifamily
1	8.6%	4.5%
2	9.1%	5.1%
3	7.4%	3.3%
4	20.3%	11.1%
5	8.1%	2.7%
6	0.0%	0.0%
7	0.0%	0.0%
8	27.5%	9.2%
9	26.1%	11.1%
10	23.5%	10.1%
11	18.4%	8.8%
12	22.6%	9.4%
13	20.4%	9.2%
14	16.7%	8.2%
15	17.0%	7.7%
16	15.7%	8.4%

TDV assigns values to electricity and natural gas delivered for each hour in the year. TDV accounts for retail rates, greenhouse gas emissions, the demand profile from consumers, and several other factors to value electricity generation. Electricity TDV can vary widely on a given day. However, the TDV of gas has a generally consistent value for several months, with the fall and winter values typically higher than spring and summer. The TDV energy budget and compliance margin is a standard output for building permit applicants completing a performance calculation.

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 4.1 represent one possible way to achieve a higher compliance margin – these packages are not intended to represent a mandatory set of reach code measures.

TRC investigated potential energy efficiency measures to apply to the low-rise residential prototype in each climate zone. TRC utilized previous reach code studies, IOU program data, and proposed 2019 Codes and Standards Enhancement (CASE) studies to investigate reach code measures that would have the greatest impact on reducing the largest energy consuming end uses. TRC conducted market research to assess measure feasibility, costs, and potential energy impact. Measures were run as packages to capture interactive effects.

TRC estimated PV energy savings by sizing PV to offset annual electricity demand after applying efficiency packages.

2.2.2 Costs

TRC initially gathered costs for four regions within California to best represent localized costs (Figure 4). TRC anticipated that the main cause of cost variation among the regions would be due to labor rates. However, based on RS Means research and local quotes, the labor rates and material costs vary minimally statewide. Therefore, except where data indicated significant cost fluctuation between regions, average statewide costs were used in the analysis.

Figure 4. Climate Zones Grouped by Geographic Region

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

TRC reviewed previous studies for relevant cost data, such as CASE studies, when available. TRC conducted cost research by accessing online retailers and interviews with contractors and distributors serving each region. Costs include first costs, maintenance, and replacement if the end of useful life is prior to the end of the measure life for a product. For replacements, an annual two percent (2%) inflation rate was assumed. Taxes and contractor markups were added as appropriate. Detailed costs are provided in *Appendix A – Cost Data*.

Costs for solar PV were estimated in coordination with the CEC and their consultant, Energy and Environmental Economics (E3), as described in Section 3.4.4.

2.3 Cost Effectiveness Methodology

TRC determined cost effectiveness by comparing the incremental costs of a measure including solar PV to the cost savings benefits, in a combined B/C ratio metric. The B/C Ratio is the present value of incremental utility costs savings divided by the present value of 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 assessed the cost savings benefits of 2016 reach code packages using two methods:

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

Both methodologies require estimating and quantifying the value of the energy impact associated with energy efficiency measures over the life of the measures (30 years) as compared to the prescriptive Title 24 requirements.

TDV values are based on long-term discounted costs over 30 years. The CEC developed the 2016 TDV values for all climate zones used in this study. The TDV values do not account for net-metered PV generation, thus 2016 TDV is only used to analyze efficiency measure packages (excluding PV). TDV energy estimates are presented in terms of "TDV kBtus," which combine electricity and natural gas energy units.[3] The present value of the energy savings is calculated by multiplying the TDV savings of the building by a Net Present Value (NPV) factor of $0.17/TDV kBtu for residential measures with a 30-year life.

The customer cost effectiveness methodology captures the energy cost savings from energy efficiency measures and solar PV resulting from lower energy bills. TRC determined the Net Present Value (NPV) of the on-bill savings over a 30-year lifetime, including a three percent (3%) discount rate and a two percent (2%) energy cost inflation rate. On-Bill savings were estimated by calculating monthly electricity (kWh) and natural gas (therms) savings resulting from energy efficiency measures using current residential utility (IOU) rate schedules as shown in Figure 5. As per net energy metering (NEM) 2.0 program rules, non-bypassable charges (NBCs) are accounted for every billing interval and cannot be offset by PV energy generation credits. As a simplifying assumption, TRC applied an average NBC rate to each billing interval and aggregated them annually. Please see *Appendix B – Utility Rate Schedules* for further schedule details.

Figure 5. Investor-Owned Utility (IOU) Rate Schedules

CLIMATE ZONES	Utility	Commodity	Rate Schedule
1, 2, 3, 4, 5, 11, 12, 13, 16	Pacific Gas and Electric Company	Electric	E-TOU Option A
		Gas	G1
6, 8, 9, 14, 15	Southern California Edison	Electric	TOU-D-T
	Southern California Gas Company	Gas	GR
7, 10	San Diego Gas and Electric Company	Electric	DR-SES
		Gas	GR

[3] kBtus = thousands of British Thermal Units.

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 listed below and the subsequent packages described in *Section 4.1* based on cost effectiveness and technical feasibility in the California low-rise residential new construction market. Single family costs presented here represent the average installation cost for the two prototypes: the 2,100 and 2,700 square foot.

- Home Energy Rating System (HERS) verification measures, as indicated for the applicable measures
- Envelope measures
  - Quality Insulation Installation (QII) (HERS)
  - Cool Roof
  - Improved Fenestration
  - Insulated Door
  - High-Performance Walls (HPW)
  - High-Performance Attics (HPA)
  - Reduced Infiltration (HERS)
- Domestic Hot Water (DHW) measures
  - Hot Water Piping Insulation of All Lines (HERS)
  - Compact Hot Water Distribution (HERS)
  - Drain Water Heat Recovery (DWHR)
- Heating, Ventilation, and Air Conditioning (HVAC) measures
  - Air Handling Unit (AHU) Reduced Fan Watt Draw (0.3 W/CFM) (HERS)
  - Verified Refrigerant Charge (HERS)
  - Verified Low-leakage Ducts entirely in Conditioned Space (HERS)
  - Heat or Energy Recovery Ventilation
- Solar Photovoltaics

3.1 HERS Verification Measures

Several of the residential measures require HERS verification in order to show compliance. HERS verification can range from a visual inspection and confirmation to a test requiring specialized equipment. HERS raters typically provide a total project verification price based on the location of a project, the number of site visits required, and the number of units and measures to be verified. It is not market practice to identify the cost for an individual HERS verification, as several factors affect the cost. TRC estimated HERS verification costs including the cost for site visits and tests by a certified HERS rater. 2016 Title 24 has mandatory HERS measures, effectively requiring that a HERS rater arrive on-site for almost every new construction project. The costs below reflect HERS verification costs when all of the indicated HERS measures are employed; therefore, a different combination of HERS measures may result in different individual measure costs.

3.1.1 Single Family

Typical single family HERS verification pricing includes a set fee for each site visit and additional fees for each HERS measure to be verified during that visit. To estimate costs for each single family HERS measure, TRC used the per-site and per-measure costs shown in Figure 6.

Figure 6. Single Family HERS Verification Costs Summary

Component	Single Family
On-site visit ($/visit) – mandatory measure	$100
Additional Measure verification ($/measure)	$84
On-site visit ($/visit) – individual measure trip	$202
Registry documentation ($/measure/visit)	$25

To estimate the cost for each HERS verification in the single family building, TRC developed a scenario to estimate the number of site visits necessary for all of the HERS measures and which measures could be verified in the same trip. Based on discussion with multiple HERS raters in California, TRC identified that builders typically minimize HERS fees by scheduling HERS raters to test and verify multiple measures and units during one visit. For single family, TRC assumed costs for HERS verifications include a cost for site visits to perform mandatory verifications, and additional verification costs for each non-mandatory measure. If a measure, such as QII, needs an additional trip where no other measure will be verified, a $202 fee is applied per trip. An additional trip is included for each measure to account for an initial model field verification, as required by the HERS testing procedures.[4] From discussions with HERS raters, common practice is to conduct a site visit to test one sample home in order for a builder to make any necessary adjustments before the rest of the homes are tested. Figure 7 provides a summary of the total costs per HERS Measure per single family home. The costs assume that one in five homes (two for QII) are tested, which reduces the cost per home.

Figure 7. Single Family Total HERS Measure Costs Summary

Single Family HERS Measure	Cost/Home
Duct Leakage (Mandatory; sampling 1-in-5)	$90
Verified Airflow/Fan Efficiency (Mandatory; sampling 1-in-5)	$90
Whole Building Mechanical Ventilation (Mandatory; sampling 1-in-5)	$90
Quality Insulation Installation (Sampling 1-in-2)	$444
Compact Hot Water Distribution (Sampling 1-in-5)	$83
Piping Insulation, All Hot Water Lines (Sampling 1-in-5)	$83
Verified Refrigerant Charge (Sampling 1-in-5)	$83
Total cost per single family home	**$964**

[4] CEC. (2015). 2016 Reference Appendices for the 2016 Building Energy Efficiency Standards.

3.1.2 Low-rise Multifamily

For multifamily buildings, HERS Rating companies either price by the number of site visits required or by the number of dwelling units. HERS raters use built in assumptions about the number of dwelling units to be verified (1-in-5 or 1-in-7) when estimating the cost per visit or per unit.

The values in Figure 8 depict the two multifamily HERS pricing methods:

- Method 1 is to price per-site-visit required. Measures that require multiple visits and large projects that cannot be verified in one visit due to construction schedules will be more costly.
- Method 2 is to price per-unit. This method makes general assumptions on a standard number of visits per measure and averages costs amongst the number of units in a project.

The cost for multiple site visits is captured in Method 1 simply by requiring a flat fee for each visit. In Method 2, QII adds an additional $50 to each unit cost due to multiple site visits required.

Figure 8. Low-rise Multifamily HERS Verification Costs Summary

Component		Multifamily
Method 1	On-site visit ($/visit)	$213
	Registry documentation ($/measure/visit)	$25
Method 2	Per unit verification, no QII ($/unit)	$175
	Per unit cost of QII ($/unit)	$50
	Registry documentation ($/unit)	$25

To estimate costs for each HERS verification in the low-rise multifamily building, TRC developed cost estimates using both methods. For Method 1, which has a fee per site visit, TRC developed three scenarios to estimate the costs for the low, middle, and highest case scenarios for the number of site visits required for each HERS measure. For Method 2, TRC priced the HERS verifications using the prototype building, including the cost for QII. To be conservative, TRC assumed that measures that require more than one site visit would be scheduled separately as additional visits. In practice, it is common and more economical for builders to schedule multiple verifications during a single visit. The final per measure costs in Figure 9 represent the average Method 1 and Method 2.

Figure 9. Low-rise Multifamily Total HERS Measure Costs Summary

Multifamily HERS Measure	Total Cost/Building
Duct Leakage (Mandatory)	$198
Verified Airflow/ Fan Efficiency (Mandatory)	$159
Whole Building Mechanical Ventilation (Mandatory)	$159
Quality Insulation Installation	$625
Compact Hot Water Distribution	$255
Piping Insulation, All Hot Water Lines	$255
Verified Refrigerant Charge	$223
Verified Low Leakage Ducts in Conditioned Space	$263
Total cost per multifamily building	**$2,138**

3.2 Envelope Measures

3.2.1 Quality Insulation Installation (QII) (HERS)

In 2016 Title 24, QII is a compliance credit for the performance path.[5] QII ensures that insulation is installed properly in floors, walls, and roofs/ceilings to maximize the thermal benefit of insulation. Depending on the type of insulation used, QII can be simple to implement for only the additional cost of HERS verification. Batt insulation may require an increase in installation time because the insulation needs to be cut to fit around penetrations and special joists. Although this should be standard practice, feedback from the field is that installers do not typically take the time to do it properly.

Measure costs shown in Figure 10 are drawn from the findings of the 2016 Residential High-Performance Walls and QII CASE Report.[6,7] Additionally, TRC spoke with over 14 HERS raters to gather more recent cost estimates. TRC assumed an increase in labor time to account for a learning curve for insulation installers.

Figure 10. Residential QII Incremental Costs Summary

Component/Material	Base Case	Proposed Update	Additional Labor (hour)	Average Installation Labor[1]	HERS Verification	Total Cost
Single Family	Standard	Improved	2.1	$103	$427	**$530**
Low-rise Multifamily	Standard	Improved	9.7	$466	$764	**$1,230**

[1] Installation labor varies by climate region. Values in Figure represents average labor cost.

3.2.2 Cool Roof

Cool roof requirements in Title 24 are specific to roof slope and building type. Title 24 defines low-sloped roofs as having a roof pitch of ≤2:12. Low-sloped roofs are generally found on high-rise multifamily and commercial construction, and can be built with a variety of roofing products. Steep-sloped roofs are more typical of low-rise residential construction in California, and are built with asphalt shingles or concrete or clay tile. For this analysis, only steep-sloped roofs were included based on the prototypes.

To develop cost estimates, TRC conducted interviews with roofers and roof supply distributors throughout California. In addition to interviews, TRC reviewed product material costs from online retailers. 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.

TRC gathered costs for asphalt shingles and concrete and clay tile that meet the current and proposed aged solar reflectance (ASR) values for steep-sloped roofs. Several interviewees mentioned that the cool roof properties of tile do not impact costs, and that costs are associated with color and other performance characteristics. Therefore, there is no incremental cost for tile meeting the proposed ASR value.

Although the residential prototypes specify tile roofing, TRC included cost estimates for asphalt shingles to represent the mix of roofing products employed in the market; therefore, the costs are greater than zero because asphalt shingles can carry a cost premium for cool roof products. Cool roof ASR values up to 0.29 can be met with white shingles, which have no incremental cost over current market standard shingles. Shingles in a

[5] QII is also included in a prescriptive package to trade instantaneous water heaters for storage water heaters

[6] California Utilities Statewide Codes and Standards Team. (September 2014) Residential High Performance Walls and QII Codes and Standards Enhancement Initiative. Available at: http://www.energy.ca.gov/title24/2016standards/prerulemaking/documents/2014-07-21_workshop/final_case_reports/2016_T24_CASE_Report-High_Perf_Walls-Sep2014.pdf

[7] California Utilities Statewide Codes and Standards Team. (April 2017) Quality Insulation Installation Codes and Standards Enhancement Initiative.

variety of non-white colors that meet the cool roof values can have an increased cost over their non-cool roof equivalents (i.e. consistent in other qualities such as durability), depending on the product. The incremental cost of non-white asphalt shingles meeting an ASR = 0.20 is minimal to zero, as compared to shingles meeting an ASR = 0.10. The most likely reason for this is that ASR = 0.20 is the prescriptive requirement in the majority of California climate zones, and product availability and costs have adjusted since this requirement was adopted under 2013 Title 24. However, achieving an ASR of 0.32 is significantly more expensive for asphalt shingles because white shingles cannot achieve this performance, and product selection meeting this value is currently limited. The incremental cost of each proposed ASR value is an average of asphalt shingles, both white and non-white, and tile roofing.

Figure 11 provides the incremental cost to go from the base case (ASR=0.10 or ASR=0.20) to a cool roof requirement (ASR = 0.28 or ASR = 0.32) for steep-sloped roofs. TRC only applied the cool roof measure to the prototypes in climate zones where they achieve energy savings; therefore, not all climate zones are included, some are proposed to 0.28, and others are proposed to 0.32.

Figure 11. Low-Rise Residential Steep-Sloped Cool Roof Incremental Costs Summary

Building Type	Base Case	Proposed Update	Average Incremental Costs/Building[1]
Single Family	ASR=0.10 or 0.20, TE=0.75	ASR=0.20, TE=0.85	$0
	ASR=0.10 or 0.20, TE=0.75	ASR=0.28, TE=0.85	$215
	ASR=0.10 or 0.20, TE=0.75	ASR=0.32, TE=0.85	$1,308
Low-rise Multifamily	ASR=0.10 or 0.20, TE=0.75	ASR=0.20, TE=0.85	$0
	ASR=0.10 or 0.20, TE=0.75	ASR=0.28, TE=0.85	$421
	ASR=0.10 or 0.20, TE=0.75	ASR=0.32, TE=0.85	$2,564

[1] Costs vary by climate region. Values in Figure represents average cost. The analysis found no cost difference between ASR 0.10 and 0.20; therefore, costs are the same for both base case scenarios.

3.2.3 Improved Fenestration

The National Fenestration Rating Council rates glazing performance by U-factor and Solar Heat Gain Coefficient (SHGC). U-factor rating describes the overall ability of the window (including framing) to resist heat transfer. SHGC describes how solar radiation is admitted through a window from sunlight exposure. The lower the value for each rating, the more resistive a window is to heat transfer.

This measure reduces the U-factor from the prescriptive value of 0.32 to 0.30 and, in climate zones with SHGC requirements, reduces the SHGC from the prescriptive value of 0.25 to 0.23. In climate zones without an SHGC requirement, the default SHGC is assumed to be 0.50. The cost of $0.20/ft^2 of window is based on the 2019 High Performance Windows and Doors CASE report (see Figure 12).[8]

[8] California Utilities Statewide Codes and Standards Team. (April 2017) Residential High Performance Windows and Doors Codes and Standards Enhancement Initiative.

Figure 12. Improved Glazing Incremental Costs Summary

Component	Climate Zones	Base Case	Proposed Update	Incremental Costs/Building	
				Single Family	Low-Rise Multifamily
Window	2, 4, 6-16	U-0.32/SHGC-0.25	U-0.30/SHGC-0.23	$94	$204
	1, 3 & 5	U-0.32/SHGC-0.50	U-0.30/SHGC-0.50	$94[1]	$204[1]

[1] TRC did not find product prices for 0.50 SHGC windows, and conservatively used the cost for an SHGC = 0.23, assuming these would be more expensive.

3.2.4 Insulated Door

This measure reduces the U-factor of the door from 0.50 to 0.20 in all climate zones except CZ6.[9] This proposed update is the same for both single family and low-rise multifamily building types. The 2019 High Performance Windows and Doors CASE Study suggests an incremental cost of $1.30 per unit resulting from material cost of $1.00/ft^2 of door with a 30% markup for overhead and profit (Figure 13). [10]

Figure 13. Improved Doors Incremental Costs Summary

Component	Base Case	Proposed Update	Incremental Costs/Building	
			Single Family	Low-rise Multifamily
Door	U-0.50	U-0.20	$26	$208

3.2.5 High Performance Walls (HPW)

High performance walls (HPW) increase the performance of the exterior above-grade walls, reducing the amount of heat transfer and reducing HVAC loads. This measure requires a lower wall U-factor, which can be achieved through various assemblies; this analysis uses improved insulation within 2x6 studs. This measure reduces the required U-factor in each climate zone beyond the 2016 T24 prescriptive requirements, except in climate zones CZ6 and CZ7 where a reduced U-factor was not found to cost effective at this time. U-0.051 is proposed in CZ6 for the LRMF prototype. Climate zones with prescriptive U-factor wall requirements of 0.051 are upgraded to 0.043, consistent with the 2019 High Performance Walls CASE Report value. [11]

Costs for this upgrade were derived from the 2019 CASE Report, which assumes U-0.051 is achieved using R-21 cavity insulation and R-4 exterior insulation, and U-0.043 is achieved using R-21 cavity insulation and an R-7.5 exterior insulation. The 2016 Title 24 CASE Report used R-19 and R-5 exterior insulation to estimate costs, but the 2019 Title 24 draft CASE Report suggests that installing R-21 and R-4 exterior insulation is a more common practice. The incremental cost includes upgrading to R-7.5 insulation, increasing weep screed and window flashing depth, and installing the continuous exterior insulation by hand rather than the traditional nail gun. These additional components are required when exterior insulation exceeds 1”. Costs to upgrade from 0.065 to 0.051 in CZ6 are derived from the 2016 Title 24 CASE Report and the 2019 Title 24 CASE Report (Figure 14).

[9] This was done to keep consistent with TRC’s previously developed study for Santa Monica’s reach code.

[10] California Utilities Statewide Codes and Standards Team. (April 2017) Residential High Performance Windows and Doors Codes and Standards Enhancement Initiative.

[11] California Utilities Statewide Codes and Standards Team. (March 2017) Residential High Performance Walls Codes and Standards Enhancement Initiative.

Figure 14. High Performance Walls Incremental Costs Summary

Climate Zone	Base Case	Proposed Update	Incremental Costs/Building	
			Single Family	Low-rise Multifamily
1-5 & 9-16	U-0.051	U-0.043	$913	$2,299
6	U-0.065	U-0.051	-	$1,615

3.2.6 High Performance Attics (HPA)

The high performance attics (HPA) measure assumes insulation is installed at the ceiling and at the roof deck, either above or below the deck. In most climate zones, the prescriptive standard assembly for 2016 Title 24 is an HPA consisting of R-38 insulation at the ceiling and R-13 insulation below the roof deck. TRC evaluated combinations of ceiling and roof deck insulation to achieve a HPA based on current 2016 Title 24 prescriptive requirements for each climate zone. This measure requires adding below roof deck insulation of R19. There are several other options for above or below deck insulation that meet the prescriptive requirement, as noted in the 2016 Title 24 High Performance Attics CASE Report.[12]

Measure costs include installing R-13 below deck insulation in CZ 1 and upgrading from R-13 to R-19 below deck insulation in CZs 8-16. TRC used cost data from the 2016 CASE Report, the 2019 Draft CASE Report, and online retailers.[13] Deck insulation costs are based on batt insulation with cabling to hold the insulation in place, as referenced in the 2019 Draft CASE Report. Figure 15 provides total incremental costs for each of the proposed measures.

Figure 15. High Performance Attics Measure Costs Summary

Climate Zone	Base Case	Proposed Update	Incremental Costs/Building	
			Single Family	Low-rise Multifamily
1	R-38	R-38 + R-13	$1,387	$2,784
8-16[1]	R-38 + R-13	R-38 + R-19	$460	$1,462

[1] R-19 is proposed only for single family in climate zone 8.

3.2.7 Reduced Infiltration ACH50 (HERS)

As described in Section 3.4.3, verified low leakage ducts in conditioned space requires that a HERS rater test envelope leakage (i.e. a blower door test) on low-rise multifamily dwelling units, and that the total duct leakage to the outside does not exceed 25 cfm.[14] QII, described in Section 3.2.1, reduces building infiltration through proper sealing and helps a project meet the 25 cfm requirement for duct leakage to the outside. Thus, for the analysis, TRC assumed QII and verified low leakage ducts in conditioned space can be implemented in order to achieve building infiltration reduction in low-rise multifamily buildings.

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[12] California Utilities Statewide Codes and Standards Team. (July 2014) Residential High Performance Walls Codes and Standards Enhancement Initiative. Available at: http://www.energy.ca.gov/title24/2016standards/prerulemaking/documents/2014-07-21_workshop/case_reports/2016_Title_24_Draft_CASE_Report-Residential_Ducts_in_Conditioned_Space-High_Performance_Attics.pdf

[13] California Utilities Statewide Codes and Standards Team. (April 2017) Residential High Performance Attics Codes and Standards Enhancement Initiative.

[14] Additionally, although not covered under Title 24, LEED for Homes requires that low-rise residential projects verify leakage to the outside. TRC interviewed HERS raters who have worked on LEED projects and have experience with this procedure.

Based on discussions with HERS raters and HVAC contractors, TRC assumes that the low-rise multifamily building would reduce infiltration down to five air changes per hour at 50 Pascals (5 ACH50), 30% lower than the 7 ACH50 software default, as a result of implementing QII and HERS verified low leakage ducts in conditioned space.[15] CBECC-Res simulation software does not allow this measure to be implemented in low-rise multifamily buildings (because there is no CEC-defined verification test method), hence the associated savings are evaluated by extrapolating the savings from single family simulations.

