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City of Palo Alto 2013 Building Energy Efficiency Reach Code

Cost Effectiveness Study

Final Report (3/24/2015)

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EXECUTIVE SUMMARY

The City of Palo Alto requires cost effectiveness analysis be completed to renew the Reach Code in Section 16.18.050 of the Palo Alto Municipal Code. The Reach Code requires that residential and nonresidential new construction use 15% less energy than a building minimally compliant with Title 24 (T24) Building Energy Efficiency Standards. The California Energy Commission's 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 four residential cost effective packages (10% and 15% above T24 for single family and multifamily buildings), as well as two cost effective nonresidential packages (10% and 15% above T24). The measures in these packages represent one possible set of measures shown to attain the Reach Code requirements cost effectively, rather than prescriptive measures adopted into the Palo Alto Municipal Code.

TRC simulated residential prototypes in CBECC-Res, and nonresidential prototypes in CBECC-Com, though some measures required spreadsheet analysis to determine savings. The first measures investigated were those that had been studied for the 2016 Title 24 Codes and Standards Enhancement (CASE) process. These studies contain energy savings, market research, and cost estimates for measures that exceed 2013 T24.

Cost effectiveness for the packages of measures is indicated by the benefit to cost ratio. A ratio greater than 1 indicates that the added cost of the measure is more than offset by the discounted (present value) energy cost savings, and the measure is deemed to be cost effective.

The 10% and 15% packages are shown highlighted in yellow for all building types in Table 1. For each package, measures are added sequentially, indicated by a '+' sign, meaning that all energy and costs impacts are cumulative. Because all of the packages proved cost effective for prototypes in the City of Palo Alto, the Palo Alto Municipal Code should renew the Reach Code ordinance requiring that single family, multifamily, and nonresidential buildings exceed the Title 24 Standards by at least 15%.

Table 1. Summary of Cost Effective Packages

Single Family Residential 10% and 15% Packages					
Measure	**TDV kBTU/ft²**	**% Above Title 24**	**Present Value of Energy Savings**	**Cost**	**Benefit to Cost Ratio**
Code Compliant Building	31	0%	$0	$0	-
+ High Performance Attic	27	12%	$1,986	$1,477	1.3
+ Instantaneous Water Heaters	24	22%	$3,438	$1,128	3.0
+ Solar Ready	24	22%	$3,438	$2,120	1.6
Multifamily Residential 10% Package					
Measure	**TDV kBTU/ft²**	**% Above Title 24**	**Present Value of Energy Savings**	**Cost**	**Benefit to Cost Ratio**
Code Compliant Building	44	0%	$0	$0	-
+ High Performance Attic	42	6%	$3,311	$3,049	1.1
+ High Performance Walls	40	9%	$4,804	$4,620	1.0
+ Cool Roofs	40	10%	$5,491	$4,886	1.1
Multifamily Residential 15% Package					
Measure	**TDV kBTU/ft²**	**% Above Title 24**	**Present Value of Energy Savings**	**Cost**	**Benefit to Cost Ratio**
Code Compliant Building	44	0%	$0	$0	-
+ Instantaneous Water Heaters	34	23%	$12,053	-$2,792	No costs
Nonresidential 10% and 15% Packages					
Measure	**TDV kBTU/ft²**	**% Above Title 24**	**Present Value of Energy Savings**	**Cost**	**Benefit to Cost Ratio**
Code Compliant Building	152	0%	$0	$0	-
+ Outdoor LPA	147	3%	$13,007	$0	No costs
+ Indoor Lighting	139	9%	$35,209	$3,832	9.2
+ Cool Roof + Roof Insulation	137	10%	$38,017	$9,650	3.9
+ HVAC Efficiency Measures	128	16%	$55,035	$34,463	1.6

1. INTRODUCTION

The City of Palo Alto, California, plans to enact a Reach Code for the 2013 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 15% less energy than a building exactly compliant with the T24 Standards. Palo Alto has enacted this Reach Code since the 2005 T24 Standards by investigating measures that allow a building to perform 15% 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 2008 T24 Standards, located in Section 16.18.050 of the Palo Alto Municipal Code. This code is partially reproduced below:

> "In addition to the requirements of the 2008 California Building Energy Efficiency Standards, the following general compliance requirements shall apply to all building permit applications subject to this chapter:
>
> (a) Nonresidential construction.
>
> (1) New construction greater than or equal to 5,000 square feet, including additions to existing buildings. The performance approach specified in Section 151 of the 2008 California Building Energy Efficiency Standards shall be used to demonstrate that the TDV energy of the proposed design is at least 15.0% less than the TDV energy of the standard design."
>
> …
>
> "(2) New construction between 500 square feet and 5,000 square feet, including additions to existing buildings. The performance approach specified in Section 151 of the 2008 California Building Energy Efficiency Standards shall be used to demonstrate that the TDV energy of the proposed building is at least 15.0% less than the TDV energy of the standard design."

Similar requirements apply to low rise residential buildings, including single family and multifamily buildings. The section of code is provided in full in *Appendix A – Current Reach Code Language*. This code has not been enforced since the enactment of the 2013 T24 Standards on July 1, 2014, because a cost effectiveness study has not been completed comparing the requirements to the 2013 T24 Standards.

Palo Alto engaged TRC to provide a cost effectiveness study to support building Reach Code requirements 10% and 15% above 2013 T24 Standards minimum requirements for single family residential, multifamily residential, and nonresidential 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 2013 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.

2.2 Package Development

TRC developed four cost effective residential packages (10% and 15% above T24 for single family and multifamily buildings), as well as two cost effective nonresidential packages (10% and 15% above T24). The measures in these packages represent one possible set of measures shown to attain the Reach Code requirements cost effectively, rather than prescriptive measures adopted into the Palo Alto Municipal Code.

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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 (February 2011) Time Dependent Valuation of Energy for Developing Building Efficiency Standards. California Energy Commission. Available at: http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/general_cec_documents/Title24_2013_TDV_Methodology_Report_23Feb2011.pdf

[3] kBTUs = thousands of British Thermal Units.

When applicable, residential prototypes were simulated in CBECC-Res version 3b and nonresidential prototypes in CBECC-Com version 3a.[4] TRC simulated all prototypes in Climate Zone 4 (CZ4), and initialized them to be perfectly compliant with the minimum 2013 T24 requirements (0% compliance margin). The TDV of energy savings for the energy efficiency measures were derived by revising default values in CBECC, 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.[5] 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
- 4,050 ft^2 single family two-story home, including a basement
- 6,960 ft^2 low-rise multifamily residential building, with two stories and eight dwelling units

The single family two-story home represents the 2,700 ft^2 prototype with the addition of a basement, at the request of the City of Palo Alto. TRC determined the area of the basement floor, 1,350 ft^2, by using the same floor area as each of the two above-grade floors. TRC created basement below-grade walls with the same geometry as the above grade walls, and with prescriptive U-factors and construction assemblies. A Palo Alto building official described that basements are typically provided with windows and light wells. Thus, TRC added windows to the basement with the same window-to-floor area ratio as the other floors of the prototype.

