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City of Palo Alto 2016 Building Energy Efficiency Reach Code

Cost Effectiveness Study

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EXECUTIVE SUMMARY

The City of Palo Alto and California Energy Commission (CEC) require a cost effectiveness study be completed to implement a Reach Code in the Palo Alto Municipal Code. The Reach Code requires that residential and nonresidential new construction use less energy than a building minimally compliant with Title 24 (T24) Building Energy Efficiency Standards. The CEC Life Cycle Cost (LCC) Methodology and prototypes were used to analyze potential cost effective energy efficiency measures. The LCC methodology involves estimating and quantifying the energy savings associated with measures using a Time Dependent Valuation (TDV) of energy savings.

TRC developed cost effective packages at 10 percent above T24 for single family and low-rise multifamily residential buildings, and nonresidential office buildings. These packages represent sets of measures shown to attain the "10 percent better" Reach Code requirements cost effectively and are used to demonstrate the feasibility of achieving the Reach Code target. These measures are not meant to be prescriptive packages of measures adopted into the Palo Alto Municipal Code.

To determine energy savings, TRC simulated residential prototypes in CBECC-Res, and nonresidential prototypes in CBECC-Com, though some measures required spreadsheet analysis. The cost effectiveness of solar photovoltaics was estimated using the CECPV calculator. The measures investigated were those studied for the 2016 and 2019 Title 24 Codes and Standards Enhancement (CASE) process. TRC leveraged previous energy savings, market research, and cost estimates from CASE studies and other resources as much as possible.

The benefit to cost ratio (B/C) is the indicator for cost effectiveness. A ratio greater than 1 indicates that the added cost of the measure is more than offset by the present value energy cost savings, and the measure is cost effective. Cost effectiveness is shown for both individual measure and packages of measures to reach at least 10 percent better than Title 24. Table 1 shows the individual impact of each measure and the impact when all measures are implemented as a package. All of the packages proved cost effective for prototypes in the City of Palo Alto; therefore, the Palo Alto Municipal Code should implement a Reach Code ordinance requiring that single family, low-rise multifamily, and nonresidential buildings exceed the Title 24 Standards by at least 10 percent.

Table 1. Summary of Cost Effective Packages

Single Family Residential 10% Package				
Measure	**% Above Title 24**	**Present Value of Energy Savings**	**Cost**	**Benefit to Cost Ratio**
Quality Insulation Installation (HERS)	9%	$971	$519	1.9
Piping Insulation, All Hot Water Lines (HERS)	1%	$144	$181	0.8
Refrigerant Charge Verification (HERS)	1%	$79	$76	1.0
Solar Ready	-	-	$343	-
Package	**11%**	**$1,243**	**$1,119**	**1.1**
Multifamily Residential 10% Package				
Measure	**% Above Title 24**	**Present Value of Energy Savings**	**Cost**	**Benefit to Cost Ratio**
Quality Insulation Installation (HERS)	5%	$2,009	$1,018	2.0
Piping Insulation, All Hot Water Lines (HERS)	1%	$522	$790	0.7
Verified Refrigerant Charge (HERS)	2%	$764	$272	2.8
Drain Water Heat Recovery	2%	$944	$774	1.2
Solar Ready	-	-	$343	-
Package	**10%**	**$4,160**	**$3,197**	**1.3**
Nonresidential 10% Package				
Measure	**% Above Title 24**	**Present Value of Energy Savings**	**Cost**	**Benefit to Cost Ratio**
Economizer	5%	$4,384	$2,000	2.1
Cool Roof	0.3%	$1,483	$741	2.0
Daylight Dimming Plus Off Lighting Controls	1%	$5,386	-	1.0*
Institutional Tuning for Lighting	3%	$9,093	$2,217	4.1
Open Office Lighting Occupancy Sensors	2%	$7,648	$3,833	2.0
Lighting Power Density Reduction	2%	$7,557	-	1.0*
Package	**10%**	**$33,052**	**$7,513**	**4.4**

*Measures with no cost are cost effective; B/C ratio is set to 1.0.

Solar photovoltaics (PV) were found to be cost effective, as shown in Table 2, and can be included in Reach Code requirements. The CEC allows compliance margin credits of up to 20.1% for single family and 11.8% for multifamily residential. The corresponding PV system sizes to achieve these compliance credits are 2 kW for single family and 8 kW for multifamily. The CEC does not provide any compliance margin credits for nonresidential buildings. However, all PV system sizes up to 40 kW were found to be cost effective, including 5 kW as recommended for the Palo Alto nonresidential Reach Code.

Table 2. Solar PV Cost Effectiveness

Size (kW)	Cost	Residential Present Value of Energy Savings	Residential Benefit to Cost Ratio	Nonresidential Present Value of Energy Savings	Nonresidential Benefit to Cost Ratio
2	$5,681	$17,135	3.0	-	-
5	$13,892	-	-	$20,843	1.5
8	$22,723	$65,530	2.9	-	-

Based on the findings in this report, TRC recommends the requirements below for the 2016 Palo Alto Reach Code. For each building type, Path B ensures that applicants are meeting the standard budget before use of the PV credit.

- Single family residential new construction projects shall demonstrate either:
  A. 10% or greater compliance margin without a PV system; OR
  B. 20% or greater compliance margin with a PV system
- Multifamily residential new construction projects shall demonstrate either:
  A. 10% or greater compliance margin without PV system; OR
  B. 12% or greater compliance margin with a PV system
- Nonresidential new construction projects shall demonstrate either:
  A. 10% or greater compliance margin without a PV system; OR
  B. 0% or greater compliance margin with a 5 kW PV system or larger.

1. INTRODUCTION

The City of Palo Alto, California, plans to enact a Reach Code for the 2016 Title 24 Part 6 Building Energy Efficiency Standards (T24 Standards). The T24 Standards are the minimum energy efficiency requirements for building construction in California. Palo Alto's Reach Code would require that residential and nonresidential buildings be constructed to consume at least 10 percent less energy than a building exactly compliant with the T24 Standards. Palo Alto has enacted a Reach Code since the 2005 T24 Standards by investigating measures that allow a building to perform 15 percent better than the Title 24 minimum requirements, while being cost effective over the lifetime of the measures, as per the requirements in Section 10-106 of the California Code of Regulations Title 24 Part 1.

The most recent Reach Code that was enforced by Palo Alto was with the 2013 T24 Standards, located in Section 16.17.050 of the Palo Alto Municipal Code. This code is partially reproduced below:

> The provisions of this chapter shall constitute local amendments to the cross-referenced provisions of the California Energy Code, 2013 Edition, and shall be deemed to replace the cross-referenced sections of said Code with the respective provisions set forth in this chapter.
>
> Section 100.3 Local Energy Efficiency Reach Code is added to read:
>
> (a) For all new single-family residential, multi-family residential, and non-residential construction: The performance approach specified within the 2013 California Energy Code shall be used to demonstrate that the TDV Energy of the proposed building is at least 15% less than the TDV Energy of the Standard Design.

The section of code is provided in full in *Appendix A – Current Reach Code Language*.

Palo Alto engaged TRC to provide a cost effectiveness study to support building Reach Code requirements above 2016 T24 Standards minimum requirements. TRC found a 10 percent compliance margin to be technically and economically feasible for single family residential, low-rise multifamily residential, and nonresidential (office building) new construction. TRC has prepared energy savings and cost effectiveness analyses for measures that support the proposed Reach Code.

2. METHODOLOGY

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

2.1 Life Cycle Cost and Time Dependent Valuation

TRC used the CEC LCC Methodology to demonstrate cost effectiveness of the proposed Reach code.[1] The LCC methodology involves estimating and quantifying the energy savings associated with measures using a Time Dependent Valuation (TDV) of energy savings.[2]

TDV is a normalized format for comparing electricity and natural gas savings that takes into account the cost of electricity and natural gas consumed during different times of the day and year. The TDV values are based on long term discounted costs (30 years for all residential measures and nonresidential envelope measures and 15 years for all other nonresidential measures). TDV energy estimates are based on present-valued cost savings but are presented in terms of "TDV kBTUs" so that the savings are evaluated in terms of energy units and measures with different periods of analysis can be combined into a single value.[3]

The CEC developed the TDV values that were used in the analyses for this report, and are representative of Palo Alto's climate zone. However, the TDV values are not representative of the characteristics of the City of Palo Alto Utility, including retail rates and emissions from generation. Developing Palo-Alto specific TDV values is outside of the scope of this report.[4]

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[1] 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

[2] 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/

[3] kBTUs = thousands of British Thermal Units.

[4] Developing local TDV values poses several challenges. Specialized analysis is necessary to adjust the TDV input factors to represent specifically Palo Alto's utility territory. The CEC may use a higher level of scrutiny on the local TDV and method used to produce it. Additionally, even with a local TDV established, building permit applicants will need special instruction to implement the local values into compliance software. The 2016 TDV is already integrated into compliance software and practices.

2.2 Package Development

TRC developed cost effective packages for single family, low-rise multifamily and nonresidential (office) buildings (10% above T24). The measures in these packages represent a feasible and cost effective way to attain the Reach Code requirements, but are not meant to be prescriptive measures adopted into the Palo Alto Municipal Code.

TRC used CBECC-Res 2016.1.0 (build 801) to simulate the residential prototypes and CBECC-Com 2016.1.0 (build 803) for the nonresidential prototypes. [5] TRC simulated all prototypes in Climate Zone 4 (CZ4), and initialized them to be exactly compliant with the minimum 2016 T24 requirements (0% compliance margin). The TDV of energy savings for the energy efficiency measures were derived by revising the code compliant models, as described in the *Measure Descriptions and Costs*.