For single family homes, TRC assumes that only QII is applied to help reduce infiltration rates (verified low-leakage ducts in conditioned space does not apply to single family homes because the ducts are assumed to be in a vented attic). The baseline infiltration of single family homes is 5 ACH50, which is proposed to be reduced to 3 ACH50. As per the PG&E CALGreen Cost Effectiveness Study, the incremental cost for reducing infiltration by 2 ACH50 (i.e., from 5 ACH50 to 3 ACH50) is $0.115 per square foot of conditioned floor area for single family homes.[16]

For low-rise multifamily buildings, TRC also estimates an additional cost of $0.115/ft^2 based on data available from the National Renewable Energy Laboratory (NREL) residential cost database.[17] See Figure 16 for full costs per building. Verification costs associated with QII and verified low leakage ducts are added separately.

Figure 16. Infiltration Incremental Costs Summary

Base Case	Proposed Update	Incremental Costs/Building	
		Single Family	Low-rise Multifamily
5 ACH50	3 ACH50	$276	-
7 ACH50	5 ACH50	-	$800

3.3 DHW Measures

3.3.1 Hot Water Piping Insulation of All Lines (HERS)

Part 6 of the 2016 Title 24 Standards include mandatory pipe insulation requirements that cover all hot water pipes ¾” and larger, as well as the hot water lines running to the kitchen use point. To receive compliance credit for pipe insulation, all pipes between the water heater and fixtures that are not covered under the mandatory requirement must be insulated and verified by a HERS rater. This measure is applied to all climate zones in single family and multifamily building types.

Beginning on January 1, 2017 the 2016 California Plumbing Code requires pipe insulation levels that are similar to that required if taking the non-HERS pipe insulation credit. Thus, the non-HERS credit is obsolete under the 2016 energy code and all pipes must be insulated. However, the HERS-Verified Pipe Insulation Credit will remain. While CBECC-Res algorithms have not yet been updated to reflect this change, for this analysis we assumed that the revised HERS verified credit would be equivalent to the current credit for pipe insulation without HERS

15 HERS raters and building professionals indicated that these two measures combined could likely achieve 3 ACH50. Thus, 5 ACH50 is a conservative assumption.

16 Davis Energy Group (September 2016) CALGreen Cost Effectiveness Study. CA Statewide Codes and Standards Program.

17 National Renewable Energy Laboratory (NREL) National Residential Efficiency Measure Database v3.0.0.

verification. TRC ran simulations that demonstrated the HERS credit is roughly twice that for pipe insulation without verification, in terms of TDV energy.[18]

Due to the 2016 California Plumbing Code requiring that all DHW pipes be insulated, the measure cost only consists of the additional HERS verification required to receive performance credit under Title 24. The HERS verification cost in Figure 17 is derived using the HERS verification methods described above.

Figure 17. Residential Pipe Insulation Incremental Costs Summary

Component/ Material	Base Case	Proposed Update	Single Family	Low-rise Multifamily
HERS Verification	None	Verified	$175	$131

3.3.2 Compact Hot Water Distribution (HERS)

Compact DHW distribution is a design strategy that reduces the length of pipe runs from the water heater to appliances and fixtures. Designing a project to meet compact DHW distribution requires forethought in floor plan and fixture placement, and/or moving a water heater to a location closer to fixtures (e.g. the attic, an exterior or interior closet). Generally, compact distribution limits the hot water pipe length between the water heater and the fixtures, thus reducing distribution heat losses, as well as water waste and time waiting for hot water to arrive to the fixture. The maximum allowed pipe lengths to qualify under the 2016 as a compact distribution compliance option are outlined in Residential Reference Appendices RA3.6.5.

Feedback from HERS raters indicates that code vaguely defines compact distribution and that it is not yet widely adopted in single family new construction. Compact distribution in single family homes can be done in a variety of ways, but this study assumes that the water heater must be moved to an interior wall of the garage, in accordance with the 2019 Draft Compact Hot Water Distribution CASE Study.[19] The low-rise multifamily prototype, which has individual water heaters and dwelling units that are typically smaller than a single family home, does not require significant changes to water heater location, floorplan, or piping design to achieve compact distribution.

TRC derived material and labor impacts from the 2019 CASE Study, and related costs from RS Means and online retailers.

Figure 18. Compact Distribution Incremental Costs Summary

Base Case	Proposed Update	Single Family	Low-rise Multifamily
Standard design	None	$498	$0
No Verification	HERS Verified	$175	$131
Total Costs		**$673**	**$131**

[18] Analysis performed in accordance with: Davis Energy Group (September 2016) CALGreen Cost Effectiveness Study. CA Statewide Codes and Standards Program.

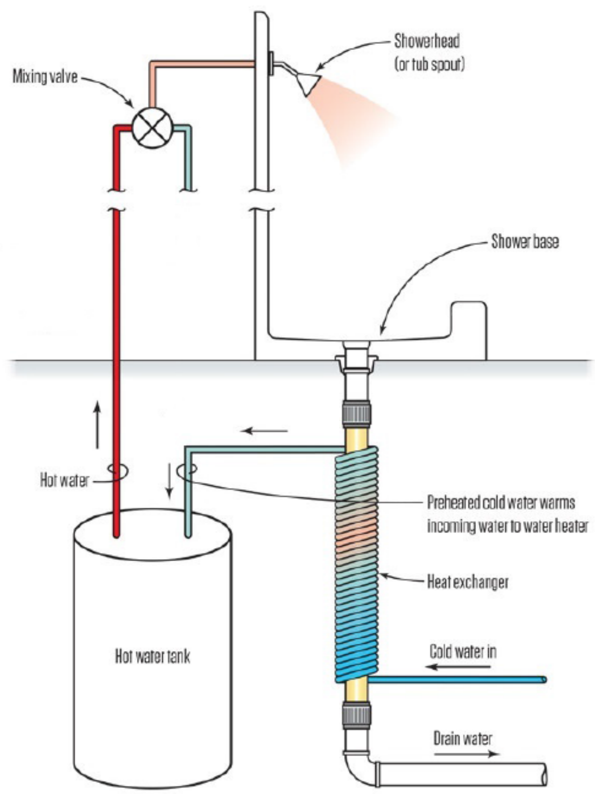
[19] California Utilities Statewide Codes and Standards Team. (April 2017) Residential Compact Hot Water Distribution Codes and Standards Enhancement Initiative.

3.3.3 Drain Water Heat Recovery

Drain water heat recovery (DWHR) is a technology used to reduce the amount of energy needed by a water heater or fixture to heat incoming water to the required temperature. The technology utilizes a heat exchanger in the shower drain line to pre-heat cold water supplied to the cold water side of a water heater or fixtures. There are multiple configurations possible, and Figure 19 shows DWHR in an equal flow configuration where all makeup flow is directed to the water heater. In an equal flow configuration, makeup flow is piped to both the water heater and the shower.

To avoid overlapping interactive effects with other DHW measures, TRC assumed an unequal flow configuration where preheated water is directed only to the water heater. This configuration reduces the energy necessary to heat cold water entering the water heater, and should not overlap with the pipe insulation and compact DHW measures, which reduce pipe distribution losses.

Figure 19. Drain Water Heat Recovery in Unequal Flow Configuration (Journal of Light Construction, September 2016)



DWHR is currently most commonly installed in a vertical configuration, so only the two-story single-family prototype will have the vertical space necessary to locate the system below showers. CBECC-Res cannot currently model the benefits of Drain Water Heat Recovery, so TRC used energy performance data and cost data from the 2019 Title 24 Draft CASE Study to estimate the maximum potential energy savings in the two-story

2,700 ft^2 single family prototype assuming an unequal flow to the water heater configuration.[20] Energy savings were translated from 2019 TDV to 2016 TDV, resulting in savings between 15-17% of the total DHW TDV energy (1%-10% of the total building TDV energy) depending on the climate zone.

The additional cost to implement DWHR, as estimated by the 2019 CASE study, is $731 for a two-story single family building, assuming a single device can be connected to all second floor showers. This measure was not applied to the low-rise multifamily prototype because each dwelling unit has an individual water heater without adequate vertical piping to apply the DWHR device; DWHR are more cost effective in multifamily buildings with a central water heater.

3.4 HVAC Measures

3.4.1 AHU Reduced Fan Watt Draw (0.3 W/CFM)

This measure upgrades the fan in the furnace or air handler from one using a permanent split capacitor (PSC) motor to one with an electronically commutated motor (ECM) that meets an efficacy of 0.3 watts/cfm or lower operating at full speed. New federal regulations that go into effect July 3, 2019 are expected to result in equivalent performance for all newly manufactured furnaces provided that the ducts are sized properly. Costs are based on the PG&E CALGreen Cost Effectiveness Study (Figure 20).[21] Fan watt draw is a mandatory HERS measure; therefore the cost does not include HERS verification fees.

Figure 20. Reduced Fan Watt Draw Incremental Costs Summary

Component/Material	Base Case	Proposed Update	Single Family	Low-rise Multifamily
ECM Motor	0.58 watts/cfm	0.30 watts/cfm	$143	$832

3.4.2 Verified Refrigerant Charge

This measure requires that a HERS rater verify the amount of refrigerant in an air-cooled conditioner or air-source heat pump system is at an appropriate level. Having too much (overcharge) or too little (undercharge) can reduce the efficiency of a system and result in early failure. The correct refrigerant charge can improve the performance of a system and reduce energy wasted from an inefficient system. The costs, as shown in Figure 21, assume HERS sampling of HVAC units for multifamily buildings.[22]

Figure 21. Refrigerant Charge Verification Incremental Costs Summary

Component	Base Case	Proposed Update	Single Family	Low-rise Multifamily
HERS Verification	None	Verified	$175	$131

[20] California Utilities Statewide Codes and Standards Team. (April 2017) Residential Drain Water Heat Recovery Codes and Standards Enhancement Initiative.

[21] Davis Energy Group (September 2016) CALGreen Cost Effectiveness Study. CA Statewide Codes and Standards Program.

[22] Sampling is typically done by performing testing on one out of every five or seven dwelling units, as determined by the HERS rater and project team.

3.4.3 Verified Low-leakage Ducts Entirely in Conditioned Space

This measure verifies that ducts and air handling equipment are located in conditioned space and meet the CEC's definition that leakage to the outside cannot exceed 25 cubic feet per minute (cfm). This low leakage requirement is achieved through three verifications:

- Duct leakage test
- Envelope leakage test (i.e., blower door test)
- Verify low leakage air handling unit

This measure is only implemented in the low-rise multifamily prototype. Prescriptive requirements are for ducts located in conditioned space; therefore, the only additional cost is for the HERS verification to confirm that the system meets the specified leakage values.

CEC has established a testing protocol for verification of low leakage ducts entirely in conditioned space in the Title 24 Reference Appendices, along with all other HERS verification tests. To test the building leakage in multifamily buildings, some HERS raters use a blower door test method by compartmentalizing individual dwelling units. Based on discussions with HERS raters, the estimated HERS verification cost for this measure would be equal to that of duct leakage testing. To be conservative, TRC assumes additional trips and time required beyond the duct leakage testing to estimate the cost for this measure. Thus, there is a $527 cost for low leakage ducts in conditioned space for low-rise multifamily buildings, about double that of only duct leakage testing (Figure 22).

Figure 22. Low Leakage Ducts in Condition Space Incremental Costs Summary

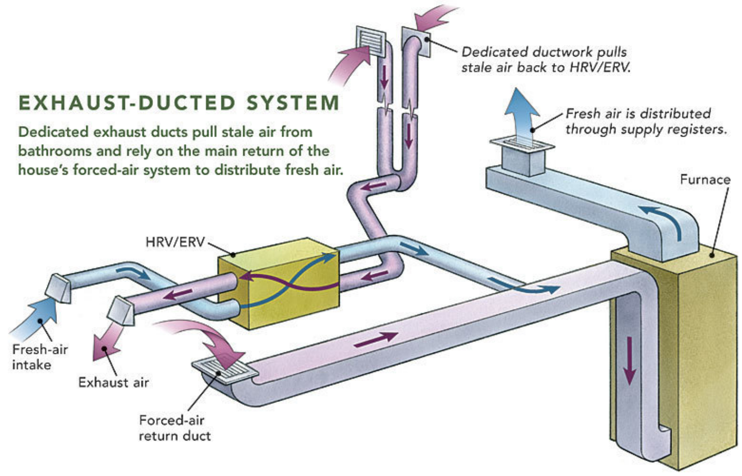
Component	Base Case	Proposed Update	Single Family	Low-rise Multifamily
HERS Verification	None	Verified	n/a	$527

3.4.4 Heat or Energy Recovery Ventilation

This measure includes installing heat or energy recovery ventilation (HRV/ERV) in single family homes to improve their energy efficiency and indoor air quality. It introduces a 'balanced' mechanical ventilation system, which exhausts air from bathrooms and supplies outdoor air in equal quantities using the existing ductwork (see Figure 23). TRC used the Home Ventilating Institute (HVI) database to identify HRV systems with airflow rates that comply with ASHRAE 62.2 ventilation standards.[23] The average Sensible Recovery Efficiency (SRE) of the selected products is 67%.

[23] https://www.hvi.org/proddirectory/CPD_Reports/section_3/index.cfm

Figure 23. Balanced HRV/ERV System Connected via Existing HVAC System



Source: http://www.finehomebuilding.com/2014/11/05/ducting-hrvs-and-ervs

Costs for this measure include the ventilator, installation of the ventilator, ducting, and wiring, and MERV6 filter replacements once per year. Costs in Figure 24 were derived from online retailers and RSMeans.

Figure 24. Heat/Energy Recovery Ventilator Incremental Cost Summary

Cost Component	Cost per Single Family Home
HRV/ERV fan	$700
Installation, including ducting	$415
Filter replacements	$186
Total Cost	**$1,301**

3.5 Solar Photovoltaics

To meet the CEC's current proposed goal for 2019 Title 24 at the time of this analysis, the PV system must be sized to offset the building's annual electricity consumption (after accounting for energy efficiency measures).[24] TRC estimated solar PV costs in coordination with the CEC and their consultant, Energy and Environmental Economics (E3). E3's PV cost estimates in 2017 dollars include two inverter replacements over a 30 year lifetime, costing $0.45/W. PV systems installed in California are eligible for both the NSHP rebate and the federal solar Investment Tax Credit (ITC), which rebates 30% of the initial cost of the system. TRC determined the median NSHP incentive of $0.17/W by reviewing recent program data for systems smaller than 10 kW. Total costs in Figure 25 reflect the upfront costs to the building owner when purchasing a PV system. TRC did not investigate other financing mechanisms such as loans and leases.

[24] Based on coordination with the CEC, TRC sized solar photovoltaic (PV) generation to offset the annual electricity kWh demanded by the buildings after maximizing efficiency, which results in an EDR > 0. This is in alignment with CEC's 2019 Title 24 goal.

Figure 25. Solar Photovoltaics Incremental Costs Summary

Cost Component	2017 $/Watt
PV Median Cost, including inverter replacements	$3.32
NSHP Incentive	-$0.17
30% Federal ITC, excluding inverter replacements	-$0.81
Net Cost	**$2.34**

4. RESULTS

The cost effectiveness and greenhouse gas savings results are presented in this section for the energy efficiency and Efficiency + PV packages in each climate zone. Figure 26 and Figure 27 list the efficiency measures implemented for the single family and low-rise multifamily prototypes, respectively. These measures have been selected because they are market feasible and optimize cost effectiveness while achieving high compliance margin targets. Single family 2100 ft^2 and 2700 ft^2 prototypes are comprised of the exact same measure package, with the exception of drain water heat recovery, which is only applied to the 2700 ft^2 two-story prototype.

Figure 26: Efficiency Measure Summary for Single Family Prototype (2100 & 2700 ft^2)

Measure			Climate Zone															
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Envelope	*Quality Insulation Installation (HERS)*		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Cool Roof	*(ASR-0.28 / TE-0.85)*								x	x	x						
		(ASR-0.32 / TE-0.85)											x	x	x	x	x	
	Improved Fenestration	*(U-0.30 / SHGC-0.23)*		x		x		x		x	x	x	x	x	x	x	x	x
		(U-0.30 / SHGC-0.50)	x		x		x											
	Insulated Door (U-0.20)		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	High Performance Walls (U-0.043)		x	x							x	x	x	x	x	x	x	x
	High Performance Attics (R13 below deck)		x															
	High Performance Attics (R19 below deck)									x	x	x	x	x	x	x	x	x
	Reduced Infiltration (3 ACH50)		x	x		x				x	x	x	x	x	x	x	x	x
DHW	*Hot Water Piping Insulation, All Lines (HERS)*		x	x	x	x	x			x	x	x	x	x	x	x	x	x
	Compact Hot Water Distribution (HERS)		x								x	x	x	x	x	x	x	x
	Drain Water Heat Recovery (2700 ft^2 only)		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
HVAC	*AHU Reduced Fan Watt Draw (0.3 W/CFM)*		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Verified Refrigerant Charge (HERS)		x		x	x	x		x									x
	Heat / Energy Recovery Ventilation		x	x	x	x	x					x	x	x	x	x	x	x

Figure 27: Efficiency Measure Summary for Low-rise Multifamily Prototype

Measure			Climate Zone															
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Envelope	Quality Insulation Installation (HERS)		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Cool Roof	(ASR-0.20 / TE-0.85)					x											
		(ASR-0.28 / TE-0.85)						x	x									
		(ASR-0.32 / TE-0.85)		x		x				x	x	x	x	x	x	x	x	x
	Improved Fenestration	(U-0.30 / SHGC-0.23)		x		x		x		x	x	x	x	x	x	x	x	x
		(U-0.30 / SHGC-0.50)	x		x		x											
	Insulated Door (U-0.20)		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	High Performance Walls (HPW)	(U-0.051)						x										
		(U-0.043)	x	x		x				x	x	x	x	x	x	x	x	x
	High Performance Attics (HPA)	R13 below deck	x															
		R19 below deck									x	x	x	x	x	x	x	x
	Reduced Infiltration (5 ACH50)		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
DHW	Hot Water Piping Insulation, All Lines (HERS)		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Compact Hot Water Distribution (HERS)		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
HVAC	AHU Reduced Fan Watt Draw (0.3 W/CFM)		x	x	x	x		x	x	x	x	x	x	x	x	x	x	x
	Verified Refrigerant Charge (HERS)		x		x	x	x	x	x									x
	Verified Low-Leakage Ducts Entirely in Conditioned Space (HERS)		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

4.1 Cost Effectiveness

TRC determined cost effectiveness by comparing the incremental cost of each measure package (Figure 26 and Figure 27) to the NPV of energy cost savings over the 30-year period. Results include measure compliance margin, present value of energy savings, costs, and B/C ratio.

TRC developed cost effectiveness for two scenarios:

- **Energy Efficiency Only:** The efficiency package energy savings benefits are measured in terms of TDV, in accordance with CEC Life Cycle Cost methodology typically used in CASE studies. The compliance margin achieved in these packages reflects only energy efficiency packages, and no solar PV or PV compliance credit.
- **Energy Efficiency + PV (EE + PV) Package:** The EE + PV package adds enough solar PV to the energy efficiency package to offset annual kWh load. Energy savings benefits are measured in terms of on-bill savings in accordance with CEC cost effectiveness analysis for solar PV.[25]

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 2.3 for further detail.

Cost-effectiveness results for the single family and multifamily prototypes are shown in Figure 28 and Figure 29, respectively:

- Column A shows the California climate zone (CZ)
- Column B shows the CALGreen Tier 3 definition targets
- Column C shows the compliance margin achieved through only the Efficiency-Only packages
- Columns D and E show the energy savings estimated with the Efficiency-Only packages
- Column F shows the TDV savings of the Efficiency-Only packages
- Column G shows the cost of the Efficiency-Only packages
- Column H is the B/C Ratio of each package (Column F divided by Column G).
- Column I shows the PV size necessary to offset annual kWh loads.
- Column J shows the 2016 EDR found to be cost effective with the efficiency package and PV array
- Column K shows the compliance margin achievable when including the PV compliance credit (refer to Figure 3 for more detail)
- Columns L and M show the energy savings estimated with the EE + PV packages.
- Column N shows the on-bill savings of the EE + PV packages
- Column O shows the cost of the EE + PV packages
- Column P is the B/C Ratio of each package (Column N divided by Column O).

[25] During the development of this study, CEC was in the process of developing TDV values for excess PV generation; TDV for the EE + PV packages are not currently included.

Single family results are as follows:

- Cost effective reach code packages were found in all climate zones except efficiency-only in CZ7. All EE + PV packages are cost effective using the on-bill cost effectiveness methodology.
- CALGreen Tier 3 compliance targets are achieved in all CZs when including the PV compliance credit (column K). When excluding the PV compliance credit, CZs 4 and 8 do not achieve the CALGreen Tier 3 compliance targets.

Low-rise multifamily results are as follows:

- Cost effective packages were found in all climate zones except efficiency-only in CZ7. All EE + PV packages are cost effective using the on-bill cost effectiveness methodology.
- CALGreen Tier 3 compliance targets are achieved in all CZs except CZs 1, 2, 5, 7, and 8 when including the PV compliance credit (column K). When excluding the PV compliance credit, only CZs 6 achieves the CALGreen Tier 3 compliance target.