Further prototype details are provided in Table 2. Detailed requirements for the compliant building prototypes are provided in the CEC Residential Alternative Calculation Method reference manual.

[4] 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

[5] 2013 Residential Alternative Calculation Method, California Energy Commission. Available at: http://www.energy.ca.gov/2013publications/CEC-400-2013-003/CEC-400-2013-003-CMF-REV.pdf

Table 2. Residential Prototypes Summary

Building Type	One-Story	Two-Story	Low-Rise Multifamily
Area	2,100	4,050	6,960
Roof Area	2,520	1,740	4,176
# of floors	1	3*	2
Window-to-Floor Area Ratio	20%	20%	15%
Attic/Roof Assembly	Tile Roof, Wood Sheathing, No Insulation, 0.40 U-factor, 2x4 @ 24" OC SR = 0.10, TE = 0.85		
Above Grade Wall Assembly	R-15 Cavity Insulation, R4 Synthetic Stucco, 0.065 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
Water Heater	Natural Gas, Small Storage, 50 Gallon Tank, EF = 0.6, 40 MBH Input Rating		

*The two-story prototype actually has three stories because of the added basement.

2.2.2 Nonresidential Prototypes

The nonresidential prototypes were developed according to the Nonresidential Alternative Calculation Method reference manual.[6]

- 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 3, and detailed requirements for the compliant building prototypes are provided in the CEC Nonresidential Alternative Calculation Method reference manual.

[6] 2013 Nonresidential Alternative Calculation Method, California Energy Commission. Available at: http://www.energy.ca.gov/2013publications/CEC-400-2013-004/CEC-400-2013-004-CMF.pdf

Table 3. Nonresidential Prototypes Summary

Building Type	Medium Office	Small Office
Floor Area	53,628	5,502
# of floors	3	1
Window-to-Floor Area Ratio	26%	23%
Roof Construction	1/16" Metal Standing Seam, R-25 Insulation SR = 0.63, TE = 0.85	
Cooling System	Direct Expansion, 11 EER, Economizer	Direct Expansion, 13 SEER, No Economizer
Heating System	Boiler, 90% Thermal Efficiency	Furnace, 78% AFUE
HVAC Distribution System	3 Packaged VAVs (1 per story) with Hot Water Reheat	5 Packaged Single Zone Systems
Thermal Zones	18 (3 unconditioned)	6 (1 unconditioned)
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. These studies contain detailed energy savings, market research, and cost estimates for measures that exceed 2013 Title 24 and serve as comprehensive data sources for the Reach Code analysis.

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. Total incremental costs represent the incremental initial construction and maintenance costs of the proposed measure relative to the 2013 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

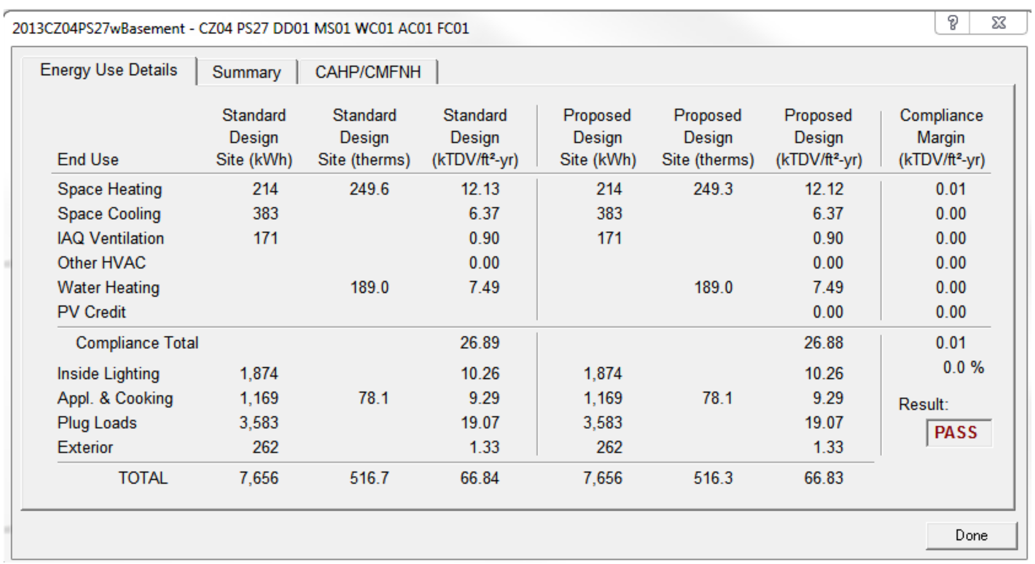
For most measures, TRC used CBECC-Com and CBECC-Res to estimate the TDV savings and percent improvement beyond the T24 Standards. CBECC is a free public domain software developed by the CEC for use in complying with the 2013 T24 Standards. CBECC-Com uses

EnergyPlus v8.1 as the simulation engine to perform the analysis. Measure specific modeling parameters are described in Section 3.

TDV energy savings are calculated and presented 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 NPV factor.[7] TRC used a straight average to blend the energy savings of the two single family prototypes, as well as the two office prototypes.

TRC simulated multiple measures together to capture potential interactive or overlapping effects of the measures. For example, adding insulation to the walls and roof may each individually produce a 10% compliance margin, but both of these measures combined may only produce a 15% compliance margin (rather than 20%). For measures that could not be simulated in software, we calculated energy savings estimates through spreadsheet analysis as described in *Appendix D – Spreadsheet Analysis Energy Savings.*

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. In developing the Reach Code measures, TRC has focused on these regulated loads so that building designers can show compliance easily. The CBECC-Res output, shown in Figure 1, shows that the unregulated loads (including lighting, appliance and cooking, plug, and exterior loads) are excluded from the compliance total.