2.2.1 Residential Prototypes

The residential prototypes are fully defined by the CEC in the Residential Alternative Calculation Method reference manual.[6] TRC's prototypes are slightly revised in order to have equal geometry oriented facing north, east, south, and west. Three residential prototypes were simulated:

- 2,100 ft^2 single family single-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

Further prototype details are provided in Table 3. Detailed requirements for the compliant building prototypes are provided in the CEC Residential Alternative Calculation Method reference manual.

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

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

Table 3. Residential Prototypes Summary

Building Type	One-Story	Two-Story	Low-Rise Multifamily
Dwelling Units	**1**	**2**	**8**
Area (ft^2)	2,100	2,700	6,960
Roof Area (ft^2)	2,520	1,740	4,176
# of floors	1	2	2
Window-to-Floor Area Ratio	20%	20%	15%
Attic/Roof Assembly	Tile Roof, Wood Sheathing, R13 Below Roof Deck Insulation (air space), 2x4 @ 24" OC, SR = 0.10, TE = 0.85		
Above Grade Wall Assembly	R-19 Cavity Insulation, R5 Synthetic Stucco, 0.051 U-factor		
Cooling System	Split Air Conditioner		
Heating System	Gas Furnace		
HVAC Distribution System	Ducts in Attic	Ducts in Attic	Ducts in Conditioned Space
Thermal Zones	1	2	4
Domestic Water Heating Prescriptive Path 1	Natural Gas Instantaneous Water Heater, 0 Gallon Tank, EF=0.82		8x Natural Gas Instantaneous Water Heater, 0 Gallon Tank, EF=0.82
Domestic Water Heating Prescriptive Path 2	Natural Gas Small Storage, 50 Gallon Tank, EF = 0.6, plus HERS Measures		Natural Gas Small Storage, 50 Gallon Tank, EF = 0.6, 40 MBH Input Rating, 0.20 Solar Fraction

2.2.2 Nonresidential Prototypes

The nonresidential prototypes were developed according to the Nonresidential Alternative Calculation Method reference manual.[7]

- 5,502 ft^2 one-story small office building
- 53,600 ft^2 three-story medium office building

Results using these prototypes are intended to represent findings for all nonresidential buildings. Further prototype details are provided in Table 4, and detailed requirements for the compliant building prototypes are provided in the CEC Nonresidential Alternative Calculation Method reference manual.

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

Table 4. Nonresidential Prototypes Summary

Building Type	Medium Office	Small Office
Floor Area (ft^2)	53,628	5,502
# of floors	3	1
Window-to-Floor Area Ratio	33%	21%
Roof Construction	1/16" Metal Standing Seam, R-29 Insulation Board	
Cool Roof	SR = 0.63 (Low-sloped), TE = 0.85	0.20 (Steep-sloped), TE = 0.85
Cooling System	Direct Expansion, 9.8 EER, Economizer	Direct Expansion, 13 SEER, No Economizer
Heating System	Boiler, 80% Thermal Efficiency	Furnace, 78% AFUE
HVAC Distribution System	3 Packaged VAVs (1 per story) with Hot Water Reheat	5 Packaged Single Zone Systems
Conditioned Thermal Zones	18	6
Regulated Lighting Power Density	0.75 Watts/ft^2	
Daylighting Controls	Continuous, 0.20 Dimming Light/Power Fraction	
Occupancy Sensors	Required in Private Offices, Conference Rooms, and Multipurpose Rooms. Not Required in Open Offices	

2.2.3 Energy Efficiency Measures

TRC investigated potential energy efficiency measures to apply to the prototype residential and nonresidential buildings. The first measures investigated were those that had been studied for the 2016 Title 24 Codes and Standards Enhancement (CASE) process. Additionally, TRC identified measures that are potential topics for the 2019 CASE process and, lastly, measures being investigated for green building codes such as CALGreen (Title 24, Part 11) and ASHRAE 189. The CASE studies to support Title 24 proposed updates contain detailed energy savings, market research, and cost estimates for measures, and serve as comprehensive data sources for the Reach Code analysis. For measures where no CASE study exists, TRC conducted internal market research to assess measure feasibility, costs, and potential energy impact.

2.2.4 Solar Measures

The California Public Utilities Commission (CPUC) set goals that California residential new construction will be Zero Net Energy (ZNE) by 2020[8] and nonresidential new construction by

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

2030[9]. The state will realize these goals partly through more stringent Building Energy Efficiency Standards and partly through renewable energy policy. In order to effectively reach these goals, building projects must balance energy efficiency and renewable energy.

The city of Palo Alto's Reach Code is intended to be a stepping stone to a ZNE code. TRC investigated the cost effectiveness and feasibility of photovoltaics (PV), solar thermal water heating, and sola ready for residential and nonresidential new construction.

2.3 Cost Effectiveness

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

The Benefit to Cost (B/C) Ratio is the incremental TDV energy costs savings divided by the total incremental costs. When the B/C ratio is greater than 1.0, the added cost of the measure is more than offset by the discounted energy cost savings and the measure is deemed to be cost effective.

2.3.1 Energy Savings

TDV energy savings are calculated 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 area, and finally by the Net Present Value (NPV) factor. The NPV factor is $0.173/TDV kBtu for residential measures, $0.154/TDV kBtu for nonresidential envelope measures, and $0.089/TDV kBtu for all other nonresidential measures. When calculating the present value of packages, NPV factors were weighted by compliance margin to capture the impact of 15-year and 30-year measures. To determine overall building type energy savings, TRC used a straight average to blend the energy savings of the two single family prototypes, as well as the two office prototypes.

Energy Efficiency Measures

For most measures, TRC used CBECC-Com and CBECC-Res to estimate the TDV savings and percent improvement beyond the T24 Standards. CBECC is a free public-domain software developed by the CEC for use in complying with the Title 24 Standards. The software is currently used for the 2013 Standards, and preliminary versions for use with the 2016 Standards have been released. The 2016 software algorithms will be updated occasionally until the implementation date of the 2016 Standards (January 1st, 2017). CBECC-Com uses EnergyPlus v8.3 as the simulation engine to perform the analysis. Measure specific modeling parameters are described in Section 3.

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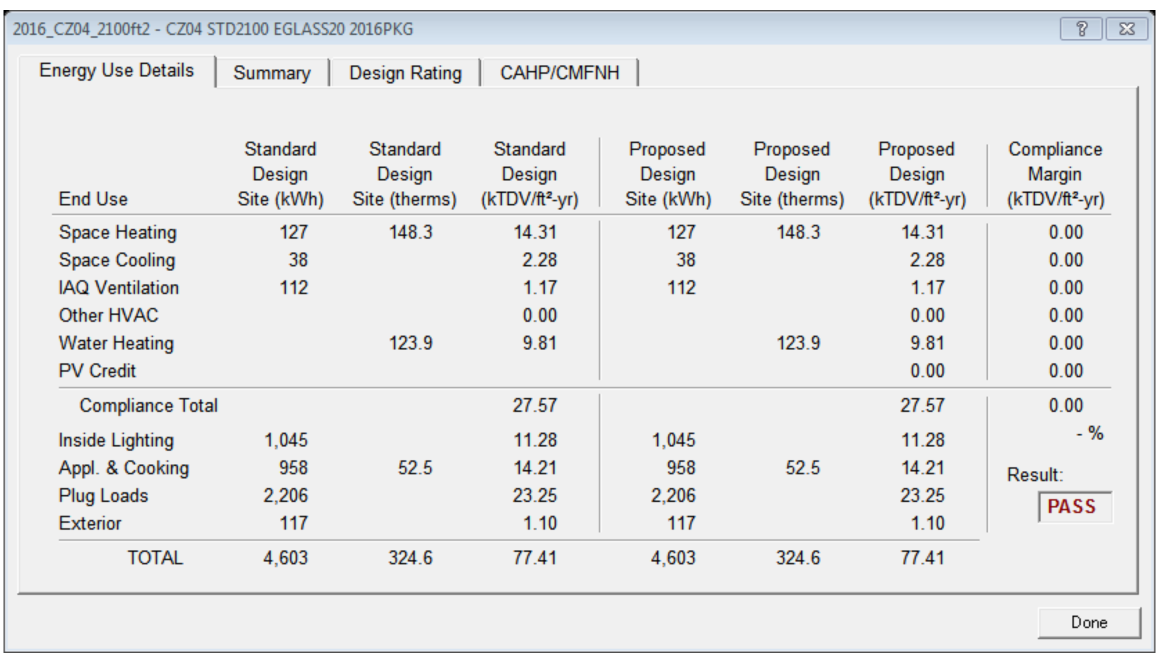
[9] CA Energy Efficiency Strategic Plan: Zero Net Energy Commercial Building Sector 2010-2012. Engage 360. June 2011. Available online at: http://www.cpuc.ca.gov/General.aspx?id=4125

Due to software limitations and performance uncertainties, CBECC is not currently capable of simulating all available measures. Measures that CBECC is not currently capable of modeling include drain water heat recovery, and open office lighting occupancy sensors. For these measures, TRC conducted a spreadsheet analysis to determine potential energy savings, as described in *Appendix C – Spreadsheet Analysis Energy Savings*.

TRC simulated multiple measures together to capture potential interactive or overlapping effects of the measures. For example, adding insulation to the hot water pipes may produce a 2% compliance margin and reducing pipe length for compact domestic hot water may produce a 3% compliance margin, but both of these measures combined may only produce a 3-4% compliance margin rather than 5%.