Figure 28. Cost Effectiveness Results for Single Family Prototype (Average of 2100 & 2700 ft^2)

CZ		ENERGY EFFICIENCY ONLY PACKAGE (TDV)						EE + PV PACKAGE (ON-BILL)							
	CALGreen Tier 3 Target	Comp-liance Margin	Annual kWh savings	Annual Therm savings	Present Value of Savings (TDV)	Present Value of Costs	B/C Ratio	PV Size (kW)	2016 Energy Design Rating	Compliance Margin with PV Compliance Credit	Annual kWh savings	Annual Therm savings	Present Value of Savings (On-Bill)	Present Value of Costs	B/C Ratio
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	**30%**	40%	341	278	$9,882	$5,807	1.7	3.6	18	49%	4,683	278	$45,481	$14,326	3.2
2	**30%**	31%	234	148	$6,066	$3,755	1.6	3.1	18	40%	4,661	148	$37,896	$11,093	3.4
3	**30%**	31%	147	120	$4,714	$2,705	1.7	3.0	13	39%	4,573	118	$35,181	$9,915	3.5
4	**30%**	28%	180	109	$4,673	$2,925	1.6	3.0	16	48%	4,650	109	$35,729	$10,053	3.6
5	**30%**	35%	140	127	$4,983	$3,169	1.6	2.8	11	43%	4,592	127	$35,226	$9,910	3.6
6	**15%**	16%	63	15	$1,279	$1,171	1.1	2.6	16	16%	3,461	15	$16,192	$7,305	2.2
7	**15%**	16%	21	11	$777	$1,680	0.5	2.5	13	16%	3,434	11	$20,600	$7,567	2.7
8	**30%**	28%	137	13	$2,344	$2,065	1.1	2.7	13	56%	3,668	13	$17,289	$8,374	2.1
9	**30%**	31%	259	24	$4,230	$3,560	1.2	2.7	15	57%	3,958	24	$18,850	$9,939	1.9
10	**30%**	34%	353	80	$6,492	$4,860	1.3	3.2	13	57%	4,842	80	$33,373	$12,470	2.7
11	**30%**	34%	799	139	$11,694	$5,789	2.0	3.7	18	53%	6,425	139	$51,718	$14,624	3.5
12	**30%**	36%	389	135	$8,728	$5,789	1.5	3.2	17	59%	5,086	135	$40,260	$13,443	3.0
13	**30%**	34%	837	124	$11,598	$5,789	2.0	3.9	18	54%	6,642	124	$52,376	$15,080	3.5
14	**30%**	34%	759	138	$11,106	$6,552	1.7	3.3	19	51%	5,689	138	$32,751	$14,312	2.3
15	**30%**	31%	1,872	28	$14,252	$6,552	2.2	5.1	15	48%	9,586	28	$51,947	$18,534	2.8
16	**30%**	31%	420	236	$9,517	$5,231	1.8	2.5	23	47%	4,904	236	$45,321	$11,142	4.1

Figure 29. Cost Effectiveness Results for Low-rise Multifamily Prototype

CZ		ENERGY EFFICIENCY ONLY PACKAGE (TDV)						EE + PV PACKAGE (ON-BILL)							
	CALGreen Tier 3 Target	Comp-liance Margin	Annual kWh savings	Annual Therm savings	Present Value of Savings (TDV)	Present Value of Costs	B/C Ratio	PV Size (kW)	2016 Energy Design Rating	Compliance Margin with PV Compliance Credit	Annual kWh savings	Annual Therm savings	Present Value of Savings (On-Bill)	Present Value of Costs	B/C Ratio
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	**30%**	21.3%	262	234	$9,068	$8,449	1.1	15.3	15	26%	20,676	234	$128,705	$44,267	2.9
2	**30%**	21.0%	483	119	$9,311	$8,406	1.1	13.2	16	26%	21,192	119	$127,503	$39,498	3.2
3	**15%**	12.6%	54	86	$3,875	$3,366	1.2	13.0	13	16%	20,580	86	$120,910	$33,921	3.6
4	**30%**	21.2%	479	95	$8,618	$8,406	1.0	12.9	11	32%	21,323	95	$127,460	$38,820	3.3
5	**15%**	11.0%	-24	79	$3,224	$2,534	1.3	12.3	12	14%	20,587	79	$120,484	$31,334	3.8
6	**15%**	16.9%	306	45	$5,319	$5,076	1.0	13.2	14	17%	21,169	45	$110,604	$36,028	3.1
7	**15%**	11.1%	127	16	$3,109	$3,257	0.95	12.6	16	11%	20,822	16	$101,450	$32,934	3.1
8	**30%**	19.1%	659	28	$7,816	$7,069	1.1	13.9	15	28%	22,626	28	$118,344	$39,612	3.0
9	**30%**	23.4%	1007	43	$12,528	$8,531	1.5	13.8	16	35%	23,604	43	$123,512	$40,957	3.0
10	**30%**	21.9%	1076	52	$11,848	$8,531	1.4	14.2	15	32%	24,231	52	$126,000	$41,748	3.0
11	**30%**	24.9%	1889	131	$21,033	$8,827	2.4	15.6	18	34%	26,705	131	$173,607	$45,417	3.8
12	**30%**	24.2%	1031	129	$15,751	$8,827	1.8	14.2	19	34%	23,244	129	$144,832	$42,071	3.4
13	**30%**	25.2%	2053	114	$21,629	$8,827	2.5	16.3	18	34%	27,298	114	$177,170	$47,171	3.8
14	**30%**	24.5%	1763	131	$19,650	$8,827	2.2	13.7	20	33%	26,385	131	$142,912	$40,949	3.5
15	**30%**	25.8%	4613	12	$31,532	$8,827	3.6	19.7	18	33%	37,580	12	$203,040	$54,984	3.7
16	**30%**	23.1%	912	270	$15,742	$8,827	1.8	12.5	23	31%	22,067	270	$141,531	$38,095	3.7

4.2 Greenhouse Gas Savings

New construction low-rise residential buildings complying with the reach code will reduce energy consumption and thereby reduce greenhouse gas (GHG) emissions. GHG reduction estimates are based on the proposed Efficiency + PV packages, however, compliance with the reach code may be achieved through a variety of measure packages. Each measure package will have varying electric and natural gas usages, and therefore varying GHG savings.

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 to estimate GHG savings.[26] Percent GHG savings are calculated by comparing GHG emission savings to the emissions a prescriptive building. Jurisdictions adopting a reach code can use Figure 30 and Figure 31 below to approximate reductions of GHG emissions in typical single family and low-rise multifamily residential buildings, respectively.

Figure 30. Estimated GHG Savings per Single Family Building

CZ	kWh Savings / Bldg	Therms Savings / Bldg	Lbs CO_2e Avoided / Bldg from Electricity	Lbs CO_2e Avoided/ from Natural Gas	GHG Savings %
1	4,683	278	3,044	3,252	54%
2	4,661	148	3,029	1,726	50%
3	4,573	118	2,973	1,375	55%
4	4,650	109	3,023	1,281	52%
5	4,592	127	2,985	1,488	58%
6	3,461	15	2,249	171	44%
7	3,434	11	2,232	134	49%
8	3,668	13	2,384	158	49%
9	3,958	24	2,573	281	51%
10	4,842	80	3,147	932	58%
11	6,425	139	4,176	1,624	59%
12	5,086	135	3,306	1,582	53%
13	6,642	124	4,317	1,455	60%
14	5,689	138	3,698	1,613	54%
15	9,586	28	6,231	327	74%
16	4,904	236	3,187	2,764	45%

[26] 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.

Figure 31. Estimated GHG Savings for Low-rise Multifamily building

CZ	kWh Savings / Bldg	Therms Savings / Bldg	Lbs CO_2e Avoided / Bldg from Electricity	Lbs CO_2e Avoided/ from Natural Gas	GHG Savings %
1	20,676	234	13,439	2,737	53%
2	21,192	119	13,775	1,387	53%
3	20,580	86	13,377	1,004	56%
4	21,323	95	13,860	1,115	56%
5	20,587	79	13,382	919	56%
6	21,169	45	13,760	530	59%
7	20,822	16	13,534	192	59%
8	22,626	28	14,707	332	61%
9	23,604	43	15,342	499	62%
10	24,231	52	15,750	609	63%
11	26,705	131	17,358	1,536	61%
12	23,244	129	15,108	1,505	57%
13	27,298	114	17,744	1,334	62%
14	26,385	131	17,150	1,532	61%
15	37,580	12	24,427	140	76%
16	22,067	270	14,344	3,155	47%

4.3 Reach Code Recommendations

TRC recommends that California jurisdictions adopt reach codes meeting the compliance margin and EDR requirements in Figure 32:

- If a jurisdiction desires an efficiency-only reach code, the efficiency-only compliance margin may be used in the ordinance.
- If a jurisdiction desires an Efficiency + PV reach code, the Efficiency + PV compliance margin and 2016 EDR may be used in the ordinance. New construction residential buildings would need to achieve the recommended compliance margins and install solar PV to achieve the 2016 EDR target.[27]

Recommended reach code values are more lenient than the levels found to be cost effective – compliance margins are rounded down, and EDR values are rounded up. To create more lenient reach codes, jurisdictions can draft ordinances further reducing compliance margins or increasing EDR requirements beyond those recommended for more lenient reach codes. There is no energy efficiency target compliance margin target for low rise residential buildings in CZ7 because TRC did not find a cost effective package of efficiency-only measures. However, because the EE + PV packages are cost effective using the on-bill methodology, TRC has provided the recommendations for reach code compliance margins and EDR ratings.

[27] EDR Targets are highly dependent on TDV. 2016 TDVs are significantly different than 2019 TDVs, which will result in different 2019 EDR Targets. Nonetheless, the solar PV size required to achieve comparable EDR targets is not expected to vary by more than 0.5 kW array size.

Figure 32. New Construction Residential Reach Code Recommendations for 2016 Title 24

CZ	Single Family			Low-rise Multifamily		
	Compliance Margin Efficiency-Only	Compliance Margin Efficiency + PV	2016 Energy Design Rating Efficiency + PV	Compliance Margin Efficiency-Only	Compliance Margin Efficiency + PV	2016 Energy Design Rating Efficiency + PV
1	40%	45%	20	20%	25%	15
2	30%	35%	20	20%	25%	20
3	30%	35%	15	10%	15%	15
4	25%	45%	20	20%	30%	15
5	30%	40%	15	10%	10%	15
6	15%	15%	20	15%	15%	15
7	None	15%	15	None	10%	20
8	25%	55%	15	15%	25%	20
9	30%	55%	15	20%	30%	20
10	30%	55%	15	20%	30%	15
11	30%	50%	20	20%	30%	20
12	35%	55%	20	20%	30%	20
13	30%	50%	20	25%	30%	20
14	30%	50%	20	20%	30%	20
15	30%	45%	15	25%	30%	20
16	30%	45%	25	20%	30%	25

TRC recommends that individual projects consider battery storage technology alongside PV installations to achieve reach code requirements while reducing hourly exports to the electric grid.

4.4 Compliance

The majority of new construction T24 compliance submittals use building simulation software. CBECC-Res is a CEC approved software tool used for the 2016 Title 24 Standards. The compliance software outputs the TDV energy usage of a proposed building and the percent compliance margin compared with a standard prescriptively-compliant building. EDRs are also standard outputs of the 2016 compliant software. For nearly all the measures described in this report, local building officials can confirm that building designs meet the Reach Code by reviewing the compliance margin and residential EDR value presented in the simulation software output reports.

For design strategies that cannot currently be modeled in CEC approved software, and thus not captured adequately in the compliance margin and EDR, the applicant must show compliance through ancillary documentation:

- **DHW Compliance Credits:** Currently, CBECC only allows one DHW distribution credit in a simulation. Therefore, for example, a project that incorporates compact distribution as well as insulating all pipes can only receive credit for one of the measures through the software. DHW distribution measures will have overlapping benefits, so it is not justified to provide the full credit of each standalone measure. To comply with multiple DHW distribution measures in one prototype, TRC suggests that the permit applicant simulate the DHW distribution measure with the lowest distribution multiplier as per in Table B-1 of Appendix B in the Residential ACM Reference Manual. Then, the applicant would simulate the other DHW distribution measures individually and reduce savings proportionally by the total number of DHW distribution measures.[28,29]

- **Drain Water Heat Recovery (DWHR):** The currently available version of CBECC-Res (v3.0) cannot model the benefits of a DWHR device. A DWHR compliance credit has been submitted as a 2019 Title 24 CASE measure and is expected to be incorporated into the 2019 version of the compliance software. To use DWHR to comply with 2016 Title 24 and a Reach Code, an applicant must indicate on the plans how many water heaters are installed. TRC recommends that the building department estimate that the DWHR system reduces the DHW kTDV load by 10% if 100% of dwelling units are connected to a DWHR system and use the same ratio if less than 100% of dwelling units are connected to DWHR. The overall building compliance margin should then be adjusted with the reduced DHW load.
- **Infiltration:** To comply with low-rise multifamily reduced building infiltration, a project will need to implement and pass HERS verified QII and low leakage ducts in conditioned space. The Title 24 documentation will state that a project is implementing both of these measures and the HERS verification documents will confirm that they pass. TRC recommends that such projects be awarded an extra 1% compliance margin credit to account for reduced HVAC loads.

[28] 2016 Residential ACM Reference Manual, California Energy Commission. Available online at: http://www.energy.ca.gov/2015publications/CEC-400-2015-024/CEC-400-2015-024-CMF-REV2.pdf

[29] For two measures, the savings of each measure simulated individually would be halved, for three measures, the savings would be 1/3, and so on.

5. Appendix A – Cost Data

The following figures provide detailed cost when necessary for the measures presented in Section 3.

Figure 33. Single Family HERS Verification Base Cost

	Single Family
On-site visit ($/visit)	$220
Standard measure verification ($/measure)	$45
Additional measure verification ($/measure)	$100
Registry documentation ($/measure/visit)	$25

Figure 34. Single Family HERS Verification Detailed Costs

Single Family HERS Measure	"Test" Visit	Site Visit 1	Site Visit 2	Site Visit 3	Total # Visits	Total Cost[2]
Duct Leakage (Mandatory)	X			X	2	$250
Verified Airflow/ Fan Efficiency (Mandatory)	X			X	2	$250
Whole Building Mechanical Ventilation (Mandatory)	X			X	2	$250
Quality Insulation Installation[1]	X	X	X	X	4	$427
Compact Hot Water Distribution[1]	X		X		2	$175
Piping Insulation, All Hot Water Lines[1]	X		X		2	$175
Verified Refrigerant Charge[1]	X			X	2	$175

[1] Denotes projects that can be verified using sampling; the cost analysis assumed 1-in-2 sampling

[2] Assumes measures that require 2 or more on-site visits will be optimally scheduled

Figure 35. Multifamily HERS Verification Base Costs

	Single Family
On-site visit ($/visit)	$213
Non-mandatory additional measure verification ($/visit)	$50
Registry documentation ($/measure/visit)	$25

Figure 36. Multifamily HERS Verification Detailed Costs

Single Family HERS Measure	Best Case # Site Visits	Mid Case # site visits	Worst Case # site visits	Avg. Measure Cost[1]
Duct Leakage (Mandatory)	1	1	2	$122
Verified Airflow/ Fan Efficiency (Mandatory)	1	1	1	$52
Whole Building Mechanical Ventilation (Mandatory)	1	1	1	$52
Quality Insulation Installation	3	4	5	$764
Compact Hot Water Distribution	1	1	2	$131
Piping Insulation, All Hot Water Lines	1	1	2	$131
Verified Refrigerant Charge	1	1	2	$131
Verified Low Leakage Ducts in Conditioned Space	2	3	4	$527

[1] Assumes that measures that require 2 or more on-site visits will be scheduled individually without consideration of other measures.

Figure 37. Residential Quality Insulation Installation Detailed Costs

Component/ Material	Climate Zones	Base Case	Proposed Update	Installation Labor	HERS Verification	Total Cost
Single Family	1-5	Standard	+2.1 hrs of labor	$111	$427	**$537**
	6-10			$99		**$526**
	11-13			$101		**$528**
	14-16			$101		**$528**
Low-rise Multifamily	1-5	Standard	+9.7 hrs of labor	$501	$764	**$1,265**
	6-10			$449		**$1,213**
	11-13			$457		**$1,221**
	14-16			$457		**$1,221**

Cost Source: RS Means 2017 and local HERS raters

[1] Additional labor hours is based on envelope surface area for each prototype

Figure 38. Cool Roof Detailed Costs

Component	Base Case	Proposed Update (ASR/TE)	Unit	IMC ($/unit)			
				North Coast	South Coast	North Central	Inland
Asphalt Shingles	NR	0.20/0.85	roof ft2	$1.16	$2.19	$1.35	$1.48
Concrete/Clay Tile				$1.59	$1.75	$1.59	$1.59
			Average	**$1.38**	**$1.97**	**$1.47**	**$1.53**
Asphalt Shingles	NR	0.28/0.85	roof ft2	$1.61	$1.15	$1.42	$1.52
Concrete/Clay Tile				$1.59	$1.75	$1.59	$1.59
			Average	**$1.60**	**$1.45**	**$1.51**	**$1.56**
Asphalt Shingles	NR	0.32/0.85	roof ft2	$2.47	$1.89	$2.29	$2.80
Concrete/Clay Tile				$1.59	$1.75	$1.59	$1.59
			Average	**$2.03**	**$1.82**	**$1.94**	**$2.19**
Asphalt Shingles	0.20/0.85	0.32/0.85	roof ft2	$1.31	($0.31)	$0.94	$1.32
Concrete/Clay Tile				$1.59	$1.75	$1.59	$1.59
			Average	**$0.66**	**($0.15)**	**$0.47**	**$0.66**

Source: Online retailers and roofing product distributors

Figure 39. Improved Fenestration Detailed Costs

Component	Base Case (U-factor/SHGC)	Proposed Update (U-factor/SHGC)	Unit	Units/Building		IMC ($/unit)
				SF	MF	
Residential Window	0.32/0.25	0.30/0.23	ft^2 window	480	1,044	$0.20
Residential Window	0.32/0.50	0.30/0.50				$0.20[1]

Source: Nittler, K. (2017). Codes and Standards Enhancement (CASE) Initiative: Residential High Performance Windows and Doors – Draft Report.

[1] The incremental cost for 0.30/0.23 windows is conservatively used for 0.30/0.50.

Figure 40. Insulated Door Detailed Costs

Component	Base Case (U-factor)	Proposed Update (U-factor)	Unit	Units/Building		IMC ($/unit)
				SF	MF	
Residential Door	0.50	0.20	ft^2 door	20	160	$1.30

Source: Nittler, K. (2017). Codes and Standards Enhancement (CASE) Initiative: Residential High Performance Windows and Doors – Draft Report.

Figure 41. High Performance Wall Detailed Costs

Component	Base Case (U-factor)	Proposed Update (U-factor)	Unit	Units/Building		IMC ($/unit)
				SF	MF	
Wall Framing	2x4 @ 16"	2x6 @ 16"	ft^2 wall	1,574	3,760	$0.29
Cavity Insulation	R-15	R-21	ft^2 wall	1,574	3,760	$0.05
Continuous Exterior Insulation	R-4	R-7.5	ft^2 wall	1,574	3,760	$0.20
Additional Sill Flashing (for R-7.5)	1"	1.5"	linear ft window perimeter	404	1,114	$0.22

Source: Rasin, J. and F., Farahmand. (2015). Codes and Standards Enhancement (CASE) Initiative: Residential High Performance Walls; German, A. (2017). Codes and Standards Enhancement (CASE) Initiative: High Performance Walls – Draft Report

Figure 42. High Performance Attic Detailed Costs

Component	Base Case	Proposed Case	Unit	Units/Building		IMC/unit ($/unit)
				SF	MF	
Below Deck Insulation (Batt)	R-0	R-19	roof deck ft^2	2,130	4,176	$0.97
Below Deck Insulation (Batt)	R-13	R-19	roof deck ft^2	2,130	4,176	$0.12
Cabling	none	installed	labor hrs	2	4	$44

Source: Hoeschele, M. (2017). Codes and Standards Enhancement (CASE) Initiative: High Performance Attics – Draft Report; Online retailers; RS Means 2017.

Figure 43. Reduced Infiltration Detailed Costs

Component	Base Case	Proposed Case	Unit	Units/Building		IMC/unit ($/unit)
				SF	MF	
Reduced envelope infiltration	5.0 ACH50	3.0 ACH50	CFA	2,400	6,960	$0.11

Source: Davis Energy Group, Inc., Enercomp, Inc., Misti Bruceri & Associates, LLC. (2016). *CALGreen Cost Effectiveness Study*.

Figure 44. Compact Domestic Hot Water Distribution Detailed Costs

Component	Base Case	Proposed Case	Unit	Units/Building		IMC/unit ($/unit)
				SF	MF	
¾" PEX piping (insulated)	Standard	Compact Design	linear ft	(17)	-	$2.23
1" Gas piping	Standard	Additional	linear ft	20	-	$7.18
5" Vent piping	Standard	Additional	linear ft	14	-	$21.79
Venting	Standard	Additional	labor hrs	1	-	$93.25
HERS Verification	Standard	Verified	-	-	-	See HERS verification

Source: Online retailers and RS Means 2017

Figure 45. Drain Water Heat Recovery Detailed Costs

Component	Base Case	Proposed Case	Unit	Units/ SF Building	IMC/unit ($/unit)
Vertical DWHR device + installation	None	1 device	# devices	1	$771.28

Source: Esser, M et al. (2017). Codes and Standards Enhancement (CASE) Initiative: Drain Water Heat Recovery – Draft Report.

Figure 46. Reduced Fan Watt Draw Detailed Costs

Component	Base Case	Proposed Case	Unit	Units/Building		IMC/ unit	
				SF	MF	SF	MF
ECM Motor	0.58 watts/cfm	0.30 watts/cfm	# motors	1	8	$143	$104

Source: Davis Energy Group, Inc., Enercomp, Inc., Misti Bruceri & Associates, LLC. (2016). *CALGreen Cost Effectiveness Study*.

Figure 47. Increased Duct Insulation Detailed Costs

Component	Base Case	Proposed Case	Unit	Units/Building		IMC/ unit
				SF	MF	
Duct Insulation	R-6	R-8	linear ft duct	248	718	$0.86

Source: Wei, J et al. (2015). Codes and Standards Enhancement (CASE) Initiative: Residential Ducts in Conditioned Space/ High Performance Attics.

6. Appendix B – Utility Rate Schedules

TRC selected electric and natural gas rates from the major utilities to evaluate customer costs for the measure packages. Rate schedules were coordinated with experts at each utility to ensure appropriate interpretation of net energy metering policies. The rates were applied to climate zones within the utility territory. Detailed rate schedules are provided in subsequent tables.

Figure 48. Rate Schedules for Each Utility

Utility	Commodity	Rate Schedule	Climate Zones	Link
PG&E	Electric	E-TOU Option A	1, 2, 3, 4, 5, 11, 12, 13, 16	https://www.pge.com/tariffs/tm2/pdf/ELEC_SCHEDS_E-TOU.pdf
	Gas	G1		https://www.pge.com/tariffs/tm2/pdf/GAS_SCHEDS_G-1.pdf
SCE	Electric	TOU-D-T	6, 8, 9, 14, 15	https://www.sce.com/NR/sc3/tm2/pdf/CE220.pdf
SCG	Gas	GR		https://www.socalgas.com/regulatory/tariffs/tm2/pdf/GR.pdf
SDG&E	Electric	DR-SES	7, 10	http://regarchive.sdge.com/tm2/pdf/ELEC_ELEC-SCHEDS_DR-SES.pdf
	Gas	GR		http://regarchive.sdge.com/tm2/pdf/GAS_GAS-SCHEDS_GN-3.pdf

6.1 Electric Rate Schedule

Figure 49. PG&E Residential Electric Rates

Pacific Gas & Electric (PG&E) Residential TOU Electric Rates	
Rate E-TOU Option A	
Summer ($/kWh) (June 1 through Sep 31)	
On-Peak	0.39336
Off-Peak	0.31778
Winter ($/kWh) (Oct 1 through May 31)	
On-Peak	0.27539
Off-Peak	0.26109
Additional Charges	
Baseline Credit (per kWh)	$0.08830
Customer Charge ($/meter/day)	$0.32854
CA Climate Credit ($/month in April and October)	-$17.40
Net Surplus Compensation (NSC) – NEM	$0.0276
Non-bypassable Charges (NEM 2.0) ($/kWh)	
Public Purpose Program, Nuclear Decommissioning, California Department of Water Resources, Energy Cost Recovery Amount, Competition Transition Charge	$0.0233

Figure 50. SCE Residential Electric Rates

Southern California Edison (SCE) Residential TOU Electric Rates		
Rate TOU-D-T		
Summer ($/kWh) (Jun 1 through Sept 31)		
On peak- Level 1		$0.35425
On peak- Level 2		$0.39242
Off peak- Level 1		$0.18132
Off peak- Level 2		$0.21949
Winter ($/kWh) (Oct 1 through May 31)		
On peak- Level 1		$0.23425
On peak- Level 2		$0.27242
Off peak- Level 1		$0.17515
Off peak- Level 2		$0.21332
Additional Charges		
Basic Charge	Single Family	$0.031
	Multi Family	$0.024
Customer Charge ($/meter/day)		$0.329
CA Climate Credit ($/month in April and October)		-$31.00
Net Surplus Compensation (NSC) – NEM		$0.0257
Non-bypassable Charges (NEM 2.0) ($/kWh)		
Public Purpose Program, Nuclear Decommissioning, California Department of Water Resources, Competition Transition Charge		$0.0233

Figure 51. SDG&E Residential Electric Rates

San Diego Gas & Electric (SDG&E) Residential TOU Electric Rates	
Rate DR-SES	
Summer ($/kWh) (May 1 through Oct 31)	
On-Peak	0.50629
Mid-Peak	0.25108
Off-Peak	0.22721
Winter ($/kWh) (Nov 1 through Apr 30)	
Mid-Peak	0.23619
Off-Peak	0.22171
Additional Charges	
Customer Charge ($/meter/day)	$0.3290
CA Climate Credit ($/month in April and October)	-$29.62
Net Surplus Compensation (NSC) – NEM	$0.0279
Non-bypassable Charges (NEM 2.0) ($/kWh)	

Public Purpose Program, Nuclear Decommissioning, California Department of Water Resources, Energy Cost Recovery Amount, Competition Transition Charge	$0.017

6.2 Natural Gas Rate Schedule

Figure 52. PG&E Residential Natural Gas Rates

Pacific Gas & Electric (PG&E) Residential Natural Gas Rates	
Rate G-1	
	Per therm
Baseline charge	$1.28697
Non-baseline charge	$1.82246
Other charges	**Per therm**
NonCARE	$0.09589
CARE	$0.06743
Average PPS surcharge	$0.08166

Figure 53. SCG Residential Natural Gas Rates

Southern California Gas (SCG) Residential Natural Gas Rates	
Rate GR	
	Per therm
Baseline charge	$0.88512
Non-baseline charge	$1.21357
Other Charges	
Customer charge (per meter per day)	$0.16438

Figure 54. SDG&E Residential Natural Gas Rates

San Diego Gas & Electric (SDG&E) Residential Natural Gas Rates	
Rate GR	
	Per therm
Baseline charge	$1.28450
Non-baseline charge	$1.47184
Other Charges	
Minimum Bill Charge	$0.0986

CA Statewide Codes and Standards Program

Title 24, Part 11
Local Energy Efficiency Ordinances

CALGreen
All-Electric Cost-Effectiveness Study

Prepared for:
Marshall Hunt
Codes and Standards Program
Pacific Gas and Electric Company

Prepared by:
Davis Energy Group, Inc.
Enercomp, Inc.
Misti Bruceri & Associates, LLC

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LEGAL NOTICE

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1 Introduction

The California Building Energy Efficiency Standards Title 24, Part 6 (Title 24) (CEC, 2016b) is maintained and updated every three years by two state agencies, the California Energy Commission (CEC) and the Building Standards Commission (BSC). In addition to enforcing the code, local jurisdictions have the authority to adopt local energy efficiency ordinances, or reach codes, that exceed the minimum standards defined by Title 24 (as established by Public Resources Code Section 25402.1(h)2 and Section 10-106 of the Building Energy Efficiency Standards). Local jurisdictions must demonstrate that the requirements of the proposed ordinance are cost effective and do not result in buildings consuming more energy than is permitted by Title 24. In addition, the jurisdiction must obtain approval from the CEC and file the ordinance with the BSC for the ordinance to be legally enforceable.