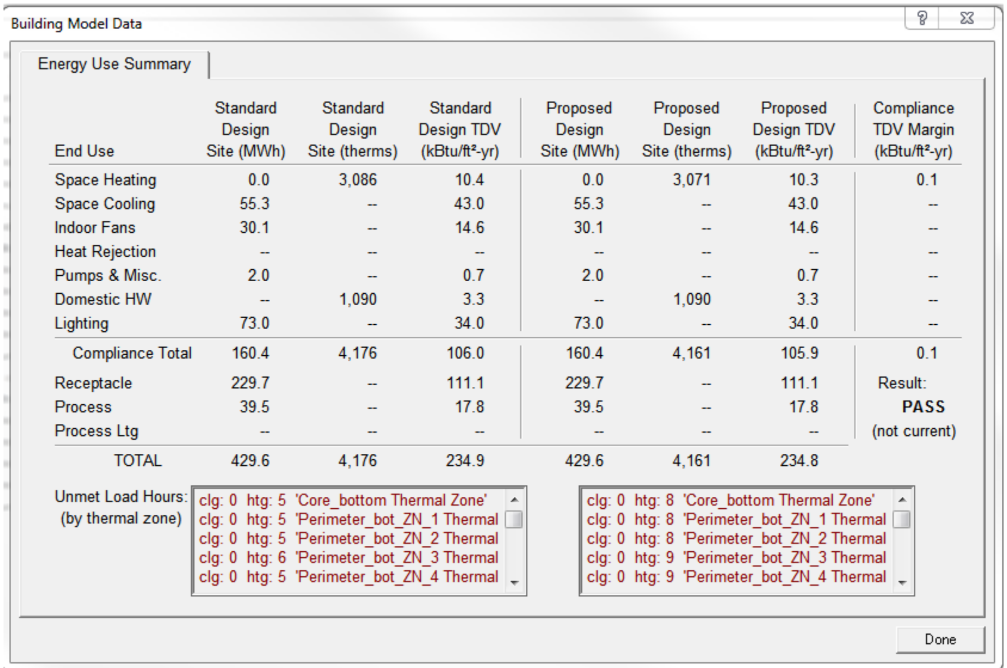


End Use	Standard Design Site (kWh)	Standard Design Site (therms)	Standard Design (kTDV/ft²-yr)	Proposed Design Site (kWh)	Proposed Design Site (therms)	Proposed Design (kTDV/ft²-yr)	Compliance Margin (kTDV/ft²-yr)
Space Heating	214	249.6	12.13	214	249.3	12.12	0.01
Space Cooling	383		6.37	383		6.37	0.00
IAQ Ventilation	171		0.90	171		0.90	0.00
Other HVAC			0.00			0.00	0.00
Water Heating		189.0	7.49		189.0	7.49	0.00
PV Credit						0.00	0.00
Compliance Total			26.89			26.88	0.01
							0.0 %
Inside Lighting	1,874		10.26	1,874		10.26	
Appl. & Cooking	1,169	78.1	9.29	1,169	78.1	9.29	
Plug Loads	3,583		19.07	3,583		19.07	
Exterior	262		1.33	262		1.33	
TOTAL	7,656	516.7	66.84	7,656	516.3	66.83	

Figure 1. CBECC-Res Output Screenshot

[7] The NPV factor is 0.173 for residential measures and 0.089 for nonresidential measures.

The CBECC-Com outputs, shown in Figure 2, shows that the unregulated receptacle, process, and process lighting loads are excluded from the compliance total.


Building Model Data

Energy Use Summary

End Use	Standard Design Site (MWh)	Standard Design Site (therms)	Standard Design TDV (kBtu/ft²-yr)	Proposed Design Site (MWh)	Proposed Design Site (therms)	Proposed Design TDV (kBtu/ft²-yr)	Compliance TDV Margin (kBtu/ft²-yr)
Space Heating	0.0	3,086	10.4	0.0	3,071	10.3	0.1
Space Cooling	55.3	--	43.0	55.3	--	43.0	--
Indoor Fans	30.1	--	14.6	30.1	--	14.6	--
Heat Rejection	--	--	--	--	--	--	--
Pumps & Misc.	2.0	--	0.7	2.0	--	0.7	--
Domestic HW	--	1,090	3.3	--	1,090	3.3	--
Lighting	73.0	--	34.0	73.0	--	34.0	--
Compliance Total	160.4	4,176	106.0	160.4	4,161	105.9	0.1
Receptacle	229.7	--	111.1	229.7	--	111.1	Result:
Process	39.5	--	17.8	39.5	--	17.8	PASS
Process Ltg	--	--	--	--	--	--	(not current)
TOTAL	429.6	4,176	234.9	429.6	4,161	234.8	

Unmet Load Hours: (by thermal zone)

Standard	Proposed
clg: 0 htg: 5 'Core_bottom Thermal Zone'	clg: 0 htg: 8 'Core_bottom Thermal Zone'
clg: 0 htg: 5 'Perimeter_bot_ZN_1 Thermal	clg: 0 htg: 8 'Perimeter_bot_ZN_1 Thermal
clg: 0 htg: 5 'Perimeter_bot_ZN_2 Thermal	clg: 0 htg: 8 'Perimeter_bot_ZN_2 Thermal
clg: 0 htg: 6 'Perimeter_bot_ZN_3 Thermal	clg: 0 htg: 9 'Perimeter_bot_ZN_3 Thermal
clg: 0 htg: 5 'Perimeter_bot_ZN_4 Thermal	clg: 0 htg: 9 'Perimeter_bot_ZN_4 Thermal

Done

Figure 2. CBECC-Com Output Screenshot

CBECC-Com does not currently model exterior lighting even though it is a T24 regulated load. TRC analyzed an outdoor lighting measure as part of the nonresidential package, thus requiring that outdoor lighting energy usage be added to the Standard Design whole building energy usage. The adjusted standard design TDV energy usage would serve as the point of comparison when calculating compliance for all measures in the nonresidential package. The derivation of the standard outdoor lighting energy usage is described in more detail in *Appendix D – Spreadsheet Analysis Energy Savings*. The energy consumption of the nonresidential prototypes is summarized in Table 4.

Table 4. Nonresidential Prototype TDV Energy Consumption

Prototypes	Small Office	Medium Office
Building Area (ft^2)	5,502	53,628
Modeled Standard Design TDV (kBtu/ft^2-yr)	179	106
Outdoor Lighting Only Standard TDV (kBtu/ft^2-yr)	9.8	
Adjusted Standard Design TDV (kBtu/ft^2-yr)	188.9	115.8

2.3.2 Costs

For the majority of measures, CASE studies provided relevant costs for the measures. TRC conducted further cost research for the Cool Roofs and HVAC Efficiency measures. 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 each of the following four measures into the residential packages:

- High Performance Attics
- High Performance Walls
- Cool Roofs
- Instantaneous Water Heaters
- Solar Ready

3.1.1 High Performance Attics (HPA)

This measure draws from the findings of the 2016 Residential Ducts in Conditioned Space / High Performance Attics CASE Report.[8] The measure improves the building thermal envelope and reduces heating, ventilation, and air-conditioning (HVAC) distribution losses in residential buildings. Components of this measure defined in the single family prototypes include:

- R-38 insulation at the ceiling below attic, from R-30 prescriptive insulation
- R-13 below deck (cavity) insulation, from no prescriptive insulation
- Duct lower leakage target of 5%, from 8% prescriptive leakage
- R-8 duct insulation, from R-6 prescriptive insulation

Two additional building products are needed for the HPA measure. First, draped netting is necessary for the below deck loose-fill insulation. Second, the prescriptive requirement for radiant barrier is unnecessary with insulation below the roof deck because it not practical to install a radiant barrier below the below-deck insulation.