CBECC software calculates the compliance total using loads regulated by Title 24. These loads include space heating, cooling, ventilation, water heating, and (for nonresidential only) pumps and indoor lighting. Building designers can easily show compliance through the software analysis using energy efficiency measures that reduce these regulated loads and can be modeled in CBECC. TRC has focused on these types of measures while developing the Reach Code. However, in order to achieve the "10% better" Reach Code, it was necessary to investigate measures that cannot currently be modeled in CBECC. The CBECC-Res output, shown in Figure 1, shows that the unregulated loads (including lighting, appliance and cooking, plug, and exterior loads) are the same for the standard and proposed design and are therefore excluded from the compliance total and compliance margin.


2016_CZ04_2100ft2 - CZ04 STD2100 EGLASS20 2016PKG

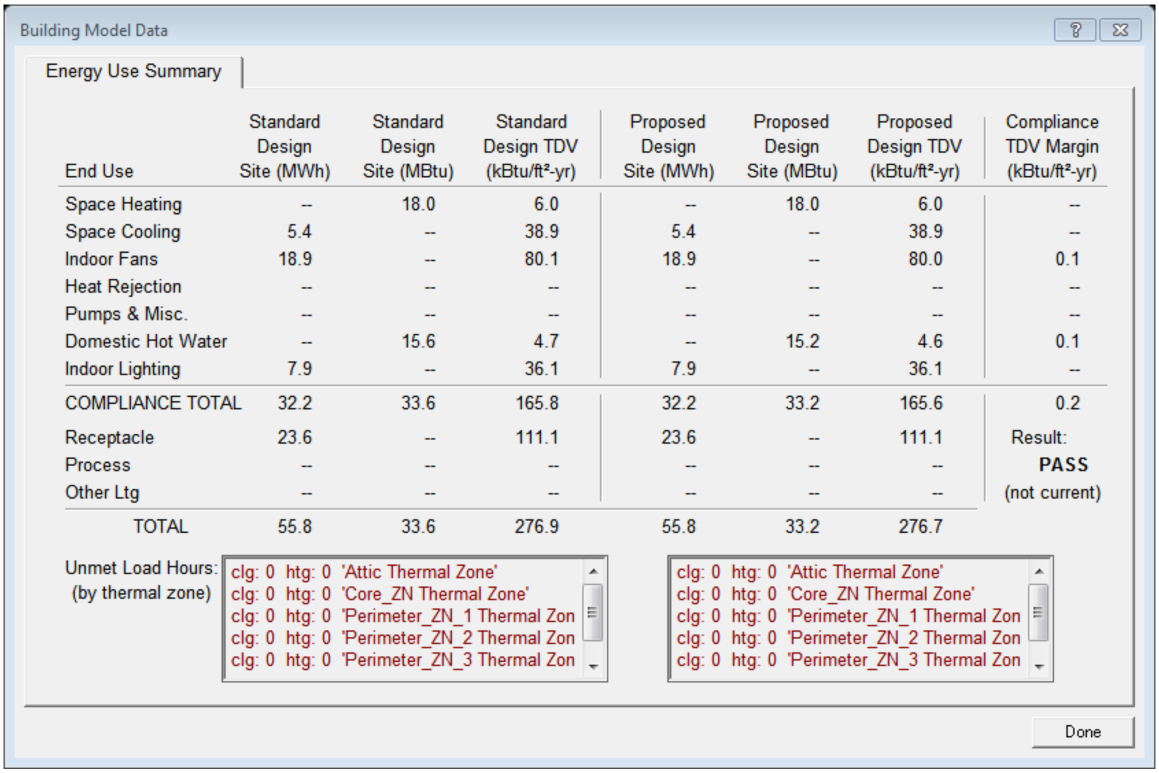
Energy Use Details | Summary | Design Rating | CAHP/CMFNH

End Use	Standard Design Site (kWh)	Standard Design Site (therms)	Standard Design (kTDV/ft²-yr)	Proposed Design Site (kWh)	Proposed Design Site (therms)	Proposed Design (kTDV/ft²-yr)	Compliance Margin (kTDV/ft²-yr)
Space Heating	127	148.3	14.31	127	148.3	14.31	0.00
Space Cooling	38		2.28	38		2.28	0.00
IAQ Ventilation	112		1.17	112		1.17	0.00
Other HVAC			0.00			0.00	0.00
Water Heating		123.9	9.81		123.9	9.81	0.00
PV Credit						0.00	0.00
Compliance Total			27.57			27.57	0.00
Inside Lighting	1,045		11.28	1,045		11.28	- %
Appl. & Cooking	958	52.5	14.21	958	52.5	14.21	Result:
Plug Loads	2,206		23.25	2,206		23.25	PASS
Exterior	117		1.10	117		1.10	
TOTAL	4,603	324.6	77.41	4,603	324.6	77.41	

Done

Figure 1. CBECC-Res Output Screenshot

The CBECC-Com output, shown in Figure 2, shows that the unregulated receptacle, process, and process lighting loads are similarly excluded from the compliance total and compliance margin. Note that a 0.2 compliance margin was as close as possible that we could achieve with this prototype – this compliance margin has been subtracted from the projected improvement of the measure packages.


Building Model Data

Energy Use Summary

End Use	Standard Design Site (MWh)	Standard Design Site (MBtu)	Standard Design TDV (kBtu/ft²-yr)	Proposed Design Site (MWh)	Proposed Design Site (MBtu)	Proposed Design TDV (kBtu/ft²-yr)	Compliance TDV Margin (kBtu/ft²-yr)
Space Heating	--	18.0	6.0	--	18.0	6.0	--
Space Cooling	5.4	--	38.9	5.4	--	38.9	--
Indoor Fans	18.9	--	80.1	18.9	--	80.0	0.1
Heat Rejection	--	--	--	--	--	--	--
Pumps & Misc.	--	--	--	--	--	--	--
Domestic Hot Water	--	15.6	4.7	--	15.2	4.6	0.1
Indoor Lighting	7.9	--	36.1	7.9	--	36.1	--
COMPLIANCE TOTAL	32.2	33.6	165.8	32.2	33.2	165.6	0.2
Receptacle	23.6	--	111.1	23.6	--	111.1	Result:
Process	--	--	--	--	--	--	**PASS**
Other Ltg	--	--	--	--	--	--	(not current)
TOTAL	55.8	33.6	276.9	55.8	33.2	276.7	

Unmet Load Hours: (by thermal zone)

Standard	Proposed
clg: 0 htg: 0 'Attic Thermal Zone'	clg: 0 htg: 0 'Attic Thermal Zone'
clg: 0 htg: 0 'Core_ZN Thermal Zone'	clg: 0 htg: 0 'Core_ZN Thermal Zone'
clg: 0 htg: 0 'Perimeter_ZN_1 Thermal Zon	clg: 0 htg: 0 'Perimeter_ZN_1 Thermal Zon
clg: 0 htg: 0 'Perimeter_ZN_2 Thermal Zon	clg: 0 htg: 0 'Perimeter_ZN_2 Thermal Zon
clg: 0 htg: 0 'Perimeter_ZN_3 Thermal Zon	clg: 0 htg: 0 'Perimeter_ZN_3 Thermal Zon

Done

Figure 2. CBECC-Com Output Screenshot

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

Table 5. Residential Prototype TDV Energy Consumption

Prototypes	**SF 1-story (kBtu/ft²-yr)**	**SF 2-story (kBtu/ft²-yr)**	**Low-Rise Multifamily (kBtu/ft²-yr)**
Space Heating	14.31	12.33	6.00
Space Cooling	2.28	3.69	8.99
IAQ Ventilation	1.17	1.15	2.47
Water Heating	9.81	8.44	15.88
Total Standard Design TDV	**27.57**	**25.61**	**33.34**

Table 6. Nonresidential Prototype TDV Energy Consumption

End Use	Small Office Energy Use (kBtu/ft²-yr)	Medium Office Energy Use (kBtu/ft²-yr)
Space Heating	6.0	10.1
Space Cooling	38.9	38.7
Indoor Fans	80.1	16.3
Pumps & Miscellaneous	0.0	0.7
Domestic Hot Water	4.7	2.2
Indoor Lighting	36.1	34.3
Total Standard Design TDV	**165.8**	**102.3**

Solar Measures

The CEC currently allows a limited credit for low-rise residential buildings with PV in CZ4 (20.1% compliance margin for single family, 11.8% compliance margin for multifamily). The credit is attained by inputting PV into CBECC-Res. The PV credit does not capture the full energy benefits of PV, and is intended to promote energy efficient design before renewables. Similar modeling and credit are not currently available for nonresidential buildings in CBECC-Com.

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

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

2.3.2 Costs

For several measures, CASE studies provided relevant cost data. TRC conducted further cost research to supplement CASE data and to gather costs for measures that are not addressed in

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

CASE studies. For the residential package, these include HERS Verified Refrigerant Charge, and Drain Water Heat Recovery; cost data for the HERS Piping Insulation is available from relevant CASE studies. For the nonresidential package, Cool Roofs and the Lighting Controls measures required supplemental data collection. Building material, equipment, and labor costs were localized when possible, and taxes and contractor markups were added as appropriate, as described in Section 3. TRC used a straight average to blend the costs for the measures in the two single family prototypes, as well as the two office prototypes.

3. Measure Descriptions and Costs

This section provides a description, general modeling parameters, market overview, and summarized costs for each measure.

3.1 Residential Measures

TRC investigated and included the following five measures into the residential packages, four of which require Home Energy Rating System (HERS) verification:

- Quality Insulation Installation (HERS)
- Hot Water Piping Insulation, All Hot Water Lines (HERS)
- Verified Refrigerant Charge (HERS)
- Drain Water Heat Recovery

3.1.1 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 lump sum amount based 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 weigh in on the cost.

HERS verification costs include 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 every new construction project. Builders typically minimize HERS fees by scheduling HERS Raters to test and verify multiple measures during one visit. TRC assumed costs for each HERS verification, as shown in Table 7 and Table 8, which include a cost for site visits and additional verification costs for each measure. Based on discussions with multiple HERS Raters in the Palo Alto area, the cost estimates include overlap in site visits where appropriate; it is assumed multiple tests can be verified in a single visit based on standard practice.