The California Statewide Codes and Standards Team completed a feasibility and cost effectiveness study of requiring new low-rise single family and multifamily residential construction to exceed the 2016 Building Energy Efficiency Standards, which became effective January 1, 2017 (DEG, 2016). The 2016 report, last modified November 16, 2016, focused on mixed-fuel (gas/electric) homes only. This report presents the results from a similar analysis, focusing on all-electric designs. This evaluation, along with the prior report, provides local jurisdictions flexibility when adopting an energy efficiency ordinance by documenting that the requirement can be met either with a mixed-fuel (gas/electric) design or, in many cases, an all-electric design. Compliance package options and cost-effectiveness analysis for all-electric scenarios in all sixteen California climate zones (CZ) are presented here. All proposed package options include a combination of efficiency measures and on-site renewable energy. Some packages use heat pump water heaters (HPWH) that are more efficient than the DOE minimum and raise federal preemption issues. These results are provided to present alternative packages that are cost effective, but cannot be mandatory in local ordinances.

This analysis uses a customer-based lifecycle cost (LCC) approach to evaluating cost effectiveness of the proposed ordinance, whereas the CEC LCC methodology uses Time Dependent Valuation (TDV) as the primary metric for energy savings. Both methodologies require estimating and quantifying the energy savings associated with energy efficiency measures, as well as quantifying the costs associated with the measures. The main difference between the methodologies is the manner in which they value energy and thus the cost savings of reduced or avoided energy use. The CEC LCC Methodology uses TDV, which is intended to capture the societal impact of energy savings, while the customer-based life cycle cost methodology uses site energy use estimates, utility rate schedules and applies net energy metering rules to estimate cost savings from onsite PV generation to the customer.

2 Methodology and Assumptions

This all-electric analysis uses the same general methodology applied in the prior CALGreen Cost-Effectiveness Study (DEG, 2016). Details are provided below.

2.1 Building Prototypes

The CEC defines building prototypes which it uses to evaluate the cost-effectiveness of proposed changes to Title 24 requirements. There exist two single family prototypes and one multifamily prototype, all three of which are used in this analysis in development of the above-code efficiency packages. Table 1 describes the basic characteristics of each prototype. Additional details on the prototypes can be found in the ACM Approval Manual (CEC, 2016a).

Table 1: Prototype Characteristics

	Single Family One-Story	Single Family Two-Story	Multifamily
Conditioned Floor Area	2,100 ft^2	2,700 ft^2	6,960 ft^2: (4) 780 ft^2 & (4) 960 ft^2 units
Num. of Stories	1	2	2
Num. of Bedrooms	3	3	(4) 1-bed & (4) 2-bed units
Window-to-Floor Area Ratio	20%	20%	15%

The CEC's standard protocol for the single family prototypes is to weight the simulated energy impacts by a factor that represents the distribution of single-story and two-story homes being built statewide, assuming 45% single-story homes and 55% two-story homes. Simulation results in this study are therefore characterized according to this ratio, which is approximately equivalent to a 2,430 ft^2 house[1].

2.2 Efficiency Measures & Package Development

The California Energy Commission (CEC) CBECC-Res 2016 compliance simulation software was used to evaluate energy impacts using the 2016 prescriptive standards as the benchmark and the 2016 time dependent valuation (TDV) values. TDV is the energy metric used by the CEC since the 2005 Title 24 energy code to evaluate compliance with the Title 24 standards. TDV values energy use differently depending on the fuel source (gas, electricity, and propane), time of day, and season. TDV was developed to reflect the "societal value or cost" of energy including long-term projected costs of energy such as the cost of providing energy during peak periods of demand and other societal costs such as projected costs for carbon emissions. Electricity used (or saved) during peak periods of the summer has a much higher value than electricity used (or saved) during off-peak periods (Horii et al, 2014).

The compliance simulation software was updated since the gas/electric analysis was conducted. The latest version of the compliance simulation software available at the time of this analysis, CBECC-RES 2016.3.0, was used for the all-electric analysis.

The methodology used in the analyses for each of the prototypical building types begins with a design that precisely meets the minimum 2016 prescriptive requirements (0% compliance margin). A table of prescriptive measures used in each base design by climate zone is located in Appendix A. Using the 2016 baseline as the starting point, performance and costs for the all-electric proposed case are compared to the compliance model standard design. Beginning with the Tier 1 and Tier 2 packages developed in the gas/electric study, the analysis team replaced the natural gas appliances in the model with the following electric appliances.

- Split-system electric heat pump that meets the minimum federal requirements for efficiency; 14 SEER, 11.7 EER for cooling and 8.2 HSPF for heating. Heating capacity was sized based on heating loads from CBECC-Res for the standard design.[2]
- Heat pump water heater (HPWH) that either meets or exceeds the minimum federal requirement for efficiency, where the latter has federal preemption issues.
- Electric cooking and electric clothes drying.

[1] 2,430 ft^2 = 45% * 2,100 ft^2 + 55% * 2,700 ft^2

[2] Cooling capacity is not a user-input in CBECC.

Due to the effects of TDV, the all-electric designs generally result in lower overall compliance margins compared to the gas/electric designs. To compensate for the compliance penalty, efficiency measures were added as necessary to attain similar compliance margins as in the gas/electric study. The costs of the additional measures are included in the analysis of cost effectiveness. It is important to note that the packages contained in this report are examples only; any project meeting requirements of a local ordinance, both single family and multifamily, must independently evaluate and identify the most cost effective approach based on project-specific factors. Any local ordiance should avoid requiring any efficiency measures that trigger federal preemption issues.

Following are descriptions of each of the efficiency measures applied in this analysis.

Quality Insulation Installation (QII): HERS rater verification of installation quality of insulation according to the procedures outlined in the 2016 Reference Appendices RA3.5 (CEC, 2016c). QII is included in all cases since it is a pre-requisite for all the voluntary tiers in 2016 CALGreen.

Reduced Infiltration (ACH50): HERS rater field verification and diagnostic testing of building air leakage according to the procedures outlined in the 2016 Reference Appendices RA3.8 (CEC, 2016c). The default infiltration assumption for single family homes is 5 air changes per hour at 50 Pascals (ACH50)[3] and the reduced level applied in this analysis is 3 ACH50. This measure was not applied to multifamily homes because the modeling software does not allow this credit unless each unit is modeled individually, which is not typical in the compliance process for multifamily buildings.

Window Performance: Reduce window U-factor from the prescriptive value of 0.32 to 0.30 in all climates and reduce the solar heat gain coefficient (SHGC) from the prescriptive value of 0.25 to 0.23 in Climate Zone 2, 4, 6 through 16. In Climate Zones 1, 3, and 5 there is no prescriptive SHGC requirement and the default value of 0.50 is left as is.

Door Performance: Install insulated doors that meet a U-value of 0.20 at the front entry and doors between the house and garage. It's assumed there is a single 3' x 6'8" entry door per single family home and multifamily unit as well as a second 3' x 6'8" door to the garage per single family home.

Cool Roof: Install a roofing product that's rated by the Cool Roof Rating Council to have an aged solar reflectance of 0.20. This measure only applies to climate zones where this is not already required prescriptively.

Exterior Wall Insulation: Increase wall cavity insulation from R-19 to R-21 in 2x6 walls.

High Performance Attics (HPA): For climates where HPA is not already prescriptive under the 2016 code (CZ 1-3, 5-7), increase attic ceiling insulation to R-38 and add insulation under the roof deck between framing (R-13 for roof with air space, R-18 for roof without air space).

High Efficacy Fan: Upgrade the fan in the furnace or air handler and the distribution system to meet an efficacy of 0.3 Watts / cfm or lower operating at full speed. This is possible with design and installation of low static pressure duct systems combined with a constant torque brushless permanent magnent motor. Fan watt draw is verified by a HERS rater according to the procedures outlined in the 2016 Reference Appendices RA3.3 (CEC, 2016c). New federal regulations that go into effect July 3, 2019 are expected to result in equivalent performance for all newly manufactured furnaces provided that the ducts are sized properly.

[3] Whole house leakage tested at a pressure difference of 50 Pascals between indoors and outdoors.

Refrigerant Charge Verification: HERS rater verification of proper air conditioner refrigerant charge according to the procedures outlined in the 2016 Reference Appendices RA3.2 (CEC, 2016c). This measure only applies to climate zones where this is not already required prescriptively.

R-8 Duct Insulation: Increase duct insulation to R-8. This measure only applies to climates zones where R-8 ducts are not already required prescriptively.

Low Leakage Ducts in Conditioned Space: This credit requires HERS rater verification that duct leakage does not exceed 25 cfm to the outside. A blower door must be used for this test.

Hot Water Pipe Insulation: As of January 1, 2017 the 2016 California Plumbing Code requires pipe insulation levels that are close to that required if taking the Title-24 pipe insulation credit. This credit will be obsolete under the 2016 energy code, however, the HERS-Verified Pipe Insulation Credit, as defined in the 2016 Reference Appendices RA3.6.3 (CEC, 2016c), will remain. While CBECC-Res has not yet been updated to reflect this, for this analysis it was assumed that the revised HERS verified credit would be equivalent to the current credit for pipe insulation without HERS verification. This was determined based on simulations that demonstrated the HERS credit to be valued at roughly twice that for pipe insulation without verification in terms of TDV energy. This credit was only applied to single family residences. For costing purposes, 120 linear feet of 1/2in insulated pipe is assumed to be insulated.

Hot Water Compact Distribution: HERS rater verification of compact distribution system requirements according to the procedures outlined in the 2016 Reference Appendices RA3.6.5 (CEC, 2016c). This measure was applied to multifamily buildings only. Many multifamily buildings with individual water heaters are expected to easily meet this credit with little or no alteration to plumbing design. This measure also requires verification of pipe insulation per the HERS-Verified Pipe Insulation Credit. Assumption is 60 linear feet per dwelling unit of 1/2in insulated pipe.

Water Heater Located within Conditioned Space: Moving the water heater into conditioned space, particularly from an exterior closet as is the standard case in certain multifamily buildings, reduces water heater energy use and provides cooling to the space which is beneficiaul during the cooling season. The additional cooling load also increases heating energy use during the heating season. HPWHs in conditioned space can be ducted to minimize thermal impacts but this option was not evaluated because CBECC-Res does not currently have the ability to model ducting of intlet or exhaust air.

PV and PV Compliance Credit: A PV compliance credit (PVCC) is available in all climate zones except six and seven. To be eligible for this compliance credit a PV system with a minimum capacity of 2 kW DC per single family home with no more than 2,000 ft^2 of conditioned floor area or 1 kW DC per multifamily unit with no more than 1,000 ft^2 of conditioned floor area is required. For the single family 2,430 ft^2 prototype the minimum capacity as calculated by CBECC-Res is 2.0 kW to 2.4 kW depending on the climate zone. The multifamily apartment units in the prototype are all under 1,000 ft^2 and therefore require a 1 kW system. See Table 18 and Table 19 in Appendix C for minimum PV system capacity required to be eligible for the PVCC. PV was modeled in CBECC-Res according to the California Flexible Installation (CFI). For costing, a micro inverter is assumed which is expected to be replaced at year 20.

2.3 All-Electric Package

The CBECC-Res compliance software requires the user to specify whether natural gas is available at the site, and adjusts the baseline assumptions and TDV values based on the selection. For newly constructed buildings, natural gas is defined as being available on site in the 2016 ACM Manual if a gas service line can be connected to the site without a gas main extension[4]. As the baseline assumptions have a significant impact on the compliance margin, this analysis evaluated the cost-effectiveness of the designs with, and without, the availability of natural gas at the site. In both cases, the proposed design is compared to a home with electric appliances, with the exception of a propane gas tankless water heater in the “No Natural Gas” scenario and a natural gas tankless water heater in the “Natural Gas Available” scenario. All other appliances are electric, consistent with the fuel selections in the proposed design. Because TDV energy use for natural gas is roughly half that of propane, the “Natural Gas Available” scenario, with a minimum efficiency HPWH of 2.0 EF produces compliance penalties relative to the “No Natural Gas” design making it challenging in some climates to even comply with code. As a result, the evaluation applied a Northwest Energy Efficiency Alliance (NEEA) rated HPWH with an energy factor equal to 3.17 in the model to attain comparable performance with the “No Natural Gas” scenario. Because this design includes a HPWH that exceeds minimum federal requirements, the “Natural Gas Available” scenario does not provide the basis for a local jurisdiction to specifically require the use of all electric equipment for new homes with access to natural gas. However, this analysis demonstrates that there are cost-effective all-electric options for buildings with natural gas available to provide builders the flexibility to select either a gas/electric or an all-electric design.

Table 2 summarizes the electric equipment measures applied in the proposed all-electric package compared with those assumed by the software in the standard design.

Table 2: Title 24 Standard Design (Baseline) Equipment Assumptions Compared with the Proposed All-Electric Package

	Single Family				**Multi-family**			
	No Natural Gas [1]		**Natural Gas Available**		**No Natural Gas**		**Natural Gas Available**	
Measure	**Standard**	**Proposed**	**Standard**	**Proposed**	**Standard**	**Proposed**	**Standard**	**Proposed**
Space Heating	Heat pump, 8.2 HSPF				Heat pump, 8.2 HSPF			
Water Heating	Propane tankless 0.82 EF[2]	HPWH 2.00 EF[3]	Nat. Gas tankless 0.82 EF	HPWH 3.17 EF[4]	Propane tankless 0.82 EF	HPWH, 2.00 EF	Nat. Gas tankless 0.82 EF	HPWH, 3.17 EF
Water Heater Location	Garage				Exterior Closet			
Stove/Cooktop	Electric				Electric			
Clothes Dryer	Electric				Electric			

[1] Refers to CBECC-Res checkbox “Natural Gas is available at the site”.
[2] Energy Factor
[3] Calculated according to the latest federal efficiency standards, which define a minimum uniform energy factor (UEF). Conversion factor equations were applied to convert UEF to EF, which is the required input for the CBECC-Res simulation. A 65 gallon heat pump electric water heater was assumed.
[4] Assumes a NEEA rated 66 gallon HPWH with an energy factor above the minimum federal efficiency requirements. DOE preemption regulations do not allow mandating the use of high efficiency federally-regulated equipment without appropriate options, thus restricting a local jurisdiction from making this package a stand-alone mandatory requirement.

[4] 2016 Residential Alternative Calculation Method Reference Manual. Section 2.2.10 http://www.energy.ca.gov/2015publications/CEC-400-2015-024/CEC-400-2015-024-CMF-REV2.pdf

2.3.1 NEEA-rated Heat Pump Water Heaters (HPWH)

The water heater used in the "Natural Gas Available" scenario is a NEEA-rated unit that exceeds federal minimum efficiency requirements. The federal standard for residential electric water heaters greater than 55 gallons requires an Energy Factor of 2.0 that precludes the use of electric resistance technology. Based on operational challenges experienced in the past, Northwest Energy Efficiency Alliance (NEEA) established rating test criteria to ensure newly installed HPWHs perform adequately, especially in colder climates. The NEEA rating requires an Energy Factor equal to the ENERGY STAR performance level, and also includes requirements regarding noise and prioritizing heat pump use over supplemental electric resistance heating. According to NEEA, virtually all HPWH sales in the Pacific Northwest territory are NEEA-certified units.

To encourage manufacturers to test their products, the CEC CBECC-Res compliance software uses conservative performance assumptions when the unit is not tested, which result in a compliance penalty for non-NEEA rated HPWHs. Using the DOE minimum in CBECC-Res for the "Natural Gas Available" scenario results in a building that is in many climate zones non-compliant with 2016 Title 24, Part 6. In some mild climate zones where the water heating load is a substantial portion of the total compliance budget, this compliance penalty is larger than the combined heating and cooling budgets, and cannot be made up with efficiency measures alone.

2.4 Measure Costs

Table 3 below summarizes the costs applied for shifting from gas to electric appliances and the savings associated with eliminating new natural gas infrastructure where it isn't already available. Cost details for other efficiency measures included in this analysis can be found in Appendix B.

Table 3: All-Electric Cost Assumptions

	Incremental Cost				
	Single Family		MF – Per Unit		
Measure	**No NG**	**NG**	**No NG**	**NG**	**Source & Notes**
Site Gas Infrastructure[1]	($350)	($1,500)	($350)	($500)	
In-house Gas Infrastructure[1]	($200)	($200)	($150)	($150)	See description below.
Electric Service Upgrade	$200	$200	$200	$200	
Heat Pump Water Heater	$1,115	$1,403	$1,115	$1,403	See description below.
Electric Dryer	$0	($100)	$0	$0	Internet search comparing product pricing. Installation labor assumed the same as base.

1. Natural gas or propane.

The all-electric infrastructure and water heater costs are based on the following assumptions:

- **Site Gas Infrastructure (to Building Meter).** Natural gas infrastructure costs for installing a service gas line from the utility main to the point of service and providing a gas meter are $1,500 for single family and $500 per dwelling unit for multifamily. Estimates are based on multiple sources including a PG&E online calculator[5], an EPRI study (EPRI, 2016), and costs provided by both single and multifamily builders and developers. Site infrastructure costs for multifamily are

[5] https://www.pge.com/en/myhome/customerservice/other/newconstruction/projectcosts/results.page?serviceType=gas&gasType=gas_new&electricOverType=&electricUnderType=&pevType=&proj=gas_new

on a per apartment unit basis assuming a single gas main run to the building, and all gas meters in a single location at the building. These costs are expected to be conservative for a new residential development, and don't include the full savings from eliminating natural gas infrastructure to serve entire subdivisions, particularly in locations with difficult or long gas piping and trenching requirements.

Costs for the "No Natural Gas" scenario represent those associated with installing a propane tank and providing propane service to the building. The $350 for both single family and multifamily represent $75 for a concrete pad, $75 for a meter/regulator, and $200 for piping. Many propane suppliers do not charge for the propane tank, provided the customer enters into a contract. To avoid overstating propane costs the analysis does not include the cost of the storage tank.

- **In-House Gas Infrastructure (from Meter to Appliances).** Installation costs to run a gas line from the meter to the appliance location is $200 per appliance for single family and $150 for multifamily. The cost estimates include providing gas to the water heater only. This estimate was based on the EPRI study and costs provided by builders.
- **Electric Service Upgrade.** The EPRI study estimated $600 for additional electric service including panel upgrades and running 220V service to the water heater, air handler, dryer, and stove. For this analysis, the incremental cost only represents additional service for the water heater, for both single family and multifamily, and the dryer for single family. It is assumed that typical practice in a mixed fuel home is to run both gas and 220V service for the dryer, therefore there is no assumed incremental cost for the electric dryer. The assumed incremental cost is $200 for both single family and multifamily.
- **Water Heater (HPWH).** Incremental costs for the heat pump water heater are relative to a gas tankless 0.82 EF water heater which meets minimum prescriptive requirements, and include equipment, labor and replacement costs. Details are provided in Table 4 below. The "No Natural Gas" case in Table 3 is based on the 2.0 Energy Factor HPWH. The "Natural Gas Available" case is based on the NEEA-rated HPWH.

Table 4: HPWH Cost Assumptions

Component	Gas Tankless	2.0 EF HPWH	NEEA HPWH	Source & Notes
First material cost	$1,150	$1,368	$1,570	Internet search comparing products
First labor cost	$326	$468	$468	Itron cost study (Itron, 2014)
Present value of replacement	$513	$1,269	$1,354	Assumes 13 year equipment life for HPWHs[6], 20-year life for tankless water heaters (DOE, 2016), and the lifecycle terms described in Section 2.6.
Total Cost	*$1,989*	*$3,105*	*$3,392*	
Incremental Cost	-	***$1,115***	***$1,403***	

2.5 PV Performance Packages

Two performance packages that include photovoltaic (PV) systems were evaluated for the all-electric scenarios, as the study assumes projects complying with an all-electric above code local ordinance will also be incorporating PV systems. Efficiency-only packages are not included in this analysis, because based on customer utility rates, all-electric efficiency-only packages result in higher utility costs than

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[6] HPWH life based on average lifetime for storage tank water heaters.

similar designs with natural gas appliances. In both these cases PV is evaluated in CBECC-Res according to the California Flexible Installation (CFI).

- **PV-Plus:** The current CEC proposal for minimum PV system sizing under the 2019 code requires a PV system large enough to offset the estimated electricity usage in a mixed-fuel building. If all-electric designs were also required to offset the total electricity use, they would be forced to purchase and install much larger PV systems, effectively penalizing all-electric designs. This package is designed to yield a minimum PV system size consistent with the PV-Plus package in the CALGreen Cost-Effectiveness study (DEG, 2016), also the same methodology used in the California Energy Commission's proposed Solar PV Ordinance (CEC, 2017). PV systems are sized to offset approximately 80% of estimated annual electricity consumption in a gas/electric home. This results in PV systems sized to offset less than 80% (33%-73%) of the total building electricity use in the all-electric design, but relies on a PV system size that is the same, independent of fuel mix. It is important to note that the system sizes in this report are examples only; all projects must independently evaluate the actual electricity use and appropriate PV system size to comply with code and meet the customer's long-term objectives.
- **Zero-Electric:** Exceed Title 24, Part 6 through building energy efficiency and install a PV system sized to offset 100% of estimated building site electricity use (total kWh), including appliances and plug loads. For the all-electric case, this system size is typically slightly larger than sizing the PV system to offset 100% of the TDV energy use, based on 2016 TDV.