The multifamily prototype is modeled with the same measures, except that the multifamily prototype has ducts located entirely in conditioned space by default. Thus, the duct insulation measure by itself does not save energy in the multifamily model, due to the assumption that all ducts are already in conditioned space. Duct leakage however, does have an energy impact by itself. To allow the user to change the duct leakage and duct insulation values, the duct location

[8] TRC Energy Services (October 2014) Residential Ducts in Conditioned Space / High Performance Attics 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_Title_24_Final_CASE_Report_HPA-DCS-Oct2014.pdf

in CBECC-Res must be changed to "multiple places," and then ducts must be specified to be located to the thermal zones.

The following excerpt from the CASE report provides a market overview HPA strategies:

> "HPA strategies are not widely implemented in the California residential market which is dominated by ducts installed above the ceiling insulation in vented attics. But the numbers are increasing in the high performance homes market due to tighter energy budgets and greater difficulty in achieving the 'above code targets' for incentive programs. [HPA will require] adjustments to attic insulation placement and possibly insulation type. There are different options and combinations of insulation that can be used which are widely available from manufacturers, distributors and retailers. […] If installed properly and according to best design guidelines, these measures will be low maintenance and persist for the life of the measure."

The incremental costs of going from the base case to the proposed HPA measure are derived from the CASE report and summarized in Table 5. CASE authors determined the costs during the CASE study development, from sources such as online retailers such as Home Depot and Lowes, RSMeans, and quotes from builders participating in research projects. The costing methodology was reviewed and revised by representatives of the California Building Industry Association (CBIA). The average cost of the measure in single family prototypes for CZ4 is $1,477, which is the value used in the cost effectiveness analysis.

Table 5. Residential HPA Incremental Costs Summary

Component/Material	Base Case	Proposed Update	1-story	2-story	Multifamily
Below Deck Insulation	none	R-13	$806	$557	$1,336
Ceiling Insulation	R-30	R-38	$294	$203	$487
Duct Insulation	R-6	R-8	$143	$183	$474
Duct Leakage	8%	5%	$0	$0	$0
Netting	None	Present	$806	$557	$1,336
Radiant Barrier	Present	None	-$353	-$244	-$585
Total Incremental Costs			$1,697	$1,256	$3,049
Average Incremental Costs			$1,477		-

Further details on costs for this measure are included in *Appendix C – Cost Details*.

3.1.2 High Performance Walls (HPW)

This measure draws from the findings of the 2016 Residential High Performance Walls and QII CASE Report.[9,10] The measure reduces the amount of heat transfer through walls and thus reduces HVAC loads. In the CASE report High Performance Walls are defined as having an overall assembly U-factor of 0.048.[11] While this U-factor may be achieved using a variety of cavity and exterior insulation combinations, TRC assumed the following components based on the lowest cost option presented in the CASE report:

- R-19 wall cavity insulation, from R-15 prescriptive insulation
- R-6 exterior sheathing insulation, from R-4 prescriptive insulation
- 2x6 at 16" on-center framing, from 2x4 at 16" on-center prescriptive framing

Another possible 2x6 assembly meeting a U-factor of 0.048 would be R-24 cavity insulation (2 inches of spray foam combined with R-13 batt) plus R-4 exterior sheathing insulation (this assembly is more costly and was not studied). For a diagram of wall assemblies and associated U-factors, please refer to the CEC's 2013 Joint Appendices, section JA4.3 – Walls (*reproduced in Appendix E – Reach Code Prescriptive Walls Path*).

Additional sill flashing at windows and doors is needed to accommodate the extra thickness of the exterior insulation. The following excerpt from the CASE report provides a market overview HPW strategies:

> "There are several components involved in constructing a high performance wall, and each was investigated for market structure, availability and useful life, persistence and maintenance […]:
>
> - Exterior rigid and cavity insulations: a variety of insulation types are available that provide varying levels of insulation per unit depth, and can meet the proposed requirement using either 2x4 or 2x6 studs. No additional maintenance is expected for these products if installed properly.
> - Framing: The use of 2x6 studs in the California residential market has increased in advanced homes since the 2013 CASE analysis, and is expected to further increase with the 2013 Standards going into effect. A market shift towards greater use of 2x6 studs will only have a minor impact on the timber industry and negligible impact on lumber use due to optimal lumber sawing practices. Framing requirements are expected to have no additional maintenance if installed properly.

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[9] 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

[10] 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 BtC 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.

[11] While this U-factor is used to calculate cost effectiveness for the 15% compliance package, it is not used as a prescriptive U-factor. Please see *Appendix E – Reach Code Prescriptive Walls* Path for details.

- External finish: Stucco is the predominant finishing for California residential new construction. It is expected that there will be labor and material increases when applying stucco over rigid insulation at depths greater than 1" due to the need for longer nails and wider door and window frames.
- Window frames and flashing: Window frames are directly affected by the thickness of the external finish; meaning adjustments must be made in the installation of windows when using thicker rigid exterior insulation."

The incremental costs of going from the base case to the proposed HPW measure are derived from the CASE report and summarized in Table 6. CASE authors determined the costs during the CASE study development, from sources including online retailers such as Home Depot and Lowes, RSMeans, quotes from builders participating in research projects, and confirmed through conversations with CBIA energy analysts. Based on this information, the average cost for the single family prototypes in Palo Alto is approximately $661, which is the value used in the cost effectiveness analysis.

Table 6. Residential HPW Incremental Costs Summary

Component/Material	Base Case	Proposed Update	1-story	2-story	Multifamily
Batt Insulation	R-15	R-19	-$245	-$413	-$715
Rigid Insulation	R-4	R-6	$214	$399	$790
Wood Framing	2x4	2x6	$476	$752	$1,427
Sill Flashing (additional)	1"	1.5"	$69	$69	$69
Total Incremental Costs			$514	$808	$1,571
Average Incremental Costs			$661		-

Further details on costs for this measure are included in *Appendix C – Cost Details*.

3.1.3 Cool Roofs

The T24 Standards currently do not have any cool roof requirements for new low rise residential buildings in CZ4. For buildings without certified cool roofs, the modeling software assumes a default 3-year aged solar reflectance (SR) of 0.10 and thermal emittance (TE) of 0.85. This measure increases the cool roof characteristics to SR = 0.28 and maintains a TE = 0.85.

TRC conducted interviews regarding steep slope roof products with several roofers and roof supply distributors in the San Francisco Bay Area. Multiple roofers stated that there is no additional labor to install cool roof products. Additionally, several distributors reported that the product prices are relatively constant for a given region (i.e. the Bay Area in general will have consistent pricing for a particular product). 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 7. The cost of a cool roof for a multifamily building constructed with asphalt shingles is $543, while there is no incremental cost for a multifamily building constructed with a tile roof. Assuming that half of the construction in Palo Alto is asphalt, and the other half tile, the average cost of a cool roof for a multifamily prototypes is $271. With the same assumptions, the average cost of a single family cool roof is $138.