HERS verification pricing methods vary for single family and multifamily buildings. 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. Multifamily HERS verification pricing differs by HERS company; HERS Raters either price by the number of site visits required or by the number of dwelling units.

Table 7. Single Family HERS Verification Costs Summary

Component	Single Family
On-site visit ($/visit)	$220
Standard Measure verification ($/measure)	$45
Additional Measure verification ($/measure)	$100

The values in Table 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 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.

Table 8. Multifamily HERS Verification Costs Summary

Component	Multifamily
Method 1: On-site visit ($/visit)	$220
Method 2: Per unit verification, no QII ($/unit)	$198
Method 2: Per unit cost of QII ($/unit)	$50

3.1.2 Quality Insulation Installation (QII)

In 2016 Title 24, QII is a compliance credit for the performance path; however, QII is included in a prescriptive package to trade instantaneous water heaters for storage water heaters. 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 over standard practice because batts may need 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.

Measure costs shown in Table 9 are drawn from the findings of the 2016 Residential High Performance Walls and QII CASE Report.[11,12] Additionally, TRC spoke with over 13 HERS Raters to gather more recent cost estimates. TRC assumed an increase in labor time to account for a learning curve for insulation installers. The HERS verification costs reflect those described in Table 7 and Table 8 at the beginning of this section.

Table 9. Residential QII Incremental Costs Summary

Component/Material	Base Case	Proposed Update	Single Family	Multifamily
Installation (labor)	Standard	Improved	$89	$310
HERS Verification	None	Verified	$430	$708
Total Incremental Costs			$519	$1,018

3.1.3 Piping Insulation for All Hot Water Lines

The 2016 Title 24 Standards include mandatory pipe insulation requirements that cover the majority of hot water pipes. To receive the 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. Pipe insulation thickness varies depending on the pipe diameter and the expected temperature of water being transported through the pipe. The majority of pipes that would be triggered under this requirement are 1/2" and are transporting water from a main branch to an end-use fixture at lower temperatures. According to Table 120.3-A in 2016 Title 24, these pipes will need 1” of insulation. TRC gathered costs from several sources, including the 2013 Single Family Domestic Hot Water and Residential Solar Water Heating Ready CASE Reports, RS Means, and online retailers. 1” of insulation for pipes less than ¾” in diameter is estimated to cost $3.87 per linear foot of pipe.

TRC estimated pipe lengths based on typical design practice. The costs and pipe length estimates are shown in Table 10. The cost of pipe insulation depends on the length of pipes.

[11] TRC Energy Services (September 2014) Residential High Performance Walls and QII Codes and Standards Enhancement Initiative. California Utilities Statewide Codes and Standards Team. 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

[12] Quality Insulation Installation, or QII, was found to be cost-effective as a standalone measure in the referenced CASE report. Table 31, Cost-effectiveness Summary for QII, shows a B/C Ratio of 1.5 for Climate Zone 4. This measure is not proposed for the Palo Alto Reach Code as it was not pursued for the 2016 Title 24.

Table 10. Residential Pipe Insulation Incremental Costs Summary

Component/ Material	Base Case	Proposed Update	1-Story	2-Story	Multifamily
Length of <3/4” diameter pipe (ft)	-	-	31	24	165
Insulation Cost	None	1 in	$118	$91	$640
HERS Verification Cost	None	Verified	$76		$150
Average Incremental Cost			**$181**		**$790**

3.1.4 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 Table 11, assume sampling of HVAC units for multifamily buildings.

Table 11. Refrigerant Charge Verification Incremental Costs Summary

Component	Base Case	Proposed Update	Single Family Cost/Bldg	Multifamily Cost/Bldg
HERS Verification	None	Verified	$76	$272

3.1.5 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 drain line to pre-heat cold water supplied to the water heater and/or to the cold water side of fixtures. Figure 3 shows a common drain water heat recovery configuration.

There are three typical heat recovery configurations available on the market that can be applied to individual water heating or central water heating systems. Heat exchanger performance has been studied by a number of organizations including: Southern California Gas Company, PG&E Food Service Technology Center, Lawrence Berkeley National Lab, FEMP Federal Energy Management Program (FEMP), Oak Ridge National Laboratory, University of Wisconsin, Florida Solar Energy Center (FSEC), and NR Canada. IECC 2015 added a performance option for DWHR and DWHR has been adopted into local codes in Canada.

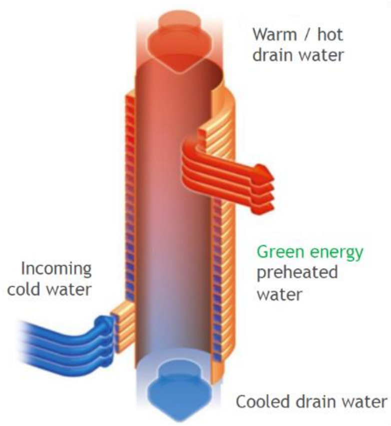


Figure 3. Drain Water Heat Recovery Diagram (courtesy of PowerPipe)

CBECC-Res cannot currently model the benefits of Drain Water Heat Recovery. TRC used energy performance data from technology studies, including those from the entities listed above. Additionally, ANSI/RESNET includes a procedure for calculating savings from DWHR.

The additional cost to implement DWHR, as shown in Table 12 is about $774 in material and labor for every 4 dwelling units.

Table 12. Drain Water Heat Recovery Costs

Cost Component	Multifamily Cost/ Bldg
Drain Water Heat Recovery Equipment	$580
Installation Labor	$194
Total Incremental Cost	**$774**

3.2 Nonresidential Measures

TRC investigated and included the following three measures into the nonresidential packages:

- Economizer
- Indoor Lighting, which is comprised of:
  - Open Office Occupancy Sensors
  - Daylight Dimming-Plus-Off
  - Institutional Tuning
  - Light Power Density Reduction
- Cool Roofs

3.2.1 Economizer

Economizers use outside air to provide cooling when the outside air temperature and humidity are at levels where it makes sense to do so. Economizers reduce energy required to provide cooling to a space, which accounts for about 23% of the TDV kBTU load of a prototypical office building in Climate Zone 4.

Economizers are required in 2016 Title 24 for air handlers with cooling capacity greater than 54,000 Btu/hr; therefore, there are no assumed cost increase for the medium office prototype. This measure will only impact small offices where the typical cooling capacity of each unit is below 54,000 Btu/hr. The cost shown in Table 13 is a conservative estimate, as the units specified with economizers also have improved cooling and heating efficiencies.

Table 13. Economizer Costs

Component	Base Case	Proposed Update	Small Office Cost/Bldg	Medium Office Cost/ Bldg
Economizer	Required for systems > 54,000 Btu/hr	For systems <54,000 Btu/hr	$1,440	N/A

3.2.2 Cool Roofs

The 2013 T24 Standards have prescriptive requirements for nonresidential buildings in CZ4, proposed by the 2013 CASE Report for Nonresidential Cool Roofs.[13] This measure requires a minimum 3-year aged solar reflectance (SR) 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. This measure increases the SR of roofs as per the following:

- SR = 0.28 for steep slopes, compared to current SR = 0.20 prescriptive requirements
- SR = 0.70 for low slopes, compared to current SR = 0.63 prescriptive requirements

The small office prototype has a steep sloped roof, while the medium office prototype has a low sloped roof. Both roof slope types have modeling defaults of Thermal Efficiency (TE) = 0.85, which was maintained for both prototypes.

TRC conducted interviews regarding low slope and steep slope roof products with roofers and roof supply distributors in the San Francisco Bay Area. Multiple roofers and product distributors

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

made the statement that there is little or no additional labor to install cool roof products, and in some instances, there is even cost savings associated with choosing a low sloped cool roof. The cost of cool roof products meeting the Reach Code can be cheaper than their darker, non-cool roof counterparts, as evidenced by recent data collection and supported by the 2013 CASE Report:

> "Within the cool roof market, many of the products with [SR] values close to 0.55 are actually tinted versions of the more conventional white versions of the same product. The products with the darker reflectance can, therefore, actually have a higher initial cost while also driving higher energy costs."

Tile roofing products do not show any cost premium for cool roof products. Roofing distributors, manufacturers, and roofers also stated that cool roof designation does not affect the price of the tile and most tile products meet cool roof standards. There are costs, however, for going from regular asphalt shingles to cool roof asphalt shingles.

The incremental costs of going from the base case to a cool roof are summarized in Table 14. The cost of a steep slope cool roof for a building constructed with asphalt shingles is $2,965, while there is no incremental cost for a building constructed with a tile roof. Assuming that half of the steep slope roof construction in Palo Alto is asphalt, and the other half is tile, the average cost of a steep slope cool roof for the small office prototype is $1,482. Low slope products that meet the cool roof requirements do not introduce a cost increase over non-cool roof products; there are even cost savings for some products. TRC estimated no incremental cost for low slope cool roof products.

Table 14. Nonresidential Cool Roof Incremental Costs Summary

					Small Office		Medium Office	
Material	**Base Case**	**Proposed Update**	**Inc. $/Unit**	**Unit**	**Units/ Bldg**	**$/Bldg**	**Units/ Bldg**	**$/Bldg**
Steep Slope Asphalt Shingles	ASR=0.20, TE=0.75	ASR=0.28, TE=0.85	$0.47	ft^2 roof	6,445	$2,965	-	-
Steep Slope Tile	ASR=0.20, TE=0.75	ASR=0.34, TE=0.85	$0.00	ft^2 roof	6,445	$0	-	-
Low Slope products	ASR=0.63, TE=0.75	ASR=0.70, TE=0.85	$0.00	ft^2 roof	-	-	17,876	$0
Average					-	$1,482	-	$0
Average Incremental Cost					$741			

3.2.3 Indoor Lighting

There are four proposed lighting measures as described below. All of these measures, except the lighting power density reduction measure, are Power Adjustment Factors (PAFs). PAFs allow a building to install wattages that are higher than prescriptively allowed, due to improvements in controls. Please note, when TRC analyzed measures that allow a PAF, we did not assume that higher wattages are installed.