In some instances, particularly in the hot valley and cold climate zones with the zero-electric package, there may not be sufficient unshaded roof space for the required PV capacity. For these cases exceptions will need to be developed similar to what the CEC is proposing for the 2019 Title 24, Part 6 Standards.

2.6 Cost-Effectiveness

This analysis uses a customer-based approach to evaluating cost effectiveness consistent with the methodology applied in the main CALGreen Cost-Effectiveness Study (DEG, 2016).

The current residential utility rates at the time of the analysis were used to calculate utility costs and determine cost effectiveness for the proposed packages. Annual utility costs were calculated using hourly electricity and gas output from CBECC-Res and applying the utility tariffs summarized in Table 5. Appendix D includes the utility rate schedules used for this study. The standard residential rate (E1 in PG&E territory, D in SCE territory, & DR in SDG&E) was applied to the base case and a time-of-use (TOU) rate was applied to all proposed cases (with PV systems).[7] Any annual electricity production in excess of annual electricity consumption is credited to the utility account at the applicable wholesale rate based on the approved NEM2 tariffs for that utility. Minimum delivery bill and mandatory non-bypassable charges have been applied. Future changes to NEM tariffs including devaluation of solar production have not been evaluated since the proposed changes are still unknown. Net surplus compensation rates for each utility are as follows[8]:

- PG&E: $0.0272 / kWh

[7] Under NEM rulings by the CPUC (D-16-01-144, 1/28/16), all new PV customers shall be in an approved TOU rate structure. As of March 2016, all new PG&E net energy metering (NEM) customers are enrolled in a time-of-use rate. (http://www.pge.com/en/myhome/saveenergymoney/plans/tou/index.page?).

[8] Net surplus compensation rates for each utility are based on a 1-year average over the period October 2016 – September 2017.

- SCE: $0.0256 / kWh
- SDG&E: $0.0275 / kWh

Table 5: IOU Utility Tariffs used based on Climate Zone

Climate Zones	Electric / Gas Utility	Electricity (Standard)	Electricity (Time-of-use)	Natural Gas
1-5, 11-13, 16	PG&E	E1	E-TOU, Option A	G1
6, 8-10, 14, 15	SCE / SoCal Gas	D	TOU-D-T	GR
7	SDG&E	DR	DR-SES	GR

Propane costs used for the Standard Design basecase in the "No Natural Gas" scenario, were based on an average rate of $2.12/gallon (equivalent to $2.32/therm). This was calculated as the average weekly U.S. residential propane rate from January 2015 through January 2017 based on data from the U.S. Energy Information Administration[9].

Cost effectiveness was evaluated for all sixteen climate zones and is presented according to lifecycle customer benefit-to-cost ratio. The benefit-to-cost ratio is a metric which represents the cost effectiveness of energy efficiency over a 30-year lifetime taking into account discounting of future savings and financing of incremental costs. A value of one (1.0) indicates the savings over the life of the measure are equivalent to the incremental cost of that measure. A value greater than one (1.0) represents a positive return on investment. The ratio is calculated as follows:

Equation 1

$$Lifecycle\ Benefit\ Cost\ Ratio = \frac{(Annual\ utility\ cost\ savings\ *\ Lifecycle\ cost\ factor)}{(First\ incremental\ cost\ *\ Financing\ factor)}$$

The lifecycle cost factor is 19.6 and was calculated using Equation 2 as follows. No utility rate escalation is assumed.

$$\boldsymbol{Lifecycle\ Cost\ Factor = \frac{1-(1+disc)^{-n}}{disc}} \quad \textbf{\textit{Equation 2}}$$

Where:

- n = analysis and financing term of 30-years
- $disc$ = real discount rate of 3%

The financing factor is calculated as follows:

$$\boldsymbol{Financing\ Factor = \frac{PV_{Mortgage\ Increase} - PV_{Tax\ Savings}}{L}} \quad \textbf{\textit{Equation 3}}$$

Where:

- L = first incremental cost ($)
- $PV_{Mortgage\ Increase}$ = Present value of increased mortgage costs
- $PV_{Tax\ Savings}$ = Present value of tax savings from additional interest payments due to increased mortgage

[9] http://www.eia.gov/dnav/pet/pet_pri_wfr_a_EPLLPA_PRS_dpgal_w.htm

$PV_{Mortgage\ Increase}$ is calculated using Equations 4 and 5.

$$\boldsymbol{P = L\frac{\left[\frac{c}{12}*\left(1+\frac{c}{12}\right)^{n*12}\right]}{\left[\left(1+\frac{c}{12}\right)^{n*12}-1\right]}} \qquad \textbf{\textit{Equation 4}}$$

$$\boldsymbol{PV_{Mortgage\ Increase} = P*12\,\frac{1-(1+disc)^{-n}}{disc}} \qquad \textbf{\textit{Equation 5}}$$

Where:

- P = incremental monthly mortgage payment ($)
- c = loan interest rate of 4.5%

$PV_{Tax\ Savings}$ is calculated using Equations 6 and 7.

$$\boldsymbol{Annual\ Tax\ Savings = balance*c*taxrate} \qquad \textbf{\textit{Equation 6}}$$

$$\boldsymbol{PV_{Tax\ Savings} = \sum_{n=1}^{30} Annual\ Tax\ Savings*\frac{1}{(1+disc)^{n}}} \qquad \textbf{\textit{Equation 7}}$$

Where:

- *taxrate* = average tax rate of 20% (to account for tax savings due to loan interest deductions)
- *balance* = balance of incremental cost of mortgage at beginning of each year

The financing factor based on the above assumptions was 1.068 for this study.

Simple payback is also presented and is calculated using the equation below. Based on the terms described above the lifecycle cost-to-benefit ratio threshold of one is roughly equivalent to a simple payback of 18 years. Maintenance costs were not included because there are no incremental maintenance costs expected for any of these measures. There is no assumed maintenance on the envelope measures and for HVAC and DHW measures there should not be any additional maintenance cost for a more efficient version of the same system type as the baseline. Replacement costs for inverters were included for PV systems.

Simple payback = First incremental cost / Annual customer utility cost savings ***Equation 8***

2.7 Greenhouse Gas Emissions

Equivalent CO_2 emission savings were calculated using the following emission factors (Table 6). Electricity factors are specific to California electricity production.

Table 6: Equivalent CO_2 Emissions Factors

		Source
Electricity	0.724 lb. CO_2-e / kWh	U.S. Environmental Protection Agency's 2007 eGRID data.[10]
Natural Gas	11.7 lb. CO_2-e / Therm	Emission rates for natural gas combustion as reported by the U.S. Environmental Protection Agency's GHG Equivalencies Calculator.[11]
Propane	139.05 lb. CO_2-e / MMBtu	Emission rates for propane combustion as reported by the U.S. Environmental Protection Agency's GHG Emissions Coefficients.[12]

3 Results

A cost-effectiveness analysis evaluating two performance packages that include both efficiency measures and PV systems was completed for all sixteen climate zones.

3.1 Single Family Results

3.1.1 Single Family Cost-Effectiveness Analysis

A comparison of cost-effectiveness for the two PV performance packages (PV-Plus and Zero-Electric) and two scenarios in each climate zone is presented in Figure 1. Results are presented for the blended 2,430 ft^2 single family prototype, which is consistent with the main report for the gas/electric cases. Table 7 and Table 8 provide the results in tabular form along with energy and greenhouse gas (GHG) savings for each PV performance tier for the "No Natural Gas" and "Natural Gas Available" scenarios, respectively. The lifecycle benefit-to-cost (B/C) ratio threshold of 1.0 is roughly equivalent to a simple payback of 18 years. Gas savings are a result of the standard design including gas water heating (both scenarios) and gas clothes drying ("Natural Gas Available" scenario). Savings for the "No Natural Gas" cases are based upon fuel costs and GHG values for propane.

The PV system capacity for the PV-Plus packages range from 1.8 to 4.6 kW DC depending on climate. The required Zero-Electric PV capacity (to offset site electricity use) ranges from 3.8 kW DC in the mild climates (CZ7) to 6.9 kW DC in very cold climates (CZ16), based on the "Natural Gas Available" scenario. Zero-Electric PV sizes for the "No Natural Gas" cases are between 0.3 and 0.7 kW larger, depending on climate zone, due to higher energy use of the minimum efficiency HPWH.

The PV-Plus cases demonstrate cost-effectiveness with a B/C ratio ranging from 1.30 to 2.58. The Zero-Electric cases also all demonstrate cost-effectiveness with a B/C ratio ranging from 1.35 to 2.11. Cost-effectiveness for the "Natural Gas Available" cases are slightly better than the "No Natural Gas" cases in all climates. Greenhouse gas (GHG) reductions for the two PV packages average 58% and 100% for the PV-Plus and Zero-Electric cases, respectively.

[10] https://www.epa.gov/energy/ghg-equivalencies-calculator-calculations-and-references

[11] https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

[12] https://www.eia.gov/environment/emissions/co2_vol_mass.php

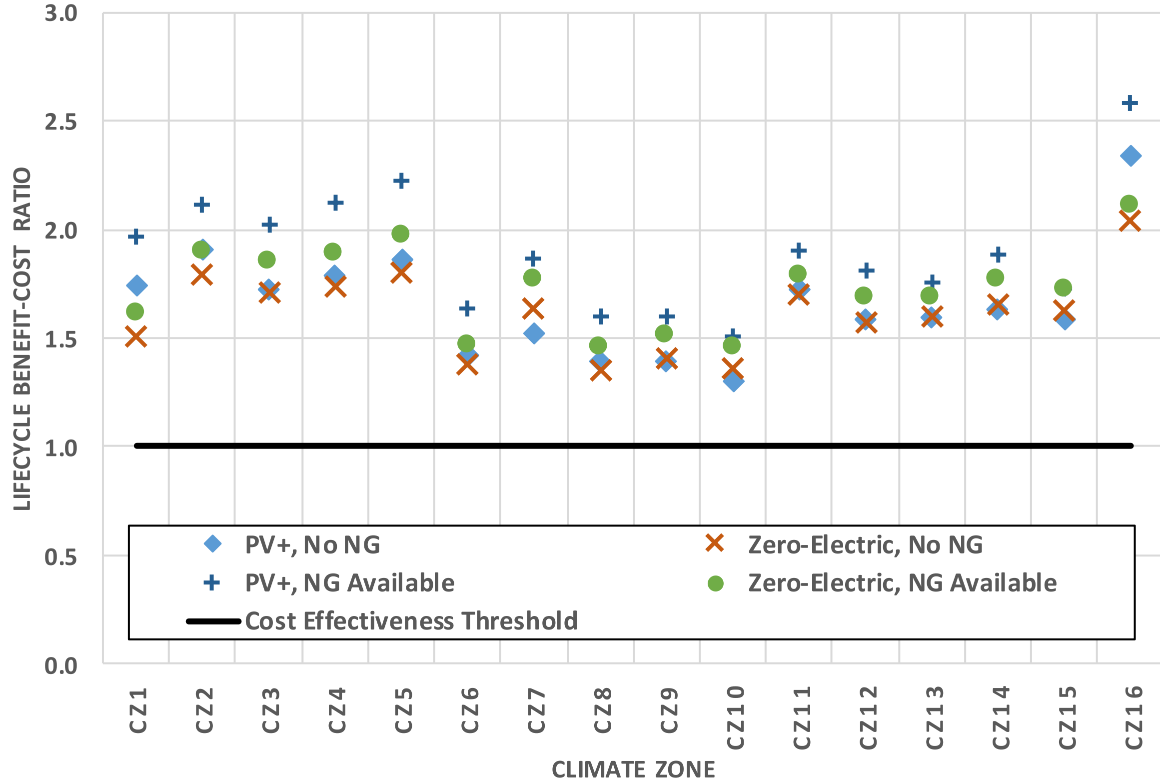

Figure 1: Single family all-electric cost-effectiveness comparison

Table 7: Single Family All-Electric PV-Plus Performance Package Cost-Effectiveness Results

Climate Zone	Compliance Margin	PV Capacity (kW)	Elec Savings (kWh)	Gas Savings (therms)[1]	GHG % Savings[2]	Package Cost[3]	Utility Cost Savings	Simple Payback	Lifecycle Benefit-to-Cost Ratio
No Natural Gas[1]									
CZ1	34.0%	3.0	3,659	137.0	52.2%	$13,052	$1,234	10.6	1.74
CZ2	33.4%	2.5	3,405	122.9	55.8%	$10,973	$1,141	9.6	1.91
CZ3	23.6%	2.6	2,714	123.5	55.5%	$10,178	$953	10.7	1.72
CZ4	34.1%	2.3	2,404	117.6	48.3%	$9,137	$890	10.3	1.79
CZ5	24.4%	2.3	2,466	126.4	53.4%	$9,137	$925	9.9	1.86
CZ6	17.9%	2.5	2,568	112.2	57.0%	$9,879	$765	12.9	1.42
CZ7	17.5%	1.8	1,592	110.4	48.9%	$7,837	$650	12.1	1.52
CZ8	43.8%	2.6	2,726	107.5	59.8%	$10,054	$761	13.2	1.39
CZ9	43.6%	2.5	2,813	107.3	56.9%	$9,846	$745	13.2	1.39
CZ10	37.9%	2.5	2,918	106.5	55.9%	$9,766	$693	14.1	1.30
CZ11	37.2%	3.5	4,802	108.7	60.4%	$13,326	$1,247	10.7	1.72
CZ12	34.7%	2.9	3,305	114.3	54.0%	$11,095	$957	11.6	1.58
CZ13	33.8%	3.7	4,725	106.6	60.6%	$13,834	$1,199	11.5	1.59
CZ14	33.7%	2.5	3,673	110.0	50.3%	$9,923	$880	11.3	1.63
CZ15	33.3%	4.6	7,568	79.6	73.4%	$16,858	$1,451	11.6	1.58
CZ16	36.4%	2.5	3,683	136.0	43.8%	$10,420	$1,327	7.9	2.34
Natural Gas Available									
CZ1	40.7%	3.0	4,570	137.0	58.3%	$11,994	$1,282	9.4	1.96
CZ2	30.9%	2.5	3,971	122.9	59.8%	$9,915	$1,141	8.7	2.11
CZ3	22.5%	2.6	3,513	123.5	62.7%	$9,120	$1,005	9.1	2.02
CZ4	32.8%	2.3	3,149	117.6	54.3%	$8,079	$935	8.6	2.13
CZ5	22.8%	2.3	3,281	126.4	60.6%	$8,079	$977	8.3	2.22
CZ6	15.7%	2.5	3,264	112.2	63.9%	$8,820	$785	11.2	1.63
CZ7	12.4%	1.8	2,259	110.4	55.8%	$6,779	$690	9.8	1.87
CZ8	41.0%	2.6	3,383	107.5	66.6%	$8,996	$781	11.5	1.59
CZ9	42.6%	2.5	3,468	107.3	63.2%	$8,788	$764	11.5	1.60
CZ10	36.2%	2.5	3,572	106.5	61.8%	$8,708	$713	12.2	1.50
CZ11	37.2%	3.5	5,484	108.7	65.4%	$12,268	$1,272	9.6	1.90
CZ12	33.6%	2.9	4,027	114.3	59.7%	$10,037	$988	10.2	1.81
CZ13	33.1%	3.7	5,386	106.6	65.6%	$12,776	$1,221	10.5	1.75
CZ14	33.2%	2.5	4,384	110.0	55.2%	$8,864	$908	9.8	1.88
CZ15	33.1%	4.6	8,073	79.6	77.0%	$15,800	$1,484	10.6	1.72
CZ16	31.9%	2.5	4,220	136.0	46.0%	$9,362	$1,316	7.1	2.58

[1] Savings for "No Natural Gas" case are propane savings from elimination of propane water heater. Gas savings are therms equivalent.
[2] Based on CA electricity production and equivalent CO_2 emission rates of 0.724 lbCO_2e/kWh, 11.7 lb-CO_2e/therm natural gas & 13.9 lb-CO_2e/therm propane.
[3] Includes ten percent markup for builder profit and overhead.

Table 8: Single Family All-Electric Zero Electric Performance Package Cost-Effectiveness Results

Climate Zone	Compliance Margin	PV Capacity (kW)	Elec Savings (kWh)	Gas Savings (therms)[1]	GHG % Savings[2]	Package Cost[3]	Utility Cost Savings	Simple Payback	Lifecycle Benefit-to-Cost Ratio
No Natural Gas[1]									
CZ1	34.0%	7.3	9,417	137.0	100%	$27,344	$2,242	12.2	1.50
CZ2	33.4%	5.4	7,972	122.9	100%	$20,612	$2,005	10.3	1.79
CZ3	23.6%	5.1	6,789	123.5	100%	$18,487	$1,719	10.8	1.71
CZ4	34.1%	5.4	7,395	117.6	100%	$19,440	$1,834	10.6	1.73
CZ5	24.4%	4.8	6,739	126.4	100%	$17,446	$1,712	10.2	1.80
CZ6	17.9%	4.7	6,131	112.2	100%	$17,191	$1,285	13.4	1.37
CZ7	17.5%	4.2	5,464	110.4	100%	$15,814	$1,409	11.2	1.64
CZ8	43.8%	4.6	5,952	107.5	100%	$16,701	$1,229	13.6	1.35
CZ9	43.6%	4.7	6,504	107.3	100%	$17,158	$1,312	13.1	1.40
CZ10	37.9%	4.9	6,839	106.5	100%	$17,742	$1,316	13.5	1.36
CZ11	37.2%	6.3	9,313	108.7	100%	$22,632	$2,090	10.8	1.69
CZ12	34.7%	5.9	7,996	114.3	100%	$21,066	$1,802	11.7	1.57
CZ13	33.8%	6.5	9,122	106.6	100%	$23,140	$2,008	11.5	1.59
CZ14	33.7%	5.7	9,383	110.0	100%	$20,558	$1,854	11.1	1.65
CZ15	33.3%	6.6	10,862	79.6	100%	$23,505	$2,078	11.3	1.62
CZ16	36.4%	7.2	11,769	136.0	100%	$26,041	$2,889	9.0	2.04
Natural Gas Available									
CZ1	40.7%	6.6	9,417	137.0	100%	$23,959	$2,102	11.4	1.61
CZ2	30.9%	5.0	7,972	122.9	100%	$18,224	$1,880	9.7	1.89
CZ3	22.5%	4.6	6,789	123.5	100%	$15,767	$1,592	9.9	1.85
CZ4	32.8%	4.9	7,395	117.6	100%	$16,720	$1,715	9.8	1.88
CZ5	22.8%	4.3	6,739	126.4	100%	$14,726	$1,582	9.3	1.97
CZ6	15.7%	4.3	6,131	112.2	100%	$14,803	$1,180	12.5	1.46
CZ7	12.4%	3.8	5,464	110.4	100%	$13,426	$1,292	10.4	1.77
CZ8	41.0%	4.2	5,952	107.5	100%	$14,314	$1,133	12.6	1.45
CZ9	42.6%	4.3	6,504	107.3	100%	$14,770	$1,214	12.2	1.51
CZ10	36.2%	4.5	6,839	106.5	100%	$15,355	$1,219	12.6	1.46
CZ11	37.2%	5.9	9,313	108.7	100%	$20,245	$1,969	10.3	1.79
CZ12	33.6%	5.4	7,996	114.3	100%	$18,346	$1,686	10.9	1.69
CZ13	33.1%	6.1	9,122	106.6	100%	$20,753	$1,909	10.9	1.69
CZ14	33.2%	5.3	9,383	110.0	100%	$18,170	$1,752	10.4	1.77
CZ15	33.1%	6.3	10,862	79.6	100%	$21,450	$2,014	10.7	1.72
CZ16	31.9%	6.9	11,769	136.0	100%	$23,986	$2,751	8.7	2.11

[1] Savings for "No Natural Gas" case are propane savings from elimination of propane water heater. Gas savings are therms equivalent.

[2] Based on CA electricity production and equivalent CO_2 emission rates of 0.724 lbCO_2e/kWh, 11.7 lb-CO_2e/therm natural gas & 13.9 lb-CO_2e/therm propane.

[3] Includes ten percent markup for builder profit and overhead.

3.1.2 Single Family Packages

PV-Plus & Zero-Electric: Cost-effective all-electric packages using both efficiency and PV to exceed the minimum requirements were identified in all 16 climate zones. Table 9 summarizes the cost-effective efficiency measures used in each climate zone. In most cases the measures in these packages reflect those in the mixed fuel PV performance packages. In Climate Zones 9 through 14, additional efficiency measures (shown as values in red in the table) were added to meet the 30% compliance margin target. The "Natural Gas Available" scenarios include the same efficiency measures with the addition of the high efficiency HPWH.

Table 9: Single Family All-Electric PV Packages: Cost-Effective Measures Summary

Climate Zone	PV Compliance Credit	QII	ACH50	Window U-value / SHGC	Door U-value	HPA	AH Fan W/cfm	HPWH Location[1]	HERS Verified HW Pipe Insul.
CZ1	Y	Y	3.0	.30/.50	0.20	Y		Gar	Y
CZ2	Y	Y		.30/.50	0.20	Y		CS	Y
CZ3	Y	Y		.30/.50	0.20			Gar	
CZ4	Y	Y		.30/.23				Gar	
CZ5	Y	Y		.30/.50				Gar	
CZ6	N/A	Y					0.30	Gar	
CZ7	N/A	Y		.30/.23	0.20		0.30	Gar	Y
CZ8	Y	Y						Gar	
CZ9	Y	Y		.30/.23	0.20			Gar	
CZ10	Y	Y			0.20			Gar	
CZ11	Y	Y		.30/.23	0.20		0.30	Gar	
CZ12	Y	Y			0.20			Gar	
CZ13	Y	Y		.30/.23	0.20			Gar	
CZ14	Y	Y			0.20		0.30	Gar	
CZ15	Y	Y					0.30	Gar	
CZ16	Y	Y	3.0	.30/.23	0.20		0.30	CS	

Values in red indicate a change between the gas/electric and all-electric results.
[1]CS = conditioned space; Gar = garage.

3.2 Multifamily Results

3.2.1 Multifamily Cost-Effectiveness Analysis

A comparison of cost-effectiveness for the multifamily prototype is presented in Figure 2. Table 10 and

Table 11 provide the results in tabular form, along with energy and greenhouse gas savings for each PV performance tier for the "No Natural Gas" and "Natural Gas Available" scenarios, respectively. *All multifamily results are presented on a per dwelling unit basis.* The above-code compliance targets are more difficult to achieve with the multifamily prototype than single family. Water heating compliance margins are lower in the multifamily model due to higher standby losses and lower efficiencies resulting from modeling the multifamily HPWH in an outdoor closet instead of in the attached garage, as in the single family prototypes.

Cost-effectiveness results are presented for the two PV performance packages (PV-Plus and Zero-Electric) in each climate zone. The lifecycle B/C ratio threshold of 1.0 is roughly equivalent to a simple payback of 18 years. Table 10 and

Table 11 summarize the cost-effectiveness of the two PV performance packages including the PV capacity necessary to offset the site electricity use for each case. Gas savings are a result of the standard design including gas water heating (both scenarios). Savings for the "No Natural Gas" cases are based upon fuel costs and GHG values for propane.