Table 7. Residential Cool Roof Incremental Costs Summary

Material	Base Case	Proposed Update	1-Story	2-Story	Multifamily
Steep Slope Asphalt Shingles	ASR=0.10, TE=0.85	ASR=0.28, TE=0.85	$328	$226	$543
Steep Slope Tile	ASR=0.10, TE=0.85	ASR=0.28, TE=0.85	$0	$0	$0
		Average	$138		$271

3.1.4 Instantaneous Water Heaters (IWH)

This measure draws from the findings of the 2016 Residential High Performance Walls and QII CASE Report.[12] The measure requires that if gas is available, an applicant can comply with the prescriptive standards by installing a gas instantaneous water heater (IWH), a high efficiency gas storage water heater, or a less efficient storage water heater in conjunction with a solar thermal system. The IWH measure requires installing a water heater defined as follows, in accordance with the CASE report:

- Small instantaneous tank type
- Tank volume of 0 gallons
- Energy factor of 0.82
- Input rating of 190,000 Btu/h

The following excerpts from the CASE report provides a market and cost analysis:

> "The proposed code change is justified given the current and future residential water heating market, as high-efficiency water heaters (including gas IWHs) have widespread availability in California. The incremental cost of high-efficiency water heaters relative to their less efficient counterparts are recovered over time by way of lower utility bills (i.e. higher energy efficiency reduces energy use and thus lowers utility costs to homeowners) and because IWH have longer lifespans than storage water heaters and will need to be replaced less frequently."

[12] Energy Solutions (September 2014) Residential Instantaneous Water Heaters 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_Title_24_Final_CASE_Report_Res_IWH-Sep2014.pdf

The CASE report describes that the incremental cost of an IWH is $494 more than the prescriptive small storage water heater (including the drain kit and installation), but that the maintenance cost of the IWH is $843 less than the maintenance cost for a storage water heater over the 30-year period of analysis. Therefore there are actually cost savings for an IWH compared to a small (50 gallon) storage tank water heater, as summarized in Table 8.

Table 8. Residential IWH Incremental Costs Summary

						Single Family		Multifamily	
Component	**Base Case**	**Proposed Update**	**Initial Cost**	**Maint. Cost**	**Inc. Cost**	**Units/ Bldg**	**Cost/ Bldg**	**Units/ Bldg**	**Cost/ Bldg**
Water Heater	Storage	Instant-aneous	$494	-$843	-$349	1	-$349	8	-$2,792

3.1.5 Solar Ready

This measure draws from the development of the 2013 Solar Ready Homes and Solar Oriented Development CASE report.[13] The CASE report proposed measures for new construction homes that include:

- Roof area be reserved for solar equipment
- A pathway for piping and/or conduit be indicated on plans
- Roof structural design loads be shown on plans
- Adequate electrical capacity be provided
- Spare electric breaker space be provided

In addition to the CASE proposed measures, the City of Palo Alto requested that TRC analyze requiring conduit to be provided to support the installation of future solar requirements.

Costs obtained from the CASE development are summarized in Table 9 below. The costs for reserving roof area, reserving a pathway for piping/conduit, and structural design load calculations are entirely design costs, which are not included in the CEC's LCC methodology (though realizing these measures will require additional attention from architects and designers). The costs for the electrical capacity and spare electrical breaker space are taken from the CASE report.

[13] 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

To determine costs for requiring conduit, TRC reviewed costs obtained by the CASE team and stakeholder feedback provided during the CASE stakeholder engagement process in 2010-11.[14] Cost values include material and labor costs for installing wiring and conduit, as well as stubbing out the attic interior to the roof to allow future accessibility of these pre-installed wires and conduit. The costs for providing conduit are unnecessarily conservative (high) because the costs found were aggregated with wiring costs.

Table 9. Solar Ready Incremental Costs Summary

Component	Costs/Home
Design requirements	$0
Provide adequate electrical capacity	$144
Provide adequate electrical breaker space	$38
Conduit and Wiring	$810
Total	$992

Because the solar ready measure is an enabling measure, rather than a requirement to install a solar system, there are no associated direct energy savings. The 2013 CASE Report researched the magnitude of savings assuming that building owners would voluntarily install solar systems. While there may be savings associated with voluntary installations, the rate of voluntary installations is not well documented and are not applicable to calculating cost-effectiveness on a per-home basis.

3.2 Nonresidential Measures

TRC investigated and included each of the following five measures into the nonresidential packages:

- Outdoor Lighting Power Allowance
- Indoor Lighting, which is comprised of:
  - Indoor Lighting Power Densities
  - Partial-ON Occupancy Sensors
  - Open Office Occupancy Sensors
  - Daylight Dimming-Plus-Off
- Cool Roofs

[14] Pre-installing conduit in new construction homes was discussed and eliminated based on stakeholder feedback. The primary concern with pre-installing conduit and wiring was compatibility with evolving technology and electrical code requirements.

- Roof Insulation
- HVAC Efficiency

3.2.1 Outdoor Lighting Power Allowance (LPA)

This measure draws from the findings of the 2016 Nonresidential Outdoor Lighting Power Allowance CASE Report.[15] This measure replaces Pulse Start Metal Halide (PSMH) light sources with Light Emitting Diodes (LEDs) as the basis for the calculation of Lighting Power Allowances (LPA) for all exterior applications where it is technically feasible to do so. The energy usage and savings associated with outdoor lighting 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 D – Spreadsheet Analysis Energy Savings*.

The following excerpt from the CASE report provides a market analysis:

> "The industry as a whole is participating in the change to LED light sources. Manufacturers are actively funding R&D efforts for the LED market, putting most of their R&D funds into LED product development. As a result, manufacturers are already supporting this change and are working to be well positioned for this market shift."

The following excerpt from the CASE report provides a cost analysis, which describes that there are no costs associated with this measure because the initial cost and the maintenance cost of LEDs are both lower than PSMHs:

> "[B]y 2017, many of the proposed lighting systems are likely to cost less than the incumbent PSMH lighting systems. This is considering cost forecasts for LED products, which estimate an approximate 30% reduction in luminaire costs by 2017. […] For the sake of the calculations, luminaire maintenance is not being considered in the comparative analysis. The incumbent systems all have higher maintenance costs compared to LED, and the very long life of LED makes them effectively last for the full duration of the 15 year life cycle without requiring maintenance."

3.2.2 Indoor Lighting

There are four components to this measure as described below.