Daylight Dimming-Plus-Off

This measure revises the control settings for daylight sensors to be able to shut-off completely when adequate daylight levels are provided to the space. There is no associated CASE report for this measure, but there is a related report by the Pacific Northwest National Laboratory.[14] The measure is modeled by revising 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 does not increase the number of sensors required, or labor to install and program a sensor, but requires a revised control strategy.

Institutional Tuning

Institutional tuning was introduced as a Power Adjustment Factor (PAF) in the 2013 T24 Standards through the 2013 CASE Report for Requirements for Controllable Lighting.[15] 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 necessary or recommended in the space (e.g. 50 footcandles). [16]

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 after installation and tune down the lighting to meet the design criteria. In the example above, the lighting designer may tune down the lighting to 60 or 55 foot candles. The designer still wants to maintain initial light levels above the minimum requirement to account for depreciation in lamp efficacy over time.

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[14] 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

[15] California Utilities Statewide Codes and Standards Team (March 2011) Requirements for Controllable Lighting. Codes and Standards Enhancement Initiative. Available at: http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/2011-04-04_workshop/review/Nonres_Controllable_Lighting.pdf

[16] 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.

Institutional tuning has been shown to reduce lighting energy consumption in a space by 10 to 15 percent of the original design. This measure cannot currently be modeled directly as a control strategy in CBECC-Com; therefore, TRC used spreadsheet analysis to determine energy savings. This analysis conservatively assumes a 10 percent reduction in LPD for an office from 0.75 W/ft^2 to 0.68 W/ft^2.

The additional cost for this measure is the labor required to tune the lighting in each space, as shown in Table 15. This cost is dependent on the particular design of an office and the number of unique areas that a lighting designer must address. The 2013 CASE Report estimates that the cost is about $0.10 per watt for an office space. TRC determined the total cost by calculating the total number of watts in each prototype based on the allowed LPD.

Table 15. Nonresidential Institutional Tuning Incremental Costs Summary

Component	Base Case	Proposed Update	Commissioning cost	Small Office	Large Office
Institutional Tuning	0.75 W/ft^2 (no tuning)	0.68 W/ft^2 (tuning)	$0.10/Watt	$330	$3,218

Open Office Occupancy Sensors

This measure draws from the findings of the 2013 Indoor Lighting Controls CASE Report.[17] 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 cannot be modeled effectively in CBECC-Com, and is instead calculated in spreadsheet analysis and added to the results of the modeling analysis, as detailed in *Appendix C – Spreadsheet Analysis Energy Savings*.

Occupancy controls have been commercially available for several decades, and the technology for this measure 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 only the costs of the sensors, according to the CASE report, which is $116.13 per sensor. Costs summarized in Table 16 assume seven (7) sensors for the small office, and 59 sensors for the medium office. Though the cost estimates are from 2011, current costs for the equipment are likely to be similar or have decreased since then due to increased market adoption.

[17] 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

Table 16. Nonresidential Open Office Occupancy Sensors Incremental Costs Summary

Component	Base Case	Proposed Update	Small Office	Medium Office
Number of Sensors	0		7	59
Infrared Occupancy Sensor, Equipment and Labor to Install, in an Open Office	No Sensor	One Sensor for Every Four Workstations	$813	$6,852
Average Incremental Cost			$3,832	

Lighting Power Density Reduction

This measure reduces the lighting power density (LPD) from the 2016 Title 24 prescriptive requirement of 0.75 W/ft2 for open office areas to 0.70 W/ft2 assuming LED fixtures as the primary fixture. Cost research shows that some T8 fluorescent basket fixtures may be more costly than LED basket fixtures, because fluorescent fixtures require dimming ballasts to comply with Title 24, while LED fixtures do not. In many cases, the cost may be equivalent or only a small difference once the dimming ballast cost is considered. Three sources of data show cost equivalency for basket fixtures. Research shows that it is technologically feasible to achieve 0.70 W/ft2 design at no incremental cost, and further, that LED luminaires are not required to achieve this, as some fluorescent luminaires are able to achieve this power density as well.

3.3 Solar Measures

3.3.1 Photovoltaics

Costs for solar PV were estimated using statewide data from the New Solar Homes Partnership (NSHP) program.[18] TRC extracted costs for both small systems (less than 10 kW) and larger systems (between 10 kW and 100 kW). Average and median costs (in $/Watt installed) were extracted from the NSHP database, and median costs were found to be higher and more conservative. Although array costs ($/Watt installed) for large systems are less than costs for small systems, TRC used only the cost of small systems in cost effectiveness analysis, to remain conservative.

For 2015 program data, the median cost for small PV systems was $4.90/Watt. Several studies have tracked the installation costs of PV to provide market trends. Lawrence Berkeley National Laboratory, for example, found that national median installed prices in 2014 declined year-over-

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

year by 9% for both residential and nonresidential systems. This decline in cost is similar to what TRC observes in the NSHP database, and a recent CEC report.[19,20] By applying this cost reduction through to 2017, the median installed cost of PV is expected to be $4.06/Watt, as shown in Table 17.

PV systems installed in Palo Alto are eligible for the federal solar Investment Tax Credit (ITC), which rebates 30% of the cost of the system.[21] When accounting for the ITC, the estimated net cost for installed solar PV in 2017 is $2.84/Watt.

Table 17. Costs for Solar PV

Installed Cost ($/Watt)	2015	2016	2017
Median Cost	$4.90	$4.46	$4.06
Federal ITC	-	-	-$1.22
Net Cost	-	-	**$2.84**

At the time of the writing of this report, future net energy metering (NEM) policy and rates were fairly uncertain. Palo Alto's NEM policy is expected to change sometime during 2016, this report does not attempt to estimate the potential impact of these policy changes.

3.3.2 Solar Thermal

Costs for solar thermal hot water systems were based on the California Solar Initiative (CSI) program data, and represent installed costs for all components, including tanks.[22] Costs for baseline systems were developed through the 2016 Instantaneous Water Heaters CASE Report and RSMeans when necessary.

The City of Palo Alto Utilities (CPAU) provides incentives for solar hot water, in addition to the Federal ITC. Incentive amounts vary depending on the therms displaced by the solar thermal system. To estimate incentive amounts, TRC estimated the size (in ft^2) of a typical solar hot water system for each prototype, attained the solar savings fraction using the Solar Water Heater Calculator from the CEC[23], and entered the solar fraction into 2016 Title 24 to attain the therms saved. These therms were then input into the program formulas used to determine incentive amounts.

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

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

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

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

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

Incremental costs from baseline systems were estimated in the following ways, and summarized in Table 18:

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

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

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

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

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

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

Table 18. Solar Thermal System Costs

	Single Family		Low-Rise Multifamily		Nonresidential
Solar Thermal System Size (ft^2)	40		700	100	40
Solar Thermal Solar Savings Fraction	0.70		0.80	0.40	0.20
Solar Thermal System Therms Displaced	70		172	94	126
Solar Thermal System Gross Cost	$12,778		$114,053	$21,065	$12,778
CPAU Incentive	$1,301		$2,499	$1,366	$1,831
Federal Investment Tax Credit	$3,833		$33,998	$5,322	$3,284
Assumed Baseline System	Instantaneous Water Heater	Storage Water Heater	Instantaneous Water Heater	Storage Water Heater + 0.20 Solar Fraction	Storage Water Heater
Baseline System Cost	$1,979	$3,078	$15,832	$8,944	$4,378
Solar Thermal System Net Cost	**$5,664**	**$4,565**	**$61,724**	**$5,433**	**$3,285**

3.3.3 Solar Ready

Single family homes located in subdivisions with ten or more single family residences, multifamily buildings, and nonresidential buildings are required to be solar ready in the 2016 Title 24. Solar ready is defined in Title 24 Section 110.10 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

Palo Alto's 2013 Reach Code requires that new construction single family residences be solar ready in accordance with Title 24's definition, except:

1. All new construction single family homes are required to be solar ready, not just homes located in subdivisions of ten or more homes
2. The solar zone required by the 2013 Reach Code is an area no less than 500 square feet
3. All residential buildings shall provide conduit to support installation of future solar PV

Regarding items #1 and #2, the 2013 CASE Report for Solar Ready Homes and Solar Oriented Development found that the solar ready requirements are cost effective to implement for all new construction homes on a statewide basis, not just homes located in subdivisions of ten or more homes.[24] Furthermore, a larger solar zone does not increase materials or labor costs and does not require cost effectiveness analysis. Therefore, a cost effectiveness analysis is not necessary as part of this report to justify these two 2013 Reach Code solar ready requirements as adoptable for the 2016 Reach Code.

Regarding item #3, costs for providing conduit include materials and labor and must be included in cost effectiveness analysis. Based on prototype geometry, the length of conduit from the main electrical panel to the solar ready area is estimated to be 42 linear feet for both single family homes and multifamily homes. Costs are summarized in Table 19 below.