The PV capacity for the PV-Plus packages are sized using the same methodology as for the single family analysis and range from 1.3 to 2.1 kW DC depending on climate. The required Zero-Electric PV capacity per apartment ranges from 2.5 kW DC in the mild climates (CZ7) to 3.7 kW DC in colder climates (CZ1) for the "Natural Gas Available" scenario. For the multifamily prototype 8-unit apartment building, this is equivalent to 20 to 30 kW for the building. Zero-Electric PV sizes for the "No Natural Gas" cases are between 0.2 and 0.4 kW larger, depending on climate zone, due to higher energy use of the minimum efficiency HPWH.

The PV-Plus cases demonstrate cost-effectiveness with a B/C ratio ranging from 1.10 to 1.73. The Zero-Electric cases also all demonstrate cost-effectiveness with a B/C ratio ranging from 1.16 to 1.65. Cost-effectiveness for the "No Natural Gas" cases is better than or equal to the "Natural Gas Available" cases in most climates except in some mild climates and Climate Zone 15.

Greenhouse gas (GHG) reductions for the two PV packages average 54% and 100% for the PV-Plus and Zero-Electric cases, respectively.

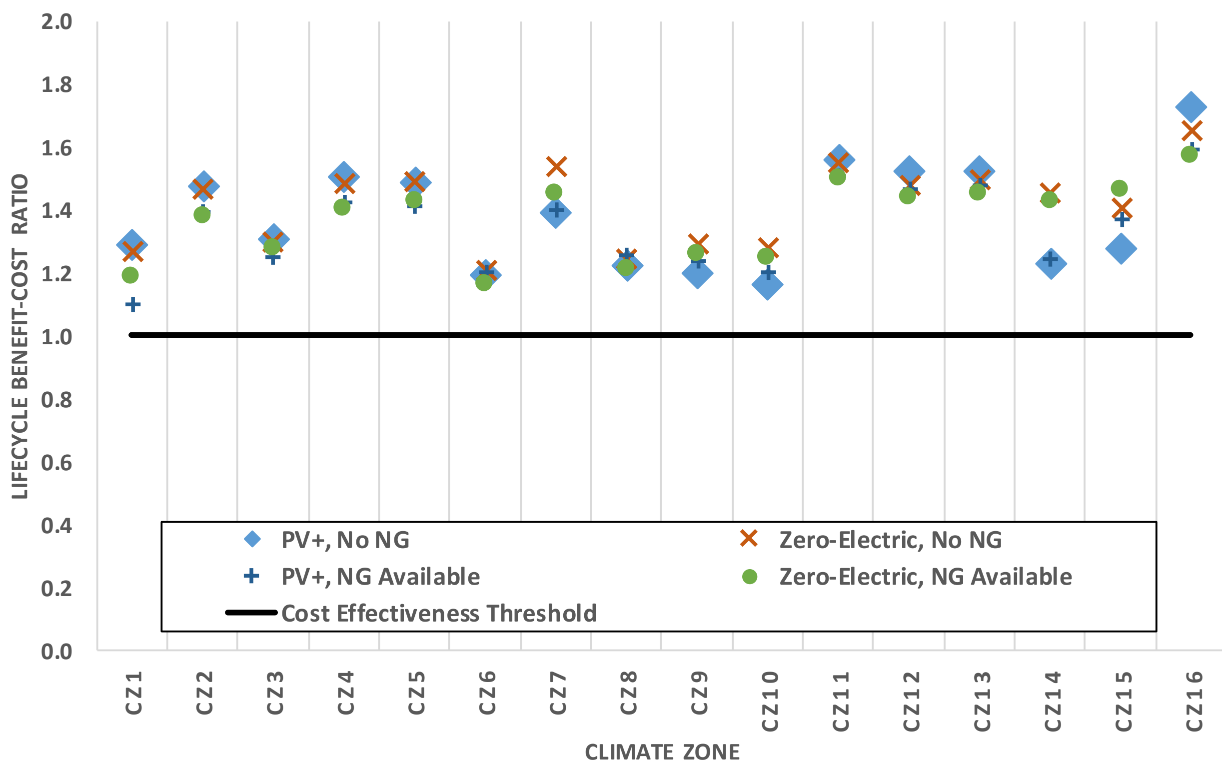

Figure 2: Multifamily all-electric cost-effectiveness comparison

Table 10: Multifamily All-Electric PV-Plus Performance Package Cost-Effectiveness Results

Climate Zone	Compliance Margin	PV Capacity (kW)	Elec Savings (kWh)	Gas Savings (therms)[1]	GHG % Savings[2]	Package Cost[3]	Utility Cost Savings	Simple Payback	Lifecycle Benefit-to-Cost Ratio
No Natural Gas[1]									
CZ1	19.2%	1.6	998	96.4	43.2%	$6,309	$444	14.2	1.29
CZ2	24.7%	1.4	1,176	86.5	46.0%	$5,686	$457	12.4	1.47
CZ3	12.8%	1.5	1,140	86.9	49.0%	$6,789	$484	14.0	1.31
CZ4	33.8%	1.3	1,155	82.8	46.4%	$5,374	$441	12.2	1.50
CZ5	22.9%	1.4	1,327	89.0	53.0%	$5,906	$478	12.4	1.49
CZ6	25.4%	1.5	1,448	79.1	54.7%	$5,997	$390	15.4	1.19
CZ7	24.9%	1.3	1,210	77.9	51.3%	$5,457	$414	13.2	1.39
CZ8	36.7%	1.5	1,573	75.8	55.3%	$5,997	$400	15.0	1.23
CZ9	37.0%	1.4	1,488	75.7	51.7%	$5,563	$364	15.3	1.20
CZ10	36.6%	1.4	1,509	75.1	50.8%	$5,563	$353	15.8	1.16
CZ11	30.1%	1.7	1,998	76.5	52.8%	$6,498	$553	11.8	1.56
CZ12	33.4%	1.5	1,502	80.5	49.1%	$5,875	$488	12.0	1.53
CZ13	30.9%	1.8	2,109	75.1	54.5%	$6,809	$565	12.1	1.52
CZ14	30.4%	1.3	1,603	77.4	46.5%	$5,251	$352	14.9	1.23
CZ15	28.4%	2.1	3,255	56.2	62.7%	$7,744	$540	14.3	1.28
CZ16	25.4%	1.3	1,105	95.5	38.6%	$5,137	$484	10.6	1.73
Natural Gas Available									
CZ1	11.4%	1.6	1,527	96.4	52.2%	$7,011	$420	16.7	1.10
CZ2	16.1%	1.4	1,553	86.5	52.7%	$5,838	$443	13.2	1.39
CZ3	12.1%	1.5	1,758	86.9	60.9%	$6,940	$474	14.6	1.25
CZ4	27.8%	1.3	1,526	82.8	53.3%	$5,526	$429	12.9	1.43
CZ5	10.8%	1.4	1,732	89.0	60.7%	$6,058	$466	13.0	1.41
CZ6	19.1%	1.5	1,829	79.1	62.3%	$6,149	$402	15.3	1.20
CZ7	20.2%	1.3	1,606	77.9	59.5%	$5,608	$427	13.1	1.40
CZ8	35.6%	1.5	1,964	75.8	63.0%	$6,149	$420	14.6	1.25
CZ9	35.6%	1.4	1,886	75.7	59.3%	$5,715	$385	14.8	1.24
CZ10	34.3%	1.4	1,900	75.1	58.1%	$5,715	$374	15.3	1.20
CZ11	28.2%	1.7	2,366	76.5	58.8%	$6,650	$547	12.2	1.51
CZ12	30.7%	1.5	1,885	80.5	55.8%	$6,026	$481	12.5	1.47
CZ13	28.6%	1.8	2,482	75.1	60.7%	$6,961	$561	12.4	1.48
CZ14	27.9%	1.3	1,971	77.4	52.5%	$5,403	$367	14.7	1.25
CZ15	29.6%	2.1	3,654	56.2	68.8%	$7,896	$589	13.4	1.37
CZ16	16.9%	1.3	1,469	95.5	44.0%	$5,289	$460	11.5	1.60

[1] Savings for "No Natural Gas" case are propane savings from elimination of propane water heater. Gas savings are therms equivalent.
[2] Based on CA electricity production and equivalent CO_2 emission rates of 0.724 lbCO_2e/kWh, 11.7 lb-CO_2e/therm natural gas & 13.9 lb-CO_2e/therm propane.
[3] Includes ten percent markup for builder profit and overhead.

Table 11: Multifamily All-Electric Zero Electric Performance Package Cost-Effectiveness Results

Climate Zone	Compliance Margin	PV Capacity (kW)	Elec Savings (kWh)	Gas Savings (therms)[1]	GHG % Savings[2]	Package Cost[3]	Utility Cost Savings	Simple Payback	Lifecycle Benefit-Cost Ratio
No Natural Gas[1]									
CZ1	19.2%	4.1	4,355	96.4	100%	$14,099	$973	14.5	1.27
CZ2	24.7%	3.3	4,198	86.5	100%	$11,606	$926	12.5	1.47
CZ3	12.8%	3.2	3,789	86.9	100%	$12,086	$855	14.1	1.30
CZ4	33.8%	3.1	4,038	82.8	100%	$10,983	$888	12.4	1.48
CZ5	22.9%	2.9	3,783	89.0	100%	$10,580	$858	12.3	1.49
CZ6	25.4%	2.9	3,709	79.1	100%	$10,360	$683	15.2	1.21
CZ7	24.9%	2.7	3,556	77.9	100%	$9,819	$823	11.9	1.54
CZ8	36.7%	2.9	3,834	75.8	100%	$10,360	$702	14.8	1.24
CZ9	37.0%	2.9	4,017	75.7	100%	$10,237	$722	14.2	1.29
CZ10	36.6%	3.0	4,142	75.1	100%	$10,548	$735	14.3	1.28
CZ11	30.1%	3.5	4,895	76.5	100%	$12,106	$1,021	11.9	1.55
CZ12	33.4%	3.4	4,409	80.5	100%	$11,795	$949	12.4	1.48
CZ13	30.9%	3.6	4,878	75.1	100%	$12,418	$1,014	12.2	1.50
CZ14	30.4%	3.1	4,891	77.4	100%	$10,860	$863	12.6	1.46
CZ15	28.4%	3.6	5,727	56.2	100%	$12,418	$950	13.1	1.40
CZ16	25.4%	3.8	5,311	95.5	100%	$12,927	$1,164	11.1	1.65
Natural Gas Available									
CZ1	11.4%	3.7	4,355	96.4	100%	$13,554	$875	15.5	1.19
CZ2	16.1%	3.1	4,198	86.5	100%	$11,135	$839	13.3	1.38
CZ3	12.1%	2.8	3,789	86.9	100%	$10,991	$765	14.4	1.28
CZ4	27.8%	2.9	4,038	82.8	100%	$10,511	$805	13.1	1.41
CZ5	10.8%	2.6	3,783	89.0	100%	$9,797	$761	12.9	1.43
CZ6	19.1%	2.7	3,709	79.1	100%	$9,888	$627	15.8	1.16
CZ7	20.2%	2.5	3,556	77.9	100%	$9,348	$740	12.6	1.45
CZ8	35.6%	2.7	3,834	75.8	100%	$9,888	$652	15.2	1.21
CZ9	35.6%	2.7	4,017	75.7	100%	$9,765	$671	14.6	1.26
CZ10	34.3%	2.8	4,142	75.1	100%	$10,077	$686	14.7	1.25
CZ11	28.2%	3.3	4,895	76.5	100%	$11,635	$949	12.3	1.50
CZ12	30.7%	3.1	4,409	80.5	100%	$11,012	$866	12.7	1.44
CZ13	28.6%	3.4	4,878	75.1	100%	$11,947	$946	12.6	1.45
CZ14	27.9%	2.9	4,891	77.4	100%	$10,389	$809	12.8	1.43
CZ15	29.6%	3.3	5,727	56.2	100%	$11,635	$927	12.6	1.46
CZ16	16.9%	3.6	5,311	95.5	100%	$12,455	$1,067	11.7	1.57

[1] Savings for "No Natural Gas" case are propane savings from elimination of propane water heater. Gas savings are therms equivalent.

[2] Based on CA electricity production and equivalent CO_2 emission rates of 0.724 lbCO_2e/kWh, 11.7 lb-CO_2e/therm natural gas & 13.9 lb-CO_2e/therm propane.

[3] Includes ten percent markup for builder profit and overhead.

3.2.2 Multifamily Packages

PV-Plus & Zero-Electric: ***Cost-effective packages using both efficiency and PV to exceed minimum requirements were identified in all 16 climate zones as demonstrated in Table 10 and*** Table 11 above. Meeting higher compliance margin targets in all-electric buildings is more challenging in multifamily than in single family. The results from the CBECC-Res simulation software are very sensitive to the HPWH selection as well as the efficiency measures selected, particularly in milder climates.

Table 12 summarizes the cost-effective efficiency measures used in each climate zone. The "Natural Gas Available" scenarios include the same efficiency measures except where indicated with the addition of the high efficiency HPWH. Values in red reflect measures added to the all-electric packages to meet the performance targets.

In most climates the HPWH was located within the conditioned space because there is a net benefit in locating the HPWH inside as a result of lower water heating and space cooling energy use when compared to an externaly located unit. In Climate Zone 3, the HPWH was evaluated in an exterior closet. As a heating dominated climate, with negligible amounts of cooling energy, the negative impact on space heating from moving the HPWH into conditioned space is greater than the water heating savings. While Climate Zone 16 is also heating dominated it has a summer cooling load and the winter temperatures are much more extreme resulting in a far higher penalty for leaving the HPWH outdoors. In Climate Zone 1 CBECC-Res predicts different trends for the "No Natural Gas" and "Natural Gas Available" cases. Water heating savings from moving the lower efficiency HPWH in the "No Natural Gas" scenario into conditioned space are greater than in the "Natural Gas Available" scenario. However, the impact on space heating in the former case is lower because the HPWH operates in electric resistance mode more of the time. This combination of effects results in the lower efficiency 2.0 Energy Factor HPWH ("No Natural Gas" scenario) optimally located in the conditioned space but the higher efficiency NEEA rated HPWH ("Natural Gas Avaialble" scenario) optimally located outdoors.

Table 12: Multifamily All-Electric PV Packages: Cost-Effective Measures Summary

Climate Zone	PV Compliance Credit	QII	Window U-value / SHGC	Door U-value	High Performance Attic	AH Fan W/cfm	LLDCS	Refrigerant Charge	HPWH Location[1]	HW Comp. Dist.
CZ1	Y	Y	0.30/0.50	0.20		0.3			CS (No NG) Ext (NG Avail)	Y
CZ2	Y	Y	0.30/0.23	0.20		0.3			CS	Y
CZ3	Y	Y	0.30/0.50	0.20	R-13	0.3			Ext	Y
CZ4	Y	Y	0.30/0.23	0.20		0.3			CS	Y
CZ5	Y	Y	0.30/0.50	0.20		0.3	Y		CS	Y
CZ6	N/A	Y	0.30/0.23	0.20		0.3			CS	Y
CZ7	N/A	Y	0.30/0.23	0.20		0.3		Y	CS	Y
CZ8	Y	Y	0.30/0.23	0.20		0.3			CS	Y
CZ9	Y	Y	0.30/0.23	0.20		0.3			CS	
CZ10	Y	Y	0.30/0.23	0.20		0.3			CS	
CZ11	Y	Y	0.30/0.23	0.20		0.3			CS	
CZ12	Y	Y	0.30/0.23	0.20		0.3			CS	
CZ13	Y	Y	0.30/0.23	0.20		0.3			CS	
CZ14	Y	Y	0.30/0.23	0.20		0.3			CS	
CZ15	Y	Y	0.30/0.23	0.20		0.3			CS	
CZ16	Y	Y	0.30/0.23	0.20					CS	

Values in red indicate a change between the gas/electric and all-electric results.
[1]CS = conditioned space; Ext = exterior closet.

4 Conclusions & Summary

This report evaluated the feasibility and cost-effectiveness of all-electric single family and low-rise multifamily residential new construction that exceeds the 2016 Building Energy Efficiency Standards through the installation of both efficiency measures and PV systems in all 16 California climate zones. The results of this evaluation provide local jurisdictions flexibility when adopting an energy efficiency ordinance ensuring that the requirement can be met either with a mixed-fuel design or an all-electric design. Two scenarios were evaluated. The "No Natural Gas" case does not trigger federal preemption issues, and represents options that local jurisdictions can adopt into a local ordinance. The "Natural Gas Available" scenario requires water heating equipment that is more efficient than federal standards, thus triggering federal preemption restrictions.

For this analysis, PG&E rates were used for gas and electricity in Climate Zones 1 through 5, 11 through 13, and 16. SCE electricity rates and Southern California Gas rates were used for Climate Zones 6, 8 through 10, 14, and 15. SDG&E rates were used for electricity and gas for Climate Zone 7.

Recommended Title 24 compliance margin targets were set based on results of the cost effectiveness analysis and match those recommended in the gas/electric analysis in most cases. When setting recommendations results from both the "Natural Gas Available" and "No Natural Gas" scenarios were reviewed to ensure that the targets could be met in either case. For single family homes 30% was achievable everywhere except Climate Zones 3, and 5-7; in those climates cost effective packages were found that achieve a 10%-20% compliance margin. Meeting higher compliance margin targets in all-electric buildings is more challenging in multifamily buildings than in single family. The results from the CBECC-Res simulation software are very sensitive to the HPWH selection as well as the efficiency measures selected, particularly in milder climates. Due to this the HPWH was located within the conditioned space in most climates. Table 13 and Table 14 summarize cost-effective ordinance criteria by climate zone for single family and multifamily buildings, respectively. The tables include the Title 24 compliance target needed to meet the criteria. Consistent with CALGreen voluntary tiers, the analysis assumes a pre-requisite for all packages includes HERS verification of Quality Insulation Installation (QII).

Table 13: Single Family Cost-Effective All-Electric Reach Code Package

Packages	Climate Zones	T-24 Compliance Target	QII	PVCC Allowed	PV
PV-Plus & Zero-Electric Packages	1, 2, 4, 8-16	30%	Yes	Yes	Yes
	3, 5	20%	Yes	Yes	Yes
	6-7	10%	Yes	N/A	Yes

Table 14: Multifamily Cost-Effective All-Electric Reach Code Package

Packages	Climate Zones	T-24 Compliance Target	QII	PVCC Allowed	PV
PV-Plus & Zero-Electric Packages	4,9-15	25%	Yes	Yes	Yes
	8	20%	Yes	Yes	Yes
	2,16	15%	Yes	Yes	Yes
	1,3,5	10%	Yes	Yes	Yes
	6-7	10%	Yes	n/a	Yes

Table 15 and Table 16 present a summary of the differences in the cost-effective packages for all-electric homes compared to those for gas/electric homes. Differences are highlighted in red. For single family, the

2016 compliance margin targets are the same as those for the gas/electric packages in all cases. The PV Compliance Credit (PVCC) may be used to meet these targets, except in Climate Zones 6 and 7, where the PVCC is not available.

With multifamily, the 2016 compliance margin targets are the same as those for the gas/electric packages except for Climate Zones 1, 2, 3, and 16 (see Table 16). In these four climate zones the predicted penalty in CBECC-Res for using a HPWH could not be fully offset with cost effective efficiency measures. The recommended compliance margin targets have been subsequently reduced by 5%-10%.

Table 15: Single Family PV Package Compliance Target Comparison

	Nat. Gas/Electric		All-Electric	
Climate Zone	**Compliance Margin Target**	**PVCC Allowed**	**Compliance Margin Target**	**PVCC Allowed**
CZ1	30%	Yes	30%	Yes
CZ2	30%	Yes	30%	Yes
CZ3	20%	Yes	20%	Yes
CZ4	30%	Yes	30%	Yes
CZ5	20%	Yes	20%	Yes
CZ6	10%	N/A	10%	N/A
CZ7	10%	N/A	10%	N/A
CZ8	30%	Yes	30%	Yes
CZ9	30%	Yes	30%	Yes
CZ10	30%	Yes	30%	Yes
CZ11	30%	Yes	30%	Yes
CZ12	30%	Yes	30%	Yes
CZ13	30%	Yes	30%	Yes
CZ14	30%	Yes	30%	Yes
CZ15	30%	Yes	30%	Yes
CZ16	30%	Yes	30%	Yes

Table 16: Multifamily PV Package Compliance Target Comparison

Climate Zone	Nat. Gas/Electric		All-Electric	
	Compliance Margin Target	PVCC Allowed	Compliance Margin Target	PVCC Allowed
CZ1	20%	Yes	10%	Yes
CZ2	20%	Yes	15%	Yes
CZ3	15%	Yes	10%	Yes
CZ4	25%	Yes	25%	Yes
CZ5	10%	Yes	10%	Yes
CZ6	10%	N/A	10%	N/A
CZ7	10%	N/A	10%	N/A
CZ8	20%	Yes	20%	Yes
CZ9	25%	Yes	25%	Yes
CZ10	25%	Yes	25%	Yes
CZ11	25%	Yes	25%	Yes
CZ12	25%	Yes	25%	Yes
CZ13	25%	Yes	25%	Yes
CZ14	25%	Yes	25%	Yes
CZ15	25%	Yes	25%	Yes
CZ16	25%	Yes	15%	Yes

Values in red indicate a change between the gas/electric and all-electric results.

In the gas/electric analysis, recommendations were made for both efficiency-only and PV performance packages. Based on current residential utility rates across all the California investor owned utilities, switching from gas to electric appliances results in higher annual utility costs for all-electric efficiency-only packages. It is also expected that the majority of projects complying with an all-electric above code local ordinance will also be incorporating PV. For this reason, only PV performance packages that incorporate both efficiency measures and PV were developed.

In addition to the PV-Plus performance package introduced in the gas/electric analysis, a Zero-Electric package was also found to be cost-effective for all-electric homes. This was evaluated in place of a Zero-TDV package. Zero-TDV was evaluated in the gas/electric analysis as a way to achieve zero net energy with mixed fuels; however, it was not found to be cost-effective. This approach is not favored by California policy in mixed fuel homes, because PV systems sized to offset both gas (natural gas or propane) and electricity TDV result in PV systems sized larger than the building electricity use. Generating more electricity than is used on site is not cost-effective to the owner under California Net Energy Metering policy and can violate utility net energy metering rules for the size of a PV system. The consumer is compensated by the utility for electricity generation in excess of annual consumption, but only at the wholesale rate, which is substantially lower than the retail rate. When all onsite energy use is supplied by electricity, excess annual generation may be minimal.

5 References

CEC. 2016a. 2016 Alternative Calculation Method Approval Manual. CEC-400-2015-039-CMF. June 2015. California Energy Commission. http://www.energy.ca.gov/2015publications/CEC-400-2015-039/CEC-400-2015-039-CMF.pdf

CEC. 2016b. 2016 Building Energy Efficiency Standards for Residential and Nonresidential Buildings. CEC-400-2015-037-CMF. June 2015. California Energy Commission. http://www.energy.ca.gov/2015publications/CEC-400-2015-037/CEC-400-2015-037-CMF.pdf

CEC. 2016c. 2016 Reference Appendices. CEC-400-2015-038-CMF. June 2015. California Energy Commission. http://www.energy.ca.gov/2015publications/CEC-400-2015-038/CEC-400-2015-038-CMF.pdf

CEC. 2016d. 2016 Residential Alternative Calculation Method Reference Manual. CEC-400-2015-024-CMF-REV. June 2016. California Energy Commission. http://www.energy.ca.gov/2015publications/CEC-400-2015-024/CEC-400-2015-024-CMF-REV.pdf

CEC. 2017. Draft Model Local Ordinance. Docket Number 17-BSTD-01. April 2017. California Energy Commission. http://docketpublic.energy.ca.gov/PublicDocuments/17-BSTD-01/TN217291_20170425T110520_Draft_Model_Local_Solar_Ordinance_v5.pdf

DEG, 2016. California Statewide Codes and Standards Program Title 24, Part 11 Local Energy Efficiency Ordinances CALGreen Cost Effectiveness Study. Davis Energy Group. October 2016.