Indoor LPDs

This measure draws from the findings of the 2016 Nonresidential Lighting: Indoor LPDs CASE Report.[16] The measure reduces the lighting power allowances, measured in Watts/ft^2 of spaces

[15] TRC Energy Services and Clanton & Associates (December 2014) Nonresidential Outdoor Lighting Power Allowance Codes and Standards Enhancement Initiative. California Utilities Statewide Codes and Standards Team. Available at: http://www.energy.ca.gov/title24/2016standards/prerulemaking/documents/2014-06-24_workshop/final_case_reports/2016_T24_CASE_Report-Outdoor_LPA-Dec_2014-V3.pdf

[16] TRC Energy Services and Clanton & Associates (October 2014) Nonresidential Lighting: Indoor LPDs Codes and Standards Enhancement Initiative. California Utilities Statewide Codes and Standards Team. Available at: http://www.energy.ca.gov/title24/2016standards/prerulemaking/documents/2014-06-24_workshop/final_case_reports/2016_T24_CASE_Report-NonresLightingLPD-Oct2014-V2.pdf

common to office buildings, such as conference rooms, mechanical rooms, lobbies, and other areas. This measure does not challenge the quality or nature of the lighting equipment employed to establish the allowances, thus there is no anticipation that the changes will trigger any additional costs.

TRC assessed the energy performance of this measure in coordination with the Partial-ON Occupancy Sensors measure, described in the next section.

Partial-ON Occupancy Sensors

This measures draws from the findings of the 2016 Nonresidential Lighting Controls: Partial-ON Occupancy Sensors CASE Report.[17] This measure is focused on spaces that are required to have an occupancy sensor currently (for offices these spaces are private offices, conference rooms, and multipurpose rooms), and meet the requirement to have multilevel lighting in the existing code. The measure requires that these sensors operate as either a partial-ON sensor, or as a vacancy sensor, saving approximately 20 percent of the baseline energy in those spaces. This control strategy does not reduce connected load, but will reduce the hours of operation and the actual load of the lighting when in a dimmed state, resulting in energy savings. This measure does not incur any incremental costs because the baseline controls infrastructure requires the same equipment with different programming. Therefore, there are no additional costs associated with this measure.

Each of the Indoor LPDs and Partial-ON Occupancy Sensor CASE reports provide a weighted average LPD reduction for various impacted building spaces. These weighted LPD reductions represent the energy impacts of each measure. TRC input the LPD reductions for impacted office spaces into CBECC-Com to model the two measures. However, the LPD reductions cannot simply be summed, as part of the savings from each measure overlap. In coordination with the lead author for both CASE reports, the default LPDs for the spaces were reduced from 0.75 W/ft^2 in each prototype to 0.682 W/ft^2 in the medium office building and 0.685 W/ft^2 for the small office building. [18] These LPD reductions represent the energy impacts of both CASE measures, and consider that the original Partial-ON savings were calculated using the baseline LPDs in the 2013 T24 Standards. TRC accounted for the overlap of savings between these measures by using the LPDs proposed in the 2016 Indoor LPDs CASE report as the baseline LPD for the Partial-ON savings calculation.

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[17] TRC Energy Services (September 2014) Nonresidential Lighting Controls: Partial-ON Occupancy Sensors Codes and Standards Enhancement Initiative. California Utilities Statewide Codes and Standards Team. Available at: http://www.energy.ca.gov/title24/2016standards/prerulemaking/documents/2014-06-24_workshop/final_case_reports/2016_Title_24_Final_CASE_Report-Nonresidential_Lighting_Controls_Partial-ON_Ocupancy_Sensors.pdf

[18] Communication with Michael Mutmansky of TRC Energy Services, January 2015.

Open Office Occupancy Sensors

This measure draws from the findings of the 2013 Indoor Lighting Controls CASE Report.[19] This CASE report investigates the use of occupancy controls in open office spaces at various control group sizes. The measure proposed in this study is for 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 D – 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 10 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 increase market adoption.

Table 10. Nonresidential Indoor Lighting Incremental Costs Summary

Component	Base Case	Proposed Update	Small Office	Medium Office
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	

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.[20] The measure is modeled by revising the daylight control type from Continuous (with a minimum

[19] 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

[20] 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

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 daylighted 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.

3.2.3 Cool Roofs

The 2013 T24 Standards have prescriptive requirements for nonresidential buildings in CZ4, proposed by the 2013 Case Report for Nonresidential Cool Roofs.[21] 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 = 0.34 for steep slopes, compared to current SR = 0.20 prescriptive requirements
- SR = 0.7 for low slopes, compared to current SR = 0.63 prescriptive requirements

The medium office prototype has a low slope roof, while the small office prototype has a steep slope roof. Both roof slope types have modeling defaults of 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 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 slope 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.

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

The incremental costs of going from the base case to a cool roof are summarized in Table 11. The cost of a steep slope cool roof for a building constructed with asphalt shingles is $1,869, 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 $934. Then, assuming the half of office roof construction is low slope, and the other half steep slope, the average cost becomes $467.

Table 11. 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=0.34, TE=0.85	$0.29	ft^2 roof	6,444	$1,869	-	-
Steep Slope Tile	ASR=0.20, TE=0.75	ASR=0.34, TE=0.85	$0.00	ft^2 roof	6,444	$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		-	$934		$0

3.2.4 Roof Insulation

This measure draws from the findings of the 2016 Nonresidential Opaque Envelope CASE Report.[22] The measure improves the cavity insulation from R-25 to R-30 for nonresidential wood framed roofs. The CASE report describes that this requirement does "not require any change in construction techniques or practices, and can be readily achieved with insulation products currently in use." The incremental cost of going from R-25 to R-30 is $0.44/ft^2 of roof area (from Table 24 of the CASE report) and summarized in Table 12.

[22] Noresco (December 2014) Nonresidential Opaque Envelope Codes and Standards Enhancement Initiative. California Utilities Statewide Codes and Standards Team. Available at: http://www.energy.ca.gov/title24/2016standards/prerulemaking/documents/2014-06-12_workshop/final_case_reports/2016_Title_24_CASE_Report-NR_Opaque_Envelope-Dec2014-V3.pdf

Table 12. Nonresidential Roof Insulation Incremental Costs Summary

					Small Office		Medium Office	
Material	**Base Case**	**Proposed Update**	**Inc. $/Unit**	**Unit**	**Units/ Bldg**	**$/Bldg**	**Units/ Bldg**	**$/Bldg**
Insulation for Wood-Framed Roof	R-25	R-30	$0.44	ft^2 roof	6,444	$2,835	17,876	$7,865
Average Incremental Cost					$5,350			

3.2.5 HVAC Efficiency

This measure improves the efficiency of the heating and cooling systems. The two prototypes have different HVAC systems: the small office has five single-zone packaged air conditioners (SZACs) with direct expansion cooling and furnace heating; the medium office has three air handling units (AHUs) serving variable air volume systems, with direct expansion cooling, economizers, and two boilers supplying hot water. Thus, different improvements were defined for each system.