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[24] California Utilities Statewide Codes and Standards Team (September 2011) Solar Ready Homes and Solar Oriented Development Codes and Standards Enhancement Initiative. Available at: http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/current/Reports/Residential/Envelope/2013_CASE_R_Solar_Ready_Solar_Oriented_Developments_Sept_2011.pdf

Table 19. Costs for Solar Ready Conduit Installation

Component	Incremental Cost / Foot	Linear Feet / Building	Cost / Residential Building
Electric Metallic Tubing (EMT), 1" Diameter, Labor and Materials[25]	$8.16	42	$343

[25] Specified based on the US Environmental Protection Agency Solar Photovoltaic Specification, Checklist and Guide. Available at: https://www1.eere.energy.gov/buildings/residential/pdfs/rerh_pv_guide.pdf

4. Energy Savings and Cost Effectiveness Results

The results for each of the three packages are presented below (single family, multifamily, and nonresidential). Results include measure compliance margin percentage, the present value of energy savings, costs, and benefit to cost (B/C) ratio. Results are first shown for a code compliant building, then for each measure when calculated independently, and finally as a package when all measures are run together.

The measures described in Section 3 were combined to produce cost effective packages presented below. When the B/C ratio is greater than 1.0, the added cost of the measure is more than offset by the discounted energy cost savings and the measure is deemed to be cost effective. Some measures do not prove cost effective individually, but can still be part of a cost effective package of measures.

4.1 Residential Packages

4.1.1 Single Family

The single family package achieves 11% savings with the combination of measures as shown in Table 20.

Table 20. Single Family 10% Package Cost Effectiveness

Single Family Residential 10% Package				
Measure	**% Above Title 24**	**Present Value of Energy Savings**	**Cost**	**Benefit to Cost Ratio**
Quality Insulation Installation (HERS)	9%	$971	$519	1.9
Piping Insulation, All Lines (HERS)	1%	$144	$181	0.8
Verified Refrigerant Charge (HERS)	1%	$79	$76	1.0
Solar Ready	-	-	$343	-
Package	**11%**	**$1,243**	**$1,119**	**1.1**

4.1.2 Multifamily

The multifamily package achieves 10% savings with the combination of the measures shown in Table 21.

Table 21. Multifamily 10% Package Cost Effectiveness

Multifamily Residential 10% Package				
Measure	**% Above Title 24**	**Present Value of Energy Savings**	**Cost**	**Benefit to Cost Ratio**
Quality Insulation Installation (HERS)	5%	$2,010	$1,018	2.0
Piping Insulation, All Lines (HERS)	1%	$522	$790	0.7
Verified Refrigerant Charge (HERS)	2%	$764	$272	2.8
Drain Water Heat Recovery	2%	$944	$774	1.2
Solar Ready	-	-	$343	-
Package	**10%**	**$4,160**	**$3,197**	**1.3**

4.2 Nonresidential Packages

The nonresidential 10% package is achieved largely through low or no incremental cost lighting measures, as shown in Table 22. In combination with the cool roof and economizer measures the package remains cost effective with a B/C ratio of 4.4.

Table 22. Nonresidential 10% Package Cost Effectiveness

Nonresidential 10% Package				
Measure	**% Above Title 24**	**Present Value of Energy Savings**	**Cost**	**Benefit to Cost Ratio**
Economizer	5%	$4,260	$1,440	2.2
Cool Roof	0.3%	$1,493	$741	1.3
Daylight Dimming Plus Off	2%	$5,386	$0	1.0*
Institutional Tuning	3%	$9,093	$2,217	4.1
Open Office Occupancy Sensors	2%	$7,648	$3,833	2.0
Lighting Power Density Reduction	2%	$7,557	$0	1.0*
Package	**10%**	**$33,052**	**$7,513**	**4.4**

*Measures with no cost are cost effective; B/C ratio is set to 1.0.

4.3 Solar Measures

Solar PV was found to be cost effective at all sizes. Solar thermal hot water was not determined to be cost effective for any building type.

4.3.1 Solar PV

Solar PV is cost effective at all sizes as shown in Table 23 below. Nonresidential benefit-to-cost ratios are lower than residential because the NPV factor for nonresidential is lower than residential, as described in Section 2.3.1.

Table 23. Solar PV Cost Effectiveness

Size (kW)	Cost	Residential Present Value of Energy Savings	Residential Benefit to Cost Ratio	Nonresidential Present Value of Energy Savings	Nonresidential Benefit to Cost Ratio
2	$5,681	$17,135	3.0	$8,805	1.5
5	$14,202	$40,562	2.9	$20,843	1.5
8	$22,723	$65,530	2.9	$33,673	1.5
10	$28,404	$82,700	2.9	$42,496	1.5
40	$113,615	$337,401	3.0	$173,376	1.5

4.3.2 Solar Thermal

Solar hot water is not cost effective under any scenario analyzed, as shown in Table 24, even in multifamily buildings with a pre-existing solar hot water system.

Table 24. Solar Thermal Cost Effectiveness

Building	Baseline	Cost	Present Value of Energy Savings	Benefit to Cost Ratio
Single Family	Instantaneous Water Heater	$5,664	$1,724	0.3
	Storage Water Heater	$4,565	$1,981	0.4
Multifamily	Instantaneous Water Heater	$61,724	$843	0.0
	Storage Water Heater + 0.20 Solar Fraction	$5,433	$2,697	0.5
Nonresidential	Storage Water Heater	$3,285	$1,909	0.6

4.4 Reach Code Recommendation

Energy efficiency packages and solar PV proved cost effective for prototypes in the City of Palo Alto. TRC recommends the Palo Alto Municipal Code require that single family, multifamily, and nonresidential buildings exceed the 2016 Title 24 Standards by at least 10%.

As an alternate compliance path, TRC recommends Palo Alto require that PV be installed on buildings that meet the 2016 prescriptive requirements. If the applicant chooses to install solar power, they can use the solar PV credit allowed by the California Energy Commission for residential buildings. The credit is capped at providing a compliance margin of approximately 20.1% for single family homes and 11.8% for multifamily homes. There is no PV credit available for nonresidential buildings, so a minimum kW size is recommended instead. For each building type, Path B ensures that applicants are meeting the standard budget first without use of the PV credit.

- Single family residential new construction projects shall demonstrate either:
  - C. 10% or greater compliance margin without a PV system; OR
  - D. 20% or greater compliance margin with a PV system
- Multifamily residential new construction projects shall demonstrate either:
  - C. 10% or greater compliance margin without PV system; OR
  - D. 12% or greater compliance margin with a PV system
- Nonresidential new construction projects shall demonstrate either:
  - C. 10% or greater compliance margin without a PV system; OR
  - D. 0% or greater compliance margin with a 5 kW PV system or larger.

4.4.1 Compliance

The majority of new construction T24 compliance submittals use building simulation software. CBECC-Res and CBECC-Com are CEC approved software tools which have released versions to be used with 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. During plan check, Palo Alto building officials can confirm that building designs meet the Reach Code by reviewing the compliance margin presented in the simulation software output reports.

For design strategies that cannot currently be modeled in CEC approved software, including Drain Water Heat Recovery and the PAF lighting measures (open office occupancy sensors, daylight dimming plus off, and institutional tuning), the applicant must show compliance through ancillary documentation:

- To comply with drain water heat recovery, the applicant must indicate on the plans how many water heaters are installed. TRC recommends that Palo Alto 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.
- To comply with the PAF lighting measures, building designers will need to apply for the Power Adjustment Factor (PAF) in T24 Standards Table 140.6-A, using the appropriate compliance form(s). This credit should not be used by the designer to increase installed wattage elsewhere in the building. This can be confirmed by plan checkers when reviewing the building model. The indoor lighting energy should not exceed the prescriptive T24 requirements *without* the PAF credit applied.

4.5 Greenhouse Gas Savings

New construction complying with the proposed Reach Code will result in greenhouse gas (GHG) savings through saving electricity and natural gas. Electricity and natural gas usage are estimated in CBECC simulations for each prototype building. Saved energy is multiplied by a factor of 0.65 lbs of CO_2 equivalent (CO_2e) per kWh, and 11.7 lbs of CO_2e per therm, as per Environmental Protection Agency research.[26]

As shown in Table 25:

- 5% GHG savings are achieved for each newly constructed single family building
- 3% GHG savings are achieved for each newly constructed multifamily building
- 7% GHG savings are achieved for each newly constructed nonresidential building

The average GHG reductions across the City are estimated to be 6%, weighted by the new construction square footage.

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 therefor varying GHG savings. Note also that these are percentage savings of the total greenhouse gas emissions from the buildings, including unregulated loads.

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

[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.

Table 25. Greenhouse Gas Savings Summary

Single Family 10% Package							
Measure	**Gas Therms / Home**	**Electric kWh / Home**	**lbs CO2e**	**lbs CO2e Avoided / Home**	**GHG Savings**	**Homes Affected / Year**	**$MTCO_2e$ Avoided / Year Citywide**
Code Compliant Building	344	5,047	7,305	-	-	119	21
Single Family 10% Package	313	5,013	6,923	382	5%		
Multifamily 10% Package							
Measure	**Gas Therms / Building**	**Electric kWh / Building**	**lbs CO2e**	**lbs CO2e Avoided / Building**	**GHG Savings**	**Buildings Affected / Year**	**$MTCO_2e$ Avoided / Year Citywide**
Code Compliant Building	1,162	23,590	28,930	-	-	10	3
Multifamily 10% Package	1,106	23,450	28,183	747	3%		
Nonresidential 10% Package							
Measure	**Gas Therms / Building**	**Electric kWh / Building**	**lbs CO2e**	**lbs CO2e Avoided / Building**	**GHG Savings**	**Buildings Affected / Year**	**$MTCO_2e$ Avoided / Year Citywide**
Code Compliant Building	2019	95,300	85,592	-	-	17	46
Nonresidential 10% Package	2088	84,800	79,565	6,027	7%		
						Total, All Building Types	**71**

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

5. Appendix A – Current Reach Code Language

Below is the full section of the current Palo Alto Reach Code, contained under Title 16 – Building Regulations, Section 17 –California Energy Code.