DOE, 2016. "Tankless Or Demand-Type Water Heaters", Department of Energy: Energy Saver. https://energy.gov/energysaver/tankless-or-demand-type-water-heaters

EPRI, 2016. SMUD All-Electric Homes Electrification Case Study: Summary for the Three-Prong Test Discussion. Electric Power Research Institute, Inc. September, 2016. Presentation to Sacramento Municipal Utility District.

Horii, B., E. Cutter, N. Kapur, J. Arent, and D. Conotyannis. 2014. "Time Dependent Valuation of Energy for Developing Building Energy Efficiency Standards." http://www.energy.ca.gov/title24/2016standards/prerulemaking/documents/2014-07-09_workshop/2017_TDV_Documents/

Itron, 2014. 2010-2012 WO017 Ex Ante Measure Cost Study: Final Report. Itron. May 2014. Presented to California Public Utilities Commission.

Appendix A – Prescriptive Package

The following presents the residential prescriptive package as printed in the 2016 Building Energy Efficiency Standards (CEC, 2016b).

						Climate Zone															
						1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Building Envelope Insulation	**Roofs/ Ceilings**	**Option A (meets §150.1(c)9A)**	Continuous Insulation Above Roof Rafter	Roofing Type	No Air Space[1]	NR	NR	NR	R 8	NR	NR	NR	R 8	R 8	R 8	R 8	R 8	R 8	R 8	R 8	R 8
					With Air Space[2]	NR	NR	NR	R 6	NR	NR	NR	R 6	R 6	R 6	R 6	R 6	R 6	R 6	R 6	R 6
			Ceiling Insulation			R 38	R 38	R 30	R 38	R 30	R 30	R 30	R 38	R 38	R 38	R 38	R 38	R 38	R 38	R 38	R 38
			Radiant Barrier			NR	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	NR
		Option B (meets §150.1(c)9A)	Below Roof Deck Insulation	Roofing Type	No Air Space	NR	NR	NR	R 18	NR	NR	NR	R 18	R 18	R 18	R 18	R 18	R 18	R 18	R 18	R 18
					With Air	NR	NR	NR	R 13	NR	NR	NR	R 13	R 13	R 13	R 13	R 13	R 13	R 13	R 13	R 13
			Ceiling Insulation			R 38	R 38	R 30	R 38	R 30	R 30	R 30	R 38	R 38	R 38	R 38	R 38	R 38	R 38	R 38	R 38
			Radiant Barrier			NR	REQ	REQ	NR	REQ	REQ	REQ	NR	NR	NR	NR	NR	NR	NR	NR	NR
		Option C (meets	Ceiling Insulation			R 38	R 30	R 30	R 30	R 30	R 30	R 30	R 30	R 30	R 30	R 38	R 38	R 38	R 38	R 38	R 38
			Radiant			NR	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	NR

TABLE 150.1-A COMPONENT PACKAGE-A STANDARD BUILDING DESIGN (CONTINUED)

				Climate Zone															
				1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Building Envelope Insulation	**Walls**	Above Grade	Framed[4]	U 0.051	U 0.051	U 0.051	U 0.051	U 0.051	U 0.065	U 0.065	U 0.051	U 0.051	U 0.051	U 0.051	U 0.051	U 0.051	U 0.051	U 0.051	U 0.051
			Mass Wall Interior[5]	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.059 R 17
			Mass Wall Exterior[6]	U 0.125 R 8.0	U 0.125 R 8.0	U 0.125 R 8.0	U 0.125 R 8.0	U 0.125 R 8.0	U 0.125 R 8.0	U 0.125 R 8.0	U 0.125 R 8.0	U 0.125 R 8.0	U 0.125 R 8.0	U 0.125 R 8.0	U 0.125 R 8.0	U 0.125 R 8.0	U 0.1025 R 8.0	U 0.125 R 8.0	U 0.070 R 13
		Below Grade	Below Grade Interior[7]	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.066 R 15
			Below Grade Exterior	U 0.200 R 5.0	U 0.200 R 5.0	U 0.200 R 5.0	U 0.200 R 5.0	U 0.200 R 5.0	U 0.200 R 5.0	U 0.200 R 5.0	U 0.200 R 5.0	U 0.200 R 5.0	U 0.200 R 5.0	U 0.200 R 5.0	U 0.200 R 5.0	U 0.200 R 5.0	U 0.100 R 10	U 0.100 R 10	U 0.053 R 19
	Floors	Slab Perimeter		NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	U 0.58 R 7.0
		Raised		U 0.037 R 19	U 0.037 R 19	U 0.037 R 19	U 0.037 R 19	U 0.037 R 19	U 0.037 R 19	U 0.037 R 19	U 0.037 R 19	U 0.037 R 19	U 0.037 R 19	U 0.037 R 19	U 0.037 R 19	U 0.037 R 19	U 0.037 R 19	U 0.037 R 19	U 0.037 R 19
		Concrete Raised		U 0.092 R 8.0	U 0.092 R 8.0	U 0.269 R 0	U 0.269 R 0	U0.269 R 0	U 0.269 R 0	U 0.269 R 0	U 0.269 R 0	U 0.269 R 0	U 0.269 R 0	U 0.092 R 8.0	U 0.138 R 4.0	U 0.092 R 8.0	U 0.092 R 8.0	U 0.138 R 4.0	U 0.092 R 8.0
Building Envelope	**Roofing Products**	**Low-sloped**	Aged Solar Reflectance	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0.63	NR	0.63	NR
			Thermal Emittance	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0.75	NR	0.75	NR
		Steep Sloped	Aged Solar Reflectance	NR	NR	NR	NR	NR	NR	NR	NR	NR	0.20	0.20	0.20	0.20	0.20	0.20	NR
			Thermal Emittance	NR	NR	NR	NR	NR	NR	NR	NR	NR	0. 75	0.75	0.75	0.75	0.75	0.75	NR
Building Envelope	**Fenestration**	Maximum U-factor		0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
		Maximum SHGC		NR	0.25	NR	0.25	NR	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
		Maximum Total Area		20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
		Maximum West Facing Area		NR	5%	NR	5%	NR	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%

TABLE 150.1-A COMPONENT PACKAGE-A STANDARD BUILDING DESIGN (CONTINUED)

				Climate Zone															
				1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
HVAC SYSTEM	**Space Heating[11]**	**Electric-Resistance Allowed**		No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
		If gas, AFUE		MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN
		If Heat Pump, HSPF[9]		MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN
	Space cooling	**SEER**		MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN
		Refrigerant Charge Verification or Fault Indicator Display		NR	REQ	NR	NR	NR	NR	NR	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	NR
		Whole House Fan[10]		NR	NR	NR	NR	NR	NR	NR	REQ	REQ	REQ	REQ	REQ	REQ	REQ	NR	NR
	Central System Air Handlers	**Central Fan Integrated Ventilation System Fan Efficacy**		REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ
	Ducts[12]	**Roof/Ceiling Options A & B**	Duct Insulation	R-8	R-8	R-6	R-8	R-6	R-6	R-6	R-8	R-8	R-8	R-8	R-8	R-8	R-8	R-8	R-8
			§150.1(c)9A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Roof/Ceiling	Duct Insulation	R-6	R-6	R-6	R-6	R-6	R-6	R-6	R-6	R-6	R-6	R-6	R-6	R-6	R-6	R-6	R-6
			§150.1(c)9B	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ
Water Heating	**All Buildings**			System Shall meet Section 150.1(c)8															

Footnote requirements to TABLE 150.1-A:[13]

1. Install the specified R-value with no air space present between the roofing and the roof deck.
2. Install the specified R-value with an air space present between the roofing and the roof deck. Such as standard installation of concrete or clay tile.
3. R-values shown for below roof deck insulation are for wood-frame construction with insulation installed between the framing members.
4. Assembly U-factors can be met with cavity insulation alone or with continuous insulation alone, or with both cavity and continuous insulation that results in an assembly U-factor equal to or less than the U-factor shown. Use Reference Joint Appendices JA4 Table 4.3.1, 4.3.1(a), or Table 4.3.4 to determine alternative insulation products to meet the required maximum U-factor.
5. Mass wall has a thermal heat capacity greater than or equal to 7.0 Btu/h-ft^2. "Interior" denotes insulation installed on the inside surface of the wall.
6. Mass wall has a thermal heat capacity greater than or equal to 7.0 Btu/h-ft^2. "Exterior" denotes insulation installed on the exterior surface of the wall.
7. Below grade "interior" denotes insulation installed on the inside surface of the wall.
8. Below grade "exterior" denotes insulation installed on the outside surface of the wall.
9. HSPF means "heating seasonal performance factor."
10. When whole house fans are required (REQ), only those whole house fans that are listed in the Appliance Efficiency Directory may be installed. Compliance requires installation of one or more WHFs whose total airflow CFM is capable of meeting or exceeding a minimum 1.5 cfm/square foot of conditioned floor area as specified by Section 150.1(c)12.
11. A supplemental heating unit may be installed in a space served directly or indirectly by a primary heating system, provided that the unit thermal capacity does not exceed 2 kilowatts or 7,000 Btu/hr and is controlled by a timelimiting device not exceeding 30 minutes.
12. For duct and air handler location: REQ denotes location in conditioned space. When the table indicates ducts and air handlers are in conditioned space, a HERS verification is required as specified by Reference Residential Appendix RA3.1.4.3.8.

[13] CBECC-Res applies Option B to the Standard Design with ductwork located in the attic for single family and in conditioned space for multifamily buildings.

Appendix B – Measure Cost Details

Table 17: Measure Descriptions & Cost Assumptions

Measure	Performance Level	Incremental Cost Single Family	Incremental Cost MF–Per Unit	Source & Notes
QII	Yes	$519	$133	City of Palo Alto 2016 Reach Code Ordinance: http://www.cityofpaloalto.org/civicax/filebank/documents/52054
ACH50	3.0	$379	N/A	NREL measure cost database ($0.115/$ft^2$ for sealing) + HERS Rater verification ($100).
Wall Insulation	R-21	$391	N/A	Relative to R-19. 2016 CASE Report: Residential High Performance Walls and QII, 2016-RES-ENV2-F.
Cool Roof	Aged Reflect = 0.20	$523	$131	$0-$0.50/ft^2 of roof area per local industry expert at LBNL. Used average of $0.25/$ft^2$.
Window U-Factor/SHGC	0.30/0.23	$73	$20	EnerComp ($0.15/$ft^2$ of window area).
Doors	0.20 U-factor	$40	$20	EnerComp ($1.00/$ft^2$ for exterior doors).
High Performance Attics (HPA)	R-13 under roof deck	$878	$219	For Climate Zones 1-3, & 5-7 only where HPA is not prescriptive. 2016 CASE Report: Residential Ducts in Conditioned Space/High Performance Attics, 2016-RES-ENV1-F.
Fan Efficacy	0.3 watts/cfm	$143	$104	HVAC contractor costs, MF reduction for smaller capacity.
Refrigerant Charge	HERS verified	N/A	$75	Local HERS Rater.
Duct Insulation	R-8	$164	N/A	For Climate Zones 3, 6, & 7 where not prescriptive. Cost is relative to R-6. 2016 CASE Report: Residential Ducts in Conditioned Space/High Performance Attics, 2016-RES-ENV1-F.
Low Leakage Ducts in Conditioned Space	25cfm leakage to outside	N/A	$379	Only includes the cost for blower door testing (see ACH50 costs for SF above) since the basecase assume ductwork located in conditioned space and duct testing.
HERS Verification of Hot Water Pipe Insulation	HERS verified	$146	N/A	Roughly equivalent to code requirements effective Jan. 2017. ten percent of $3.87 per ft (2013 SF DHW CASE Report) for additional labor to pass HERS inspection. $100 for HERS verification per local HERS Raters.
Hot Water Compact Distribution	HERS verified	N/A	$112	Assume compact design already or easily achieved in MF units – no added cost. $100 HERS verification fee per local HERS Rater. Pipe insulation cost per the pipe insulation measure assumptions.
Ducted Heat Pump Water Heater in Conditioned Space	Exhaust air ducted to the outdoors	N/A	$500	Costs includes ducting kit and installation
PV System	System size varies	$2.80/W DC	$2.63/W DC	Source: Tracking the Sun IX. (https://emp.lbl.gov/sites/default/files/tracking_the_sun_ix_report.pdf). Single Family: Avg. system cost of $4.00/watt in 2015 for residential new construction. Multifamily systems: an average residential and small commercial system costs @ $3.25/watt was used. Systems are expected to be typically greater than 10 kW, although not as large as some commercial systems reported on in the database. In both cases, costs assume 30 percent for the solar investment tax credit. No NSHP incentive was used.
PV Inverter–Replacement	Micro inverter	$0.40/W DC	$0.40/W DC	Assumes inverter replacement at 20 years based on life of micro inverters. NREL cost study: $0.29/W based on new construction. (http://www.nrel.gov/docs/fy15osti/64746.pdf). Add labor cost of $275.

Appendix C – Efficiency Package Summaries

Table 18 and Table 19 summarize the measures selected to cost effectively meet the performance targets in the report. Values in red reflect measures added to the all-electric packages to meet the performance targets. Blank cells mean that values are the same as 2016 prescriptive values for that climate zone.

Table 18: Single Family PV Packages

Climate Zone	Compliance Margin Target	QII	ACH50	Window U-value / SHGC	Door U-value	HPA	AH Fan W/cfm	HPWH Location[1]	HW Pipe Insul.	PV Credit Size (kW)
CZ1	30%	Y	3	.30/.50	0.20	Y		Gar	PI	2.1
CZ2	30%	Y		.30/.50	0.20	Y		CS	PI	2.1
CZ3	20%	Y		.30/.50	0.20			Gar		2.0
CZ4	30%	Y		.30/.23				Gar		2.1
CZ5	20%	Y		.30/.50				Gar		2.0
CZ6	10%	Y					0.30	Gar		n/a
CZ7	10%	Y		.30/.23	0.20		0.30	Gar	PI	n/a
CZ8	30%	Y						Gar		2.1
CZ9	30%	Y		.30/.23	0.20			Gar		2.0
CZ10	30%	Y			0.20			Gar		2.1
CZ11	30%	Y		.30/.23	0.20		0.30	Gar		2.2
CZ12	30%	Y			0.20			Gar		2.1
CZ13	30%	Y		.30/.23	0.20			Gar		2.2
CZ14	30%	Y			0.20		0.30	Gar		2.2
CZ15	30%	Y					0.30	Gar		2.2
CZ16	30%	Y	3	.30/.23	0.20		0.30	CS		2.1

[1]CS = conditioned space; Gar = garage.

Table 19: Multifamily PV Packages

Climate Zone	Compliance Margin Target	QII	Window U-value / SHGC	Door U-value	AH Fan W/cfm	Refrigerant Charge	HPWH Location[1]	HW Comp. Dist.	PV Credit Size (kW)
CZ1	20%	Y	0.30/0.50	0.20	0.3		CS (No NG) Ext (NG Avail)	Y	1.0
CZ2	20%	Y	0.30/0.23	0.20	0.3		CS	Y	1.0
CZ3	15%	Y	0.30/0.50	0.20	0.3		Ext	Y	1.0
CZ4	25%	Y	0.30/0.23	0.20	0.3		CS	Y	1.0
CZ5	10%	Y	0.30/0.50	0.20	0.3		CS	Y	1.0
CZ6	10%	Y	0.30/0.23	0.20	0.3		CS	Y	
CZ7	10%	Y	0.30/0.23	0.20	0.3	Y	CS	Y	
CZ8	20%	Y	0.30/0.23	0.20	0.3		CS	Y	1.0
CZ9	25%	Y	0.30/0.23	0.20	0.3		CS		1.0
CZ10	25%	Y	0.30/0.23	0.20	0.3		CS		1.0
CZ11	25%	Y	0.30/0.23	0.20	0.3		CS		1.0
CZ12	25%	Y	0.30/0.23	0.20	0.3		CS		1.0
CZ13	25%	Y	0.30/0.23	0.20	0.3		CS		1.0
CZ14	25%	Y	0.30/0.23	0.20	0.3		CS		1.0
CZ15	25%	Y	0.30/0.23	0.20	0.3		CS		1.0
CZ16	25%	Y	0.30/0.23	0.20			CS		1.0

[1]CS = conditioned space; CS-Duct = ducted unit in conditioned space.

Appendix D – Utility Rate Tariffs

Following are the PG&E electricity, both standard and time-of-use, and natural gas tariffs applied in this study. The PG&E monthly gas rate in $/therm was applied on a monthly basis for the 12-month period ending September 2017.

Pacific Gas and Electric Company
U 39 San Francisco, California

	Revised	Cal. P.U.C. Sheet No.	40030-E
Cancelling	Revised	Cal. P.U.C. Sheet No.	38021-E

ELECTRIC SCHEDULE E-1
RESIDENTIAL SERVICES

Sheet 1

APPLICABILITY: This schedule is applicable to single-phase and polyphase residential service in single-family dwellings and in flats and apartments separately metered by PG&E; to single-phase and polyphase service in common areas in a multifamily complex (see Special Condition 8); and to all single-phase and polyphase farm service on the premises operated by the person whose residence is supplied through the same meter.

The provisions of Schedule S—Standby Service Special Conditions 1 through 6 shall also apply to customers whose premises are regularly supplied in part (but not in whole) by electric energy from a nonutility source of supply. These customers will pay monthly reservation charges as specified under Section 1 of Schedule S, in addition to all applicable Schedule E-1 charges. See Special Conditions 11 and 12 of this rate schedule for exemptions to standby charges.

TERRITORY: This rate schedule applies everywhere PG&E provides electric service.

RATES: Total bundled service charges are calculated using the total rates below. Customers on this schedule are subject to the delivery minimum bill amount shown below applied to the delivery portion of the bill (i.e. to all rate components other than the generation rate). In addition, total bundled charges will include applicable generation charges per kWh for all kWh usage.

Customers receiving a medical baseline allowance shall pay for all usage in excess of 200 percent of baseline at a rate $0.04000 per kWh less than the applicable rate for usage in excess of 200 percent of baseline. No portion of the rates paid by customers that receive a Medical Baseline allowance shall be used to pay the DWR Bond charge. For these customers, the Conservation Incentive Adjustment is calculated residually based on the total rate less the sum of: Transmission, Transmission Rate Adjustments, Reliability Services, Distribution, Generation, Public Purpose Programs, Nuclear Decommissioning, Competition Transition Charges (CTC), New System Generation Charges,[1] and Energy Cost Recovery Amount. Customers receiving a medical baseline allowance shall also receive a 50 percent discount on the delivery minimum bill amount shown below.

Direct Access (DA) and Community Choice Aggregation (CCA) charges shall be calculated in accordance with the paragraph in this rate schedule titled Billing.

TOTAL RATES

Total Energy Rates ($ per kWh)		
Baseline Usage	$0.19979 (I)	
101% - 400% of Baseline	$0.27612 (I)	(T)
High Usage Over 400% of Baseline	$0.40139	(T)
Delivery Minimum Bill Amount ($ per meter per day)	$0.32854	
California Climate Credit (per household, per semi-annual payment occurring in the April and October bill cycles)	($17.40)	

[1] Per Decision 11-12-031, New System Generation Charges are effective 1/1/2012.

(Continued)

Advice	5011-E-A	Issued by	Date Filed	February 24, 2017
Decision		**Robert S. Kenney**	Effective	March 1, 2017
		Vice President, Regulatory Affairs	Resolution	

Pacific Gas and Electric Company		Revised	Cal. P.U.C. Sheet No.	40052-E
U 39 San Francisco, California	Cancelling	Revised	Cal. P.U.C. Sheet No.	38051-E

ELECTRIC SCHEDULE E-TOU
RESIDENTIAL TIME-OF-USE SERVICE

Sheet 2

RATES
(Cont'd.):

OPTION A TOTAL RATES

Total Energy Rates ($ per kWh)	PEAK		OFF-PEAK	
Summer				
Total Usage	$0.39336	(R)	$0.31778	(R)
Baseline Credit (Applied to Baseline Usage Only)	($0.08830)	(I)	($0.08830)	(I)
Winter				
Total Usage	$0.27539	(R)	$0.26109	(R)
Baseline Credit (Applied to Baseline Usage Only)	($0.08830)	(I)	($0.08830)	(I)
Delivery Minimum Bill Amount ($ per meter per day)	$0.32854			
California Climate Credit (per household, per semi-annual payment occurring in the April and October bill cycles)	($17.40)			

Total bundled service charges shown on customer's bills are unbundled according to the component rates shown below. Where the delivery minimum bill amount applies, the customer's bill will equal the sum of (1) the delivery minimum bill amount plus (2) for bundled service, the generation rate times the number of kWh used. For revenue accounting purposes, the revenues from the delivery minimum bill amount will be assigned to the Transmission, Transmission Rate Adjustments, Reliability Services, Public Purpose Programs, Nuclear Decommissioning, Competition Transition Charges, Energy Cost Recovery Amount, DWR Bond, and New System Generation Charges[1] based on kWh usage times the corresponding unbundled rate component per kWh, with any residual revenue assigned to Distribution.*

[1] Per Decision 11-12-031, New System Generation Charges are effective 1/1/2012.
* This same assignment of revenues applies to direct access and community choice aggregation customers.

(Continued)

Advice	5011-E-A	*Issued by*	*Date Filed*	February 24, 2017
Decision		**Robert S. Kenney**	*Effective*	March 1, 2017
		Vice President, Regulatory Affairs	*Resolution*	

Pacific Gas and Electric Company
U 39 *San Francisco, California*

	Revised	Cal. P.U.C. Sheet No.	33319-G
Cancelling	Revised	Cal. P.U.C. Sheet No.	33280-G

GAS SCHEDULE G-1
RESIDENTIAL SERVICE

Sheet 1

APPLICABILITY: This rate schedule* applies to natural gas service to Core End-Use Customers on PG&E's Transmission and/or Distribution Systems. To qualify, service must be to individually-metered single family premises for residential use, including those in a multifamily complex, and to separately-metered common areas in a multifamily complex where Schedules GM, GS, or GT are not applicable. Common area accounts that are separately metered by PG&E have an option of switching to a core commercial rate schedule. Common area accounts are those accounts that provide gas service to common use areas as defined in Rule 1.

TERRITORY: Schedule G-1 applies everywhere within PG&E's natural gas Service Territory.

RATES: Customers on this schedule pay a Procurement Charge and a Transportation Charge, per meter, as shown below. The Transportation Charge will be no less than the Minimum Transportation Charge, as follows:

Minimum Transportation Charge:**	Per Day
	$0.09863

	Per Therm Baseline		Per Therm Excess	
Procurement:	$0.39848	(R)	$0.39848	(R)
Transportation Charge:	$0.88798		$1.42077	
Total:	$1.28646	(R)	$1.81925	(R)

Public Purpose Program Surcharge:

Customers served under this schedule are subject to a gas Public Purpose Program (PPP) Surcharge under Schedule G-PPPS.

See Preliminary Statement, Part B for the Default Tariff Rate Components.

The Procurement Charge on this schedule is equivalent to the rate shown on informational Schedule G-CP—Gas Procurement Service to Core End-Use Customers.