- The small office SZACs measures included:
  - Economizers, with integrated controls using a fixed dry bulb control method, and with high and low dry bulb temperature lockouts of 75°F and 50°F, respectively.
  - 14 SEER cooling efficiency, from 13 SEER mandatory requirements
  - 90% AFUE heating efficiency, from 78% AFUE mandatory requirements
- The medium office measures included:
  - 11 EER cooling efficiency, from 9.8 EER mandatory requirements
  - 90% boiler thermal efficiency, from 80% thermal efficiency mandatory requirements

TRC contacted manufacturer representatives to attain incremental cost data for these systems, using the average size of the systems in the CZ4 prototypes. These costs, summarized in Table 13, include an additional 10% for taxes and 25% contractor markup.

A variety of HVAC system combinations are possible depending on the size and function of a given building. TRC attempted to capture the potential variability in costs and savings by blending the results from the small office and medium office measures.

Table 13. Nonresidential HVAC Measures Incremental Costs Summary

Component/ Material	Base Case	Proposed Update	Small Office	Medium Office
Five SZACs 2.5 Tons Cooling Capacity 38 MBH Heating Capacity	No Economizer 13 SEER 78% AFUE	Economizer 14 SEER 90% AFUE	$7,219	-
Three AHUs 40 Tons Cooling Capacity	9.8 EER	11 EER	-	$27,500
Two Boilers 400 MBH Heating Capacity	80% TE	90% TE	-	$14,908
Total Incremental Cost			$7,219	$42,408
Average Incremental Cost			$24,813	

Further details on costs for this measure are included in *Appendix C – Cost Details*.

4. Energy Savings and Cost Effectiveness Results

The results for each of the six packages are presented below, including TDV energy savings, percent compliance, the present value of energy savings, measure costs, and benefit to cost (B/C) ratio.

4.1 Residential Packages

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.

4.1.1 Single Family

The single family 10% package can be met with two individual measures: high performance attics, or instantaneous water heaters, as shown in Table 14.

Table 14. Single Family 10% Package Cost Effectiveness

Single Family Residential 10% Package					
Measure	**TDV kBTU/ft²**	**% Above Title 24**	**Present Value of Energy Savings**	**Cost**	**Benefit to Cost Ratio**
Code Compliant Building	31	0%	$0	$0	-
+ High Performance Attic	27	12%	$1,986	$1,477	1.3

The single family 15% package adds the high performance walls measure to the instantaneous water heater measure, as shown in Table 15.

Table 15. Single Family 15% Package Cost Effectiveness

Single Family Residential 15% Package					
Measure	**TDV kBTU/ft²**	**% Above Title 24**	**Present Value of Energy Savings**	**Cost**	**Benefit to Cost Ratio**
Single Family 10% Package	27	12%	$1,986	$1,477	1.3
+ Instantaneous Water Heaters	24	22%	$3,438	$1,128	3.0
+ Solar Ready	24	22%	$3,438	$2,120	1.6

4.1.2 Multifamily

The multifamily 10% package is a combination of the High Performance Attics, High Performance Walls, and Cool Roofs measures, as shown in Table 16.

Table 16. Multifamily 10% Package Cost Effectiveness

Multifamily Residential 10% Package					
Measure	**TDV kBTU/ft²**	**% Above Title 24**	**Present Value of Energy Savings**	**Cost**	**Benefit to Cost Ratio**
Code Compliant Building	44	0%	\$0	\$0	-
+ High Performance Attic	42	6%	\$3,311	\$3,049	1.1
+ High Performance Walls	40	9%	\$4,804	\$4,620	1.0
+ Cool Roofs	40	10%	\$5,491	\$4,886	1.1

Simulation results in Table 17 show that the Instantaneous Water Heater measure alone would exceed Title 24 2013 by 23%. The reason that the IWH measure performs better in the multifamily prototype than the single family prototypes is due to the multiple water heaters. Water heating also represents about 60% of the energy usage in the multifamily prototype, as opposed to about 36% in the single family prototype, therefore the IWH measure has a larger energy savings impact.

Table 17. Multifamily 15% Package Cost Effectiveness

Multifamily Residential 15% Package					
Measure	**TDV kBTU/ft²**	**% Above Title 24**	**Present Value of Energy Savings**	**Cost**	**Benefit to Cost Ratio**
Code Compliant Building	44	0%	\$0	\$0	-
+ Instantaneous Water Heaters	34	23%	\$12,053	-\$2,792	No costs

4.2 Nonresidential Packages

The nonresidential 10% package is achieved largely through low or no incremental cost lighting measures, which by themselves show a B/C ratio of 9.2, as shown in Table 18. In combination with the roof measures and HVAC efficiency measures, the B/C ratios reduce to 3.9 for the 10% package and 1.9 for the 15% package, but remain cost effective.

Table 18. Nonresidential 10% Package Cost Effectiveness

Nonresidential 10% Package					
Measure	**TDV kBTU/ft²**	**% Above Title 24**	**Present Value of Energy Savings**	**Cost**	**Benefit to Cost Ratio**
Code Compliant Building	152	0%	\$0	\$0	-
+ Outdoor LPA	147	3%	\$13,007	\$0	No costs
+ Indoor Lighting	139	9%	\$35,209	\$3,832	9.2
+ Cool Roof + Roof Insulation	137	10%	\$38,017	\$9,650	3.9

The nonresidential 15% package adds the HVAC efficiency measure to the nonresidential 10% package, as shown in Table 19.

Table 19. Nonresidential 15% Package Cost Effectiveness

Nonresidential 15% Package					
Measure	**TDV kBTU/ft^2**	**% Above Title 24**	**Present Value of Energy Savings**	**Cost**	**Benefit to Cost Ratio**
Nonresidential 10% Package	137	10%	$38,017	$9,650	3.9
+ HVAC Efficiency Measures	128	16%	$55,035	$34,463	1.6

4.3 Reach Code Recommendation

Because all of the packages proved cost effective for prototypes in the City of Palo Alto, the Palo Alto Municipal Code should renew the Reach Code ordinance requiring that single family, multifamily, and nonresidential buildings exceed the Title 24 Standards by at least 15%. The single family and multifamily packages cost effectively exceeded T24 by 22% and 23%, respectively, giving room for Palo Alto to extend the Reach Code requirements for these building types beyond 15%. The single family 15% package can include solar ready requirements and remain cost effective.

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. However, for simulation software that cannot model the nonresidential Outdoor LPA and Open Office Occupancy Sensors (like CBECC-Com), the lighting designer will show compliance on ancillary CEC compliance forms.

- To comply with the Outdoor LPA measure, lighting designers will need show that the outdoor lighting power densities are at least 40% below the 2013 T24 Standards outdoor lighting power allowances. This installed wattage reduction would roughly provide the TDV savings estimated by the Outdoor LPA CASE report.
- To comply with the open office occupancy sensor measure, building designers will need to apply for the Power Adjustment Factor (PAF) in T24 Standards Table 140.6-A, Occupant Sensing Controls in Large Open Plan Offices, using compliance form NRCC-LTI-02-E. 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.