16.17.040 – Local Amendments.

The provisions of this chapter shall constitute local amendments to the cross-referenced provisions of the California Energy Code, 2013 Edition, and shall be deemed to replace the cross-referenced sections of said Code with the respective provisions set forth in this chapter.

(Ord. 5345 § 1 (part), 2015)

16.17.050 Section 100.3 Local Energy Efficiency Reach Code.

Section 100.3 Local Energy Efficiency Reach Code is added to read:

(a) For all new single-family residential, multi-family residential, and non-residential construction: The performance approach specified within the 2013 California Energy Code shall be used to demonstrate that the TDV Energy of the proposed building is at least 15% less than the TDV Energy of the Standard Design.

(b) For all single-family residential, multi-family residential, and nonresidential tenant improvements, renovations, or alterations, one of the following must be satisfied:

(1) Performance Path: The performance approach specified within the 2013 California Energy Code shall be used to demonstrate that the TDV Energy of the proposed building exceeds the TDV Energy of the Standard Design, when expressed as a percent savings, by at least 5% for single-family residential, 10% for multi-family residential, and 5% for nonresidential tenant improvements, renovations, or alterations.

a. Exceptions. The requirements in this section shall not apply to the following projects:

(1) Multi-family residential renovations or alterations of less than 50% of the existing unit square footage that include replacement or alteration of only one of the following: HVAC system, building envelope, hot water system, or lighting system.

(2) Single-family or two-family residential additions or rebuilds of less than 1,000 square feet.

(3) Non-residential tenant improvements, alterations, or renovations less than 5,000 square feet that include replacement or alteration of only one of the following systems: HVAC system, building envelope, hot water system, or lighting system.

(2) Prescriptive Path: Projects that involve any of the following building components must use the prescriptive measures described below:

Residential	
Single-Family	
Cool Roofs (Alterations Only) Applies to complete roof alterations that are not considered repairs.	Aged Solar Reflectance of ≥ 0.28

Exterior Walls (Additions Only)	High performance walls (u-factor = 0.048 or lower)
Multi-Family	
Roofs (Alterations Only)	Aged Solar Reflectance of ≥ 0.28

Non-Residential	
Cool Roofs (Alterations Only)	Steep Slopes- Aged Solar Reflectance of ≥0.34
	Low Slopes- Aged Solar Reflectance of ≥0.7
Indoor Lighting (Additions and Alterations)	15% below Title 24 Standard Lighting Energy Usage

(Ord. 5345 § 1 (part), 2015)

16.17.060 Section 110.10 Mandatory requirements for solar ready buildings.

Section 110.10 Mandatory Requirements for Solar Ready Buildings is amended as follows:

(a) Subsection 110.10(a)1 is amended to read:

1. Single-family residences. New single family residences shall comply with the requirements of Sections 110.10(b) through 110.10(e).

(b) Subsection 110.10(b)1A is amended to read:

A. Single Family Residences. The solar zone shall be located on the roof or overhang of the building and have a total area no less than 500 square feet.

EXCEPTION 1 to Section 110.10(b)1A: Single family residences with a permanently installed solar electric system having a nameplate DC power rating, measured under Standard Test Conditions, of no less than 1000 watts.

EXCEPTION 2 to Section 110.10(b)1A: Single family residences with a permanently installed domestic solar water-heating system meeting the installation criteria specified in the Reference Residential Appendix RA4 and with a minimum solar savings fraction of 0.50.

EXCEPTION 3 to Section 110.10(b)1A: Single family residences with three stories or more and with a total floor area less than or equal to 2000 square feet and having a solar zone total area no less than 150 square feet.

EXCEPTION 4 to Section 110.10(b)1A: Single family residences located in Climate zones 8-14 and the Wildland-Urban Interface Fire Area as defined in Title 24, Part 2 and having a whole house fan and having a solar zone total area no less than 150 square feet.

EXCEPTION 5 to Section 110.10(b)1A: Buildings with a designated solar zone area that is no less than 50 percent of the potential solar zone area. The potential solar zone area is the total area of any low-sloped roofs where the annual solar access is 70 percent or greater and any steep-sloped roofs oriented between 110 degrees and 270 degrees of true north where the annual solar access is 70 percent or greater. Solar access is the ratio of solar insolation including shade to the solar insolation without shade. Shading from obstructions located on the roof or any other part of the building shall not be included in the determination of annual solar access.

EXCEPTION 6 to Section 110.10(b)1A: Single family residences having a solar zone total area no less than 150 square feet and where all thermostats comply with Reference Joint Appendix JA5 and are capable of receiving and responding to Demand Response Signals prior to granting of an occupancy permit by the enforcing agency.

EXCEPTION 7 to Section 110.10(b)1A: Single family residences meeting the following conditions:

A. All thermostats comply with Reference Joint Appendix JA5 and are capable of receiving and responding to Demand Response Signals prior to granting of an occupancy permit by the enforcing agency.

B. All applicable requirements of Section 150.0(k), except as required below:

i. All permanently installed indoor lighting is high efficacy as defined in TABLE 150.0-A or 150.0-B and is installed in kitchens, bathrooms, utility rooms, and garages at a minimum.

ii. All permanently installed lighting in bathrooms is controlled by a vacancy sensor.

EXCEPTION to EXCEPTION 7Bii: One high efficacy luminaire as defined in TABLE 150.0-A or 150.0-B with total lamp wattage rated to consume no greater than 26 watts of power is not required to be controlled by a vacancy sensor.

iii. Every room which does not have permanently installed lighting has at least one switched receptacle installed.

iv. Permanently installed night lights complying with Section 150.0(k)1E are allowed.

v. Lighting integral to exhaust fans complying with Section 150.0(k)1F is allowed.

vi. All permanently installed outdoor lighting is high efficacy as defined in TABLE 150.0-A or 150.0-B and is controlled as required in Section 150.0(k)9Ai and iii.

(c) Subsection 110.10(c) is amended to read:

(c) Interconnection pathways.

1. The construction documents shall indicate a location for inverters and metering equipment and a pathway for routing of conduit from the solar zone to the point of interconnection with the electrical service. For single-family residences the point of interconnection will be the main service panel.

2. Residential buildings shall provide conduit to support the installation of future solar requirements. The conduit shall be located adjacent to the solar ready area and shall extend from the roofline and terminate at the main electrical panel.

3. The construction documents shall indicate a pathway for routing of plumbing from the solar zone to the water-heating system.

(d) Subsection 110.10(f) is added to read:

(f) Existing tree canopies. In the event of a conflict between the provisions of this section, the Solar Shade Act of 2009, and the Palo Alto Tree Ordinance (Chapter 8.10), the most protective of existing tree canopies shall prevail.

(Ord. 5345 § 1 (part), 2015)

16.17.070 Infeasibility exemption.

(a) Exemption. If an applicant for a covered project believes that circumstances exist that makes it infeasible to meet the requirements of this chapter, the applicant may request an exemption as set forth below. In applying for an exemption, the burden is on the applicant to show infeasibility.

(b) Application. If an applicant for a covered project believes such circumstances exist, the applicant may apply for an exemption at the time of application submittal in accordance with the Development Services administrative guidelines. The applicant shall indicate the maximum threshold of compliance he or she believes is feasible for the covered project and the circumstances that make is infeasible to fully comply with this Chapter. Circumstances that constitute infeasibility include, but are not limited to the following:

(1) There is conflict with the compatibility of the currently adopted green building ordinance and/or California Building Standards Code;

(2) There is conflict with other city goals, such as those requiring historic preservation or the architectural review criteria;

(3) There is a lack of commercially available materials and technologies to comply with the requirements of this chapter;

(4) Applying the requirements of this chapter would effectuate an unconstitutional taking of property or otherwise have an unconstitutional application to the property.

(c) Review by Architectural Review Board (ARB). For any covered project for which an exemption is requested and architectural review is required by the ARB, the ARB shall provide a recommendation to the Director or designee regarding whether the exemption shall be granted or denied, along with its recommendation on the project.

(d) Granting of Exemption. If the Director, or designee, determines that it is infeasible for the applicant to fully meet the requirements of this chapter based on the information provided, the Director, or designee, shall determine the maximum feasible threshold of compliance reasonably achievable for the project. The decision of the Director, or designee, shall be provided to the applicant in writing. If an exemption is granted, the applicant shall be required to comply with this chapter in all other respects and shall be required to achieve, in accordance with this chapter, the threshold of compliance determined to be achievable by the Director or designee.

(e) Denial of Exemption. If the Director determines that it is reasonably possible for the applicant to fully meet the requirements of this chapter, the request shall be denied and the Director or designee shall so notify the applicant in writing. The project and compliance documentation shall be modified to comply with this chapter prior to further review of any pending planning or building application.

(f) Council Review of Exemption. For any covered project that requires review and action by the City Council, the Council shall act to grant or deny the exemption, based on the criteria outlined above, after recommendation by the Director.

(Ord. 5345 § 1 (part), 2015)

16.17.080 Appeal.

(a) Any aggrieved applicant may appeal the determination of the Director regarding the granting or denial of an exemption pursuant to 16.17.070.

(b) Any appeal must be filed in writing with the Development Services Department not later than fourteen (14) days after the date of the determination by the Director. The appeal shall state the alleged error or reason for the appeal.

(c) The appeal shall be processed and considered by the City Council in accordance with the provisions of Section 18.77.070(f) of the City of Palo Alto Municipal Code.