BASELINE QUANTITIES: The delivered quantities of gas shown below are billed at the rates for baseline use.

BASELINE QUANTITIES (Therms Per Day Per Dwelling Unit)

Baseline Territories***	Summer Effective Apr. 1, 2016	Winter Effective Nov. 1, 2015
P	0.46	2.15
Q	0.69	1.98
R	0.46	1.79
S	0.46	1.92
T	0.69	1.79
V	0.69	1.79
W	0.46	1.69
X	0.59	1.98
Y	0.85	2.55

* PG&E's gas tariff's are available online at www.pge.com.
** The Minimum Transportation charge does not apply to submetered tenants of master-metered customers served under gas rate Schedules GS and GT.
*** The applicable baseline territory is described in Preliminary Statement, Part A.

(Continued)

Advice	3836-G	*Issued by*	*Date Filed*	April 24, 2017
Decision	97-10-065 & 98-07-025	**Robert S. Kenney**	*Effective*	May 1, 2017
		Vice President, Regulatory Affairs	*Resolution*	

Pacific Gas and Electric Company

Residential Non-CARE and CARE Gas Tariff Rates
January 1, 2016, to Present
($/therm)[1/]

Effective Date	Advice Letter Number	Minimum Transportation Charge[2/] (per day)	Procurement Charge	Transportation Charge[2/]		TOTAL Residential Non-CARE Schedules Charge[3/]	
10/01/16	3760-G	$0.09863	$0.38660	$0.96817	$1.54907	$1.35477	$1.93567
11/01/16	3775-G	$0.09863	$0.45875	$0.96817	$1.54907	$1.42692	$2.00782
12/01/16	3785-G	$0.09863	$0.39428	$0.96817	$1.54907	$1.36245	$1.94335
01/01/17	3793-G	$0.09863	$0.45305	$0.88798	$1.42077	$1.34103	$1.87382
02/01/17	3800-G	$0.09863	$0.44251	$0.88798	$1.42077	$1.33049	$1.86328
03/01/17	3812-G	$0.09863	$0.40169	$0.88798	$1.42077	$1.28967	$1.82246
04/01/17	3827-G	$0.09863	$0.42225	$0.88798	$1.42077	$1.31023	$1.84302
05/01/17	3836-G	$0.09863	$0.39848	$0.88798	$1.42077	$1.28646	$1.81925
06/01/17	3844-G	$0.09863	$0.39102	$0.88798	$1.42077	$1.27900	$1.81179
07/01/17	3859-G	$0.09863	$0.31906	$0.88566	$1.41705	$1.20472	$1.73611
08/01/17	3870-G	$0.09863	$0.32821	$0.88566	$1.41705	$1.21387	$1.74526
09/01/17	3879-G	$0.09863	$0.27240[7/]	$0.88566	$1.41705	$1.15806	$1.68945

[1/] Unless otherwise noted
[2/] Effective July 1, 2005, the Transportation Charge will be no less than the Minimum Transportation Charge of $0.09863 (per day). Applicable to Rate Schedule G-1 only and does not apply to submetered tenants of master-metered customers served under gas Rate Schedule GS and GT.
[3/] Schedule G-PPPS (Public Purpose Program Surcharge) needs to be added to the TOTAL Non-CARE Charge and TOTAL CARE Charge for bill calculation. See Schedule G-PPPS for details and exempt customers.
[4/] CARE Schedules include California Solar Initiative (CSI) Exemption in accordance with Advice Letter 3257-G-A.
[5/] Per dwelling unit per day (Multifamily Service)
[6/] Per installed space per day (Mobilehome Park Service)
[7/] This procurement rate includes a charge of $0.02431 per therm to reflect account balance amortizations in accordance with Advice Letter 3157-G.
Seasons: **Winter** = Nov-Mar **Summer** = April-Oct

Following are the SCE electricity tariffs, both standard and time-of-use, and SoCalGas natural gas tariffs applied in this study.

SOUTHERN CALIFORNIA EDISON
AN EDISON INTERNATIONAL Company

Southern California Edison — Revised — Cal. PUC Sheet No. 61658-E
Rosemead, California (U 338-E) — Cancelling Revised — Cal. PUC Sheet No. 60925-E

Schedule D
DOMESTIC SERVICE

Sheet 2

(Continued)

RATES

	Delivery Service Total[1]	Generation[2] UG***	Generation[2] DWREC[3]
Energy Charge- $/kWh/Meter/Day			
Baseline Service			
Summer	0.06766 (R)	0.07477	0.00000
Winter	0.06766 (R)	0.07477	0.00000
Nonbaseline Service*			
101% - 400% of Baseline - Summer	0.17276 (R)	0.07477	0.00000
Winter	0.17276 (R)	0.07477	0.00000
High Usage Charge			
(Over 400% of Baseline) - Summer	0.23747 (R)	0.07477	0.00000
- Winter	0.23747 (R)	0.07477	0.00000
Basic Charge - $/Meter/Day			
Single-Family Accommodation	0.031		
Multi-Family Accommodation	0.024		
Minimum Charge** - $/Meter/Day			
Single-Family Accommodation	0.329		
Multi-Family Accommodation	0.329		
Minimum Charge (Medical Baseline)** - $/Meter/Day			
Single-Family Accommodation	0.164		
Multi-Family Accommodation	0.164		
California Climate Credit[4]	(31.00)		
Peak Time Rebate - $kWh		(0.75)	
Peak Time Rebate w/enabling technology - $/kWh		(1.25)	

* Nonbaseline Service includes all kWh in excess of applicable Baseline allocations as described in Preliminary Statement, Part H, Baseline Service.
** The Minimum Charge is applicable when the Delivery Service Energy Charge, plus the applicable Basic Charge is less than the Minimum Charge.
*** The ongoing Competition Transition Charge (CTC) of $(0.00034) per kWh is recovered in the UG component of Generation.
1 Total = Total Delivery Service rates are applicable to Bundled Service, Direct Access (DA) and Community Choice Aggregation Service (CCA Service) Customers, except DA and CCA Service Customers are not subject to the DWRBC rate component of this Schedule but instead pay the DWRBC as provided by Schedule DA-CRS or Schedule CCA-CRS.
2 Generation = The Generation rates are applicable only to Bundled Service Customers.
3. DWREC = Department of Water Resources (DWR) Energy Credit - For more information on the DWR Energy Credit, see the Billing Calculation Special Condition of this Schedule.
4. Applied on an equal basis, per household, semi-annually. See the Special Conditions of this Schedule for more information.

(Continued)

(To be inserted by utility)
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Decision
2C17

Issued by
Caroline Choi
Senior Vice President

(To be inserted by Cal. PUC)
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Resolution E-3930

EDISON

Southern California Edison
Rosemead, California (U 338-E)

Revised Cal. PUC Sheet No. 61672-E
Cancelling Revised Cal. PUC Sheet No. 60939-E

Schedule TOU-D-T
TIME-OF-USE TIERED DOMESTIC

Sheet 2

(Continued)

RATES

	Delivery Service Total[1]	Generation[2] UG***	Generation[2] DWREC[3]
Energy Charge - $/kWh/Meter/Day			
Summer Season - On-Peak			
Level I (up to 130% of Baseline)	0.12304 (R)	0.23031	0.00000
Level II (More than 130% of Baseline)	0.16121 (R)	0.23031	0.00000
Summer Season - Off-Peak			
Level I (up to 130% of Baseline)	0.12304 (R)	0.05736	0.00000
Level II (More than 130% of Baseline)	0.16121 (R)	0.05736	0.00000
Winter Season - On-Peak			
Level I (up to 130% of Baseline)	0.12304 (R)	0.11031	0.00000
Level II (More than 130% of Baseline)	0.16121 (R)	0.11031	0.00000
Winter Season - Off-Peak			
Level I (up to 130% of Baseline)	0.12304 (R)	0.05121	0.00000
Level II (More than 130% of Baseline)	0.16121 (R)	0.05121	0.00000
Basic Charge - $/Meter/Day			
Single-Family Accommodation	0.031		
Multi-Family Accommodation	0.024		
Minimum Charge* - $/Meter/Day			
Single-Family Accommodation	0.329		
Multi-Family Accommodation	0.329		
Minimum Charge (Medical Baseline)** - $/Meter/Day			
Single-Family Accommodation	0.164		
Multi-Family Accommodation	0.164		
California Climate Credit[4]	(31.00)		
California Alternate Rates for Energy Discount - %	100.00*		
Peak Time Rebate - $kWh		(0.75)	
Peak Time Rebate w/enabling technology - $/kWh		(1.25)	

* The Minimum Charge is applicable when the Delivery Service Energy Charge, plus the applicable Basic Charge is less than the Minimum Charge.
** Represents 100% of the discount percentage as shown in the applicable Special Condition of this Schedule.
*** The ongoing Competition Transition Charge (CTC) of $(0.00034) per kWh is recovered in the UG component of Generation.
1 Total = Total Delivery Service rates are applicable to Bundled Service, Direct Access (DA) and Community Choice Aggregation Service (CCA Service) Customers, except DA and CCA Service Customers are not subject to the DWRBC rate component of this Schedule but instead pay the DWRBC as provided by Schedule DA-CRS or Schedule CCA-CRS
2 Generation = The Gen rates are applicable only to Bundled Service Customers.
3 DWREC = Department of Water Resources (DWR) Energy Credit – For more information on the DWR Energy Credit, see the Billing Calculation Special Condition of this Schedule.
4 Applied on an equal basis, per household, semi-annually. See the Special Conditions of this Schedule for more information.

(Continued)

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Decision
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Caroline Choi
Senior Vice President

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SOUTHERN CALIFORNIA GAS COMPANY Revised CAL. P.U.C. SHEET NO. 54294-G
LOS ANGELES, CALIFORNIA CANCELING Revised CAL. P.U.C. SHEET NO. 54268-G

Schedule No. GR
RESIDENTIAL SERVICE
(Includes GR, GR-C and GT-R Rates)

Sheet 1

APPLICABILITY

The GR rate is applicable to natural gas procurement service to individually metered residential customers.

The GR-C, cross-over rate, is a core procurement option for individually metered residential core transportation customers with annual consumption over 50,000 therms, as set forth in Special Condition 10.

The GT-R rate is applicable to Core Aggregation Transportation (CAT) service to individually metered residential customers, as set forth in Special Condition 11.

The California Alternate Rates for Energy (CARE) discount of 20%, reflected as a separate line item on the bill, is applicable to income-qualified households that meet the requirements for the CARE program as set forth in Schedule No. G-CARE.

TERRITORY

Applicable throughout the service territory.

RATES	GR	GR-C	GT-R
Customer Charge, per meter per day:	16.438¢	16.438¢	16.438¢
For "Space Heating Only" customers, a daily Customer Charge applies during the winter period from November 1 through April 30[1]:	33.149¢	33.149¢	33.149¢
Baseline Rate, per therm (baseline usage defined in Special Conditions 3 and 4):			
Procurement Charge: [2]	33.735¢	34.213¢	N/A
Transmission Charge: [3]	51.195¢	51.195¢	51.220¢
Total Baseline Charge:	84.930¢	85.408¢	51.220¢
Non-Baseline Rate, per therm (usage in excess of baseline usage):			
Procurement Charge: [2]	33.735¢	34.213¢	N/A
Transmission Charge: [3]	84.028¢	84.028¢	84.053¢
Total Non-Baseline Charge:	117.763¢	118.241¢	84.053¢

[1] For the summer period beginning May 1 through October 31, with some exceptions, usage will be accumulated to at least 20 Ccf (100 cubic feet) before billing.

(Footnotes continue next page.)

(Continued)

(TO BE INSERTED BY UTILITY)
ADVICE LETTER NO. 5185
DECISION NO.
1C5

ISSUED BY
Dan Skopec
Vice President
Regulatory Affairs

(TO BE INSERTED BY CAL. PUC)
DATE FILED Sep 8, 2017
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RESOLUTION NO. G-3351

Following are the SDG&E electricity, both standard and time-of-use, and natural gas tariffs applied in this study.

San Diego Gas & Electric Company
San Diego, California

Revised Cal. P.U.C. Sheet No. 29081-E

Canceling Revised Cal. P.U.C. Sheet No. 28651-E

Sheet 1

SCHEDULE DR

RESIDENTIAL SERVICE
(Includes Rates for DR-LI)

APPLICABILITY

Applicable to domestic service for lighting, heating, cooking, water heating, and power, or combination thereof, in single family dwellings, flats, and apartments, separately metered by the utility; to service used in common for residential purposes by tenants in multi-family dwellings under Special Condition 8; to any approved combination of residential and nonresidential service on the same meter; and to incidental farm service under Special Condition 7.

This schedule is also applicable to customers qualifying for the California Alternate Rates for Energy (CARE) Program and/or Medical Baseline, residing in single-family accommodations, separately metered by the Utility, and may include Non-profit Group Living Facilities and Qualified Agricultural Employee Housing Facilities, if such facilities qualify to receive service under the terms and conditions of Schedule E-CARE. The rates for CARE and Medical Baseline customers are identified in the rates tables below as DR-LI and DR-MB rates, respectively.

Customers on this schedule may also qualify for a semi-annual California Climate Credit $(29.62) per Schedule GHG-ARR.

TERRITORY

Within the entire territory served by the Utility.

RATES

Total Rates:

Description - DR Rates	UDC Total Rate		DWR-BC Rate	EECC Rate + DWR Credit	Total Rate	
Summer:						
Up to 130% of Baseline Energy ($/kWh)	0.07718	I	0.00549	0.14106	0.22373	I
Above 130% of Baseline ($/kWh)	0.25498	R	0.00549	0.14106	0.40153	R
Winter:						
Up to 130% of Baseline Energy ($/kWh)	0.12807	I	0.00549	0.07196	0.20552	I
Above 130% of Baseline ($/kWh)	0.29139	R	0.00549	0.07196	0.36884	R
Minimum Bill ($/day)	0.329				0.329	

Description -DR-LI Rates	UDC Total Rate		DWR-BC Rate	EECC Rate + DWR Credit	Total Rate		Total Effective CARE Rate N
Summer – CARE Rates:							
Up to 130% of Baseline Energy ($/kWh)	0.07671	I	0.00000	0.14106	0.21777	I	0.13766
Above 130% of Baseline ($/kWh)	0.25451	R	0.00000	0.14106	0.39557	R	0.25230
Winter – CARE Rates:							
Up to 130% of Baseline Energy ($/kWh)	0.12760	I	0.00000	0.07196	0.19956	I	0.12614
Above 130% of Baseline ($/kWh)	0.29092	R	0.00000	0.07196	0.36288	R	0.23126
Minimum Bill ($/day)	0.164				0.164		0.164

(Continued)

1C13

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Dan Skopec
Vice President
Regulatory Affairs

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Resolution No. 4870

San Diego Gas & Electric Company
San Diego, California

Revised Cal. P.U.C. Sheet No. 28663-E

Canceling Revised Cal. P.U.C. Sheet No. 28533-E

SCHEDULE DR-SES

Sheet 1

DOMESTIC TIME-OF-USE FOR HOUSEHOLDS WITH A SOLAR ENERGY SYSTEM

APPLICABILITY

Service under this schedule is available on a voluntary basis for individually metered residential customers with Solar Energy Systems. Service is limited to individually metered residential customers with a Solar Energy System with domestic service for lighting, heating, cooking, water heating, and power, or combination thereof, in single family dwellings and flats. Qualifying California Alternative Rates for Energy (CARE) customers are eligible for service on this schedule, as further described under Special Condition 8 of this schedule.

Customers on this schedule may also qualify for a semi-annual California Climate Credit $(29.62) per Schedule GHG-ARR. F

TERRITORY

Within the entire territory served by the Utility.

RATES

Total Rates:

Description – DR-SES Rates	UDC Total Rate		DWR-BC Rate	EECC Rate + DWR Credit		Total Rate	
Energy Charges ($/kWh)							
On-Peak – Summer	0.14184	I	0.00549	0.35896	I	0.50629	I
Semi-Peak– Summer	0.14184	I	0.00549	0.10375	I	0.25108	I
Off-Peak – Summer	0.14184	I	0.00549	0.07988	I	0.22721	I
Semi-Peak – Winter	0.14184	I	0.00549	0.08886	I	0.23619	I
Off-Peak – Winter	0.14184	I	0.00549	0.07438	I	0.22171	I
Minimum Bill ($/day)	0.329					0.329	

(1) Total Rates consist of UDC, Schedule DWR-BC (Department of Water Resources Bond Charge), and Schedule EECC (Electric Energy Commodity Cost) rates, with the EECC rates reflecting a DWR Credit of $0.00000 that customers receive on their monthly bills.

(2) Total Rates presented are for customers that receive commodity supply and delivery service from Utility. Differences in total rates paid by Direct Access (DA) and Community Choice Aggregation (CCA) customers are identified in Schedule DA-CRS and CCA-CRS, respectively.

(3) DWR-BC charges do not apply to CARE or Medical Baseline customers.

UDC Rates

Description-DR-SES	Transm	Distr	PPP	ND	CTC		LGC		RS	TRAC	UDC Total	
Energy Charges ($/kWh)												
On-Peak – Summer	0.03829	0.08877	0.01063	(0.00049)	0.00177	R	0.00268	I	0.00019	0.00000	0.14184	I
Semi-Peak – Summer	0.03829	0.08877	0.01063	(0.00049)	0.00177	R	0.00268	I	0.00019	0.00000	0.14184	I
Off-Peak - Summer	0.03829	0.08877	0.01063	(0.00049)	0.00177	R	0.00268	I	0.00019	0.00000	0.14184	I
Semi-Peak - Winter	0.03829	0.08877	0.01063	(0.00049)	0.00177	R	0.00268	I	0.00019	0.00000	0.14184	I
Off-Peak - Winter	0.03829	0.08877	0.01063	(0.00049)	0.00177	R	0.00268	I	0.00019	0.00000	0.14184	I
Minimum Bill ($/day)		0.329									0.329	

(Continued)

1C8

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Dan Skopec
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San Diego Gas & Electric Company
San Diego, California

Revised Cal. P.U.C. Sheet No. 22788-G

Canceling Revised Cal. P.U.C. Sheet No. 22775-G

SCHEDULE GR

Sheet 1

RESIDENTIAL NATURAL GAS SERVICE
(Includes Rates for GR, GR-C, GTC/GTCA)

APPLICABILITY

The GR rate is applicable to natural gas procurement service for individually metered residential customers.

The GR-C, cross-over rate, is a core procurement option for individually metered residential core transportation customers with annual consumption over 50,000 therms, as set forth in Special Condition 10.

The GTC/GTCA rate is applicable to intrastate gas transportation-only services to individually metered residential customers, as set forth in Special Condition 11.

Customers taking service under this schedule may be eligible for a 20% California Alternate Rate for Energy (CARE) program discount, reflected as a separate line item on the bill, if they qualify to receive service under the terms and conditions of Schedule G-CARE.

TERRITORY

Within the entire territory served natural gas by the utility.

RATES

	GR	GR-C	GTC/GTCA[1]
Baseline Rate, per therm (baseline usage defined in Special Conditions 3 and 4):			
Procurement Charge:[2]	$0.33755	$0.33755 R	N/A
Transmission Charge:	$0.91113	$0.91113	$0.91113
Total Baseline Charge:	$1.24868	$1.24868 R	$0.91113
Non-Baseline Rate, per therm (usage in excess of baseline usage):			
Procurement Charge:[2]	$0.33755	$0.33755 R	N/A
Transmission Charge:	$1.09834	$1.09834	$1.09834
Total Non-Baseline Charge:	$1.43589	$1.43589 R	$1.09834
Minimum Bill, per day:[3]			
Non-CARE customers:	$0.09863	$0.09863	$0.09863
CARE customers:	$0.07890	$0.07890	$0.07890

[1] The rates for core transportation-only customers, with the exception of customers taking service under Schedule GT-NGV, include any FERC Settlement Proceeds Memorandum Account (FSPMA) credit adjustments.

[2] This charge is applicable to Utility Procurement Customers and includes the GPC and GPC-A Procurement Charges shown in Schedule GPC which are subject to change monthly as set forth in Special Condition 7.

[3] Effective starting May 1, 2017, the minimum bill is calculated as the minimum bill charge of $0.09863 per day times the number of days in the billing cycle (approximately $3 per month) with a 20% discount applied for CARE customer resulting in a minimum bill charge of $0.07890 per day (approximately $2.40 per month).

(Continued)

1C5

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	Dan Skopec	Effective	Sep 10, 2017
Decision No.	Vice President Regulatory Affairs	Resolution No.	

436 14th St, Oakland, CA 92618
Phone: (916) 844-1033
Email: FFarahmand@trcsolutions.com

Statewide Nonresidential Reach Code Cost Effectiveness Analysis

July 2017

Submitted To:

Southern California Edison
Mr. Chris Kuch
1515 Walnut Grove
Rosemead, CA 91770

TABLE OF CONTENTS

TABLE OF FIGURES

TRC would like to acknowledge and thank the following entities for their support during this study: sixteen5hundred, EFCO Corporation, Viracon, and SSG MEP, Inc.

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.

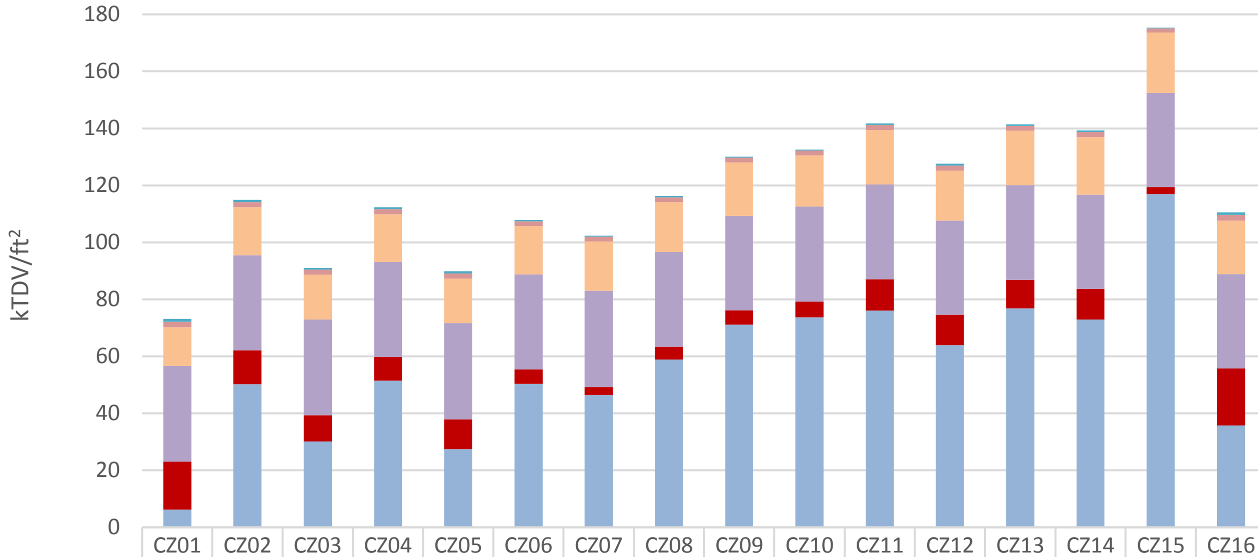
[6] Available at: http://www.energy.ca.gov/title24/2016standards/nonresidential_manual.html

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/ft^2 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/ft^2 (no tuning)	0.68 W/ft^2 (with tuning)	$0.06/ft^2	$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/ft^2. 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/ft^2	0.65 W/ft^2	0.58 W/ft^2	0.52 W/ft^2

[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 ($/ft^2)			
		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