(Ord. 5345 § 1 (part), 2015)

6. Appendix B – Cost Details

Table 26. Single Family HERS Verification Base Costs

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

Table 27. Single Family HERS Verification Detailed Costs

Single Family HERS Measure	Site Visit 1	Site Visit 2	Site Visit 3	Total # Visits	Total Cost
Duct Leakage (Mandatory)		X		1	$76
Verified Airflow/ Fan Efficiency (Mandatory)		X		1	$76
Whole Building Mechanical Ventilation (Mandatory)		X		1	$76
Quality Insulation Installation (Additional)	X	X	(X)	2-3	$430
Piping Insulation, All Hot Water Lines (Standard)		X		1	$76
Verified Refrigerant Charge (Standard)		X		1	$76

*Assuming measures that require 2 or more on-site visits can be verified on the same visit.

Table 28. Multifamily HERS Verification Base Costs

	Multifamily
Method 1: On-site visit ($/visit)	$245
Method 2: Per unit verification, no QII ($/unit)	$198
Method 2: Per unit verification, with QII ($/unit)	$248

Table 29. Multifamily HERS Verification Detailed Costs

Multifamily HERS Measure	Best Case # Site Visits	Mid Case # Site Visits	Worst Case # Site Visits	Total Average Cost
Duct Leakage (Mandatory)	1	1	2	$272
Verified Airflow/ Fan Efficiency (Mandatory)	1	1	1	$150
Whole Building Mechanical Ventilation (Mandatory)	1	1	1	$150
Quality Insulation Installation	3	4	5	$708
Piping Insulation, All Hot Water Lines	1	1	1	$150
Verified Refrigerant Charge	1	1	2	$272

*Assuming measures that require 2 or more on-site visits can be verified on the same visit.

Table 30. Residential Quality Insulation Installation Detailed Costs

					Single Family		Multifamily	
Component/ Material	**Base Case**	**Proposed Update**	**Incremental $/Unit**	**Unit**	**Units/ Home**	**$/Home**	**Units/ Building**	**$/Building**
Installation Labor	Standard	+2 hrs	$44.29	hour	2	$89	8	$354
HERS Verification	None	Verified (2-3 visits)	$430 or $708	-	1	$430	1	$708
				Totals	**$519**		**$1,062**	

Cost source: Local HERS Raters

Table 31. Residential Piping Insulation for All Hot Water Lines Detailed Costs

					1-story		2-story		Multifamily	
Component/ Material	**Base Case**	**Proposed Update**	**Incremental $/Unit**	**Unit**	**Units/ Home**	**$/Home**	**Units/ Home**	**$/Home**	**Units/ Building**	**$/Building**
1/2" Pipes Insulation + Labor	None	1"	$3.87	Linear ft	31	$118	24	$91	165	$640
HERS Verification	None	Verified	$76 or $150	Dwelling Unit	-	$76	-	$76	-	$150
				Totals	**$194**		**$167**		**$790**	

Costs source: 2013 Single Family Water Heating Distribution System Improvements CASE Report: http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/current/Reports/Residential/Water_Heating/2013_CASE_R_SEMPRA_Single_Family_DHW_%20Sept_2011.pdf

Table 32. Multifamily Drain Water Heat Recovery Detailed Costs

					Multifamily	
Material/ Component	**Base Case**	**Proposed Update**	**Incremental $/Unit**	**Unit**	**Units/ Building**	**$/Building**
Heat Recovery Equipment	None	Installed	$580	1 per 4 dwelling units	1	$580
Installation Labor	None	2-hr	$96.82	hrs	2	$194
				Total	**$774**	

Cost source: Online retailers, RS Means, Craftsman Cost Book: https://www.craftsman-book.com/media/static/previews/2013_NPH_book_preview.pdf

Table 33. Nonresidential HVAC Efficiency – 2.5-Ton, 38 MBH SZAC Costs

Source	Cost for 13 SEER, 78% AFUE, No Economizer	Cost for 14 SEER, 90% AFUE, Economizer	Incremental $/unit	Average Inc. $/unit	+ 25% Contractor Markup and 10% Taxes
Trane	$4,500	$5,500	$1,000	$1,050	$1,444
Atlas Trillo	$3,500	$4,600	$1,100		

*Costs include upgrades in cooling and heating efficiency; incremental costs for economizer addition only are likely lower.

Table 34. Nonresidential Cool Roof Detailed Costs

					Small Office		Medium Office	
Material/ Component	Base Case	Proposed Update	Incremental $/Unit	Unit	Units/ Building	$/ Building	Units/ Building	$/ Building
Steep Slope Asphalt Shingles	ASR=0.10, TE=0.85	ASR=0.28, TE=0.85	$0.47	ft^2 roof area	6,445	$3,009	-	-
Steep Slope Tile	ASR=0.10, TE=0.85	ASR=0.28, TE=0.85	$0.00	ft^2 roof area	6,445	$0	-	-
Low Slope Products	ASR=0.63, TE=0.85	ASR=0.70, TE=0.85	$0.00	ft^2 roof area	5,502	$330	17,876	$0

Cost source: Online retailers, local distributors

Table 35. Nonresidential Institutional Tuning for Lighting Detailed Costs

					Small Office		Large Office	
Material/ Component	**Base Case**	**Proposed Update**	**Incremental $/Unit**	**Unit**	**Units/ Building**	**$/ Building**	**Units/ Building**	**$/ Building**
Installation Labor	None	Additional labor time	$0.10	Watt	4,127	$413	4,221	$4,022

Cost source: 2013 Nonresidential Controllable Lighting CASE Report:
http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/2011-04-04_workshop/review/Nonres_Controllable_Lighting.pdf

Table 36. Nonresidential Open Office Lighting Occupancy Sensors Detailed Costs

					Small Office		Large Office	
Material/ Component	**Base Case**	**Proposed Update**	**Incremental $/Unit**	**Unit**	**Units/ Building**	**$/ Building**	**Units/ Building**	**$/ Building**
Occupancy Sensors	None	1 sensor per 4 workstations	$116.13	Sensor	7	$813	59	$6,852

Cost source: 2013 Nonresidential Lighting Controls CASE Report:
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

Table 37. Nonresidential Lighting Power Density (LPD) Reduction Detailed Costs

Source	0.75 W/ft² Product	0.70 W/ft² Product	\$/ft² Cost for 0.75 W/ft²	\$/ft² Cost for 0.70 W/ft²	\$/ft² Incremental Cost
The Lighting Agency, Chris Davis	T8 Basket Fixture - e.g. Lithonia 2VT8	LED Basket Fixture - e.g. Lithonia 2BLT	\$1.68	\$1.38	(\$0.30)
Associated Lighting Representatives			Stated that prices are the same for some options, did not provide product pricing		
Online			\$2.18	\$2.25	\$0.06
		Average	**\$1.93**	**\$1.82**	**(\$0.11)**

7. Appendix C – Spreadsheet Analysis Energy Savings

The energy impact of the Drain Water Heat Recovery, Open Office Occupancy Sensors, and Manual-On Time Switch Controls measures described in Section 3 could not be calculated using CBECC. TRC estimated the energy impact using spreadsheet analysis using information from the respective CASE reports.

7.1 Drain Water Heat Recovery

The energy savings for this measure are based on data from RenewABILITY, a registered provider with the American Institute of Architects and the U.S. Green Building Council. RenewABILITY's data provides estimates for DWHRs serving 4 dwelling units of multifamily residential buildings, among many other configurations, of 25-30% of the domestic water heating load.[27]

To be conservative, TRC assumed the following:

- A recovery rate of 25%, the low end of RenewABILITY's estimates.
- Showers are the only hot water fixture that would benefit from DWHR due to their long hot water draws and high volumes. TRC assumes that 40% of the volume of hot water waste flow in a home is from showers.
- Only 50% of showers are affected in the multifamily prototype, which has eight dwelling units. This is because the prototype is only 2 stories, meaning that a vertical waste line on which a DWHR system could be installed exists only below the top four dwelling units on the second story.

As a result of these factors, the DHW load savings is reduced to 5%, down from the initial estimate of 25%.

7.2 Open Office Occupancy Sensors

To determine the potential energy savings associated with this measure, TRC estimated the number of occupancy sensors using the floor plan provided in Figure 5 of the 2013 CASE report

[27] Further information available: https://www.resnet.us/uploads/documents/conference/2012/pdfs/Buchalter-Drain_Water_Heat_Recovery_Systems.pdf & http://aceee.org/files/pdf/conferences/hwf/2011/4B%20-%20Gerald%20Van%20Decker.pdf

was used. [28] This floor plan shows that open office workstations occupies approximately 53% of the floor plan area, and each work station occupied about 120 ft^2. Using the CASE savings for 4 workstations per occupancy sensor (or, one occupancy sensor per 480 ft^2), TRC determined the total number of occupancy sensors for each prototype, as well as the associated costs and TDV savings. (The costs and TDV savings per sensor are provided in tables in the executive summary of the CASE report, on page 9 and 14, respectively).

Since daylight sensors are required by the 2013 T24 Standards, overlapping savings were estimated to be 20% of non-daylit spaces when in primary daylight zones. Thus, the portion of the open office spaces in the floor plan that were in primary daylight zones (approximately 21% of the workstation floor area) had savings reduced by 80%. Savings were also reduced by the proportion that lighting power density would be reduced from the Reduced LPD and Tuning measures. The summary of findings is provided in Table 38.

Table 38. Nonresidential Proximity Sensors TDV Energy Savings

	Small Office	Medium Office
Workstation Proportion	53%	53%
Workstation Area (ft^2)	2,913	28,201
# Sensors	7	59
Building Cost	$813	$6,852
TDV $ Savings*	$1,608*	$13,553*
TDV kBtu Savings*	18,068*	152,289*
Percent Savings	2.0%	2.8%

* Accounting for overlap with potential daylight sensor savings.

[28] 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