4.4 Greenhouse Gas Savings

New construction complying with the 15% Reach Code will result in greenhouse gas (GHG) savings. Because the City of Palo Alto Utilities have a carbon neutral electricity supply composed of hydroelectric and renewable sources, avoided greenhouse gas emissions are solely due to reduced natural gas usage.

The natural gas usage in therms are estimated in CBECC simulations for each prototype building. These savings are multiplied by a factor of 11.7 lbs of CO_2 equivalent (CO_2e) per therm, as per Environmental Protection Agency research.[23] As shown in Table 21:

- 20% GHG savings are achieved for each newly constructed single family building
- 32% GHG savings are achieved for each newly constructed multifamily building
- 8% GHG savings are achieved for each newly constructed nonresidential building

These GHG reduction estimates are based on complying with the 15% compliance package using the measures analyzed in this study. Compliance with the 15% Reach Code may be achieved through a variety of measures, each of which will have varying natural gas and GHG savings.

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 2013 Calendar year, provided by the Palo Alto planning department. GHG savings are expressed in metric tons of carbon dioxide equivalent ($MTCO_2e$).

[23] United States Environmental Protection Agency. 2011. "Emission Factors for Greenhouse Gas Inventories." Available at: http://www.epa.gov/climateleadership/documents/emission-factors.pdf.

Table 20. Greenhouse Gas Savings Summary

Single Family 15% Package						
Measure	**Gas Therms / Home**	**lbs CO2e**	**lbs CO2e Avoided**	**GHG Savings**	**Homes Affected / Year**	**$MTCO_2e$ Avoided / Year**
Code Compliant Building	401	4,687	0	0%	117	0
Single Family 15% Package	320	3,744	943	20%		110,318
Multifamily 15% Package						
Measure	**Gas Therms / Home**	**lbs CO2e**	**lbs CO2e Avoided**	**GHG Savings**	**Buildings Affected / Year**	**$MTCO_2e$ Avoided / Year**
Code Compliant Building	1356	15,848	0	0%	5	0
Multifamily 15% Package	922	10,782	5,067	32%		25,335
Nonresidential 15% Package						
Measure	**Gas Therms / Home**	**lbs CO2e**	**lbs CO2e Avoided**	**GHG Savings**	**Buildings Affected / Year**	**$MTCO_2e$ Avoided / Year**
Code Compliant Building	2259	26,410	0	0%	16	0
Nonresidential 15% Package	2067	24,166	2,245	8%		35,915

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 18 – Local Energy Efficiency Standards Covered for Certain Buildings and Improvements Covered by the California Energy Code, 2008 Edition.

"16.18.050 – General compliance requirements.

In addition to the requirements of the 2008 California Building Energy Efficiency Standards, the following general compliance requirements shall apply to all building permit applications subject to this chapter:

(a) Nonresidential construction.

(1) New construction greater than or equal to 5,000 square feet, including additions to existing buildings. The performance approach specified in Section 151 of the 2008 California Building Energy Efficiency Standards shall be used to demonstrate that the TDV energy of the proposed design is at least 15.0% less than the TDV energy of the standard design. Compliance with this section shall constitute achievement of LEED's minimum energy prerequisite as described in Table A of the "City of Palo Alto Green Building Standards for Compliance for Private Nonresidential Construction and Renovation."

(2) New construction between 500 square feet and 5,000 square feet, including additions to existing buildings. The performance approach specified in Section 151 of the 2008 California Building Energy Efficiency Standards shall be used to demonstrate that the TDV energy of the proposed building is at least 15.0% less than the TDV energy of the standard design. Compliance with this section shall constitute achievement of LEED's minimum energy LEED prerequisite as described in Table A of the "City of Palo Alto Green Building Standards for Compliance for Private Nonresidential Construction and Renovation."

(3) Tenant improvements, renovation or alterations greater than or equal to 5,000 square feet that include replacement or alteration of at least two of the following: HVAC system, building envelope, hot water system, or lighting system. Energy efficiency beyond 2008 California Building Energy Efficiency Standard minimums is not required for projects covered by this section.

(4) Tenant improvements, renovations or alternations greater than or equal to 500 square feet with greater than $100,000 in building permit valuation in a single unit, that are not otherwise covered under Section 3 of Table A of the "City of Palo Alto Green Building Standards for Compliance for Private Nonresidential Construction." The applicant shall attain an Energy STAR Portfolio Manager Building Energy Performance Rating prior to the issuance of a building permit, although achievement of a particular rating is not required. Compliance with this section shall constitute achievement of the building energy performance rating described in Table A of the "City of Palo Alto Green Building Standards for Compliance for Private Nonresidential Construction and Renovation."

(b) Residential construction.

(1) Multi-family residential new construction of three or more attached units. The building permit applicant must determine whether the building is low-rise or high-rise as defined by the 2008 California Building Energy Efficiency Standards, and then use the appropriate approach as described below:

(A) Low rise (three stories or less). The performance approach specified in Section 151 of the 2008 California Building Energy Efficiency Standards shall be used to demonstrate that the TDV energy of the proposed building is at least 15.0% less than the

TDV energy of the standard design. Compliance with this section shall constitute achievement of GreenPoint Rated's minimum energy prerequisite for new "multi-family residential" construction, as described in Table B of the "City of Palo Alto Green Building Standards for Compliance for Private Residential Construction and Renovation".

(B) High rise (four stories or more). The applicant shall model the building envelope and mechanical system of the proposed design consistent with the 2008 Title 24 performance method rules. The applicant shall demonstrate that the TDV energy of the proposed design is less than the TDV energy of the standard design by the percentage required for minimum energy performance specified in the 2009 GreenPoint Rated new "multi-family residential" construction guidelines. Compliance with this section shall constitute achievement of GreenPoint Rated's minimum energy prerequisite required for new "multi-family residential" construction as described in Table B of the "City of Palo Alto Green Building Standards for Compliance for Private Residential Construction and Renovation."

(2) Multi-family renovations or alterations greater than or equal to 50% of the existing unit square footage that include replacement or alteration of at least two of the following: HVAC system, building envelope, hot water system, or lighting system. The building permit applicant shall determine whether the building is low-rise or high-rise as defined by the 2008 California Building Energy Efficiency Standards, and then use the appropriate approach as described below:

(A) Low rise (three stories or less). The performance approach specified in Section 151 of the 2008 California Building Energy Efficiency Standards shall be used to demonstrate that the TDV energy of the proposed design is at least 15.0% less than the TDV energy of the standard design. Compliance with this section shall constitute achievement of GreenPoint Rated's minimum energy prerequisite for new "multi-family residential" construction, as described in Table B of the "City of Palo Alto Green Building Standards for Compliance for Private Residential Construction and Renovation".

(B) High rise (four stories or more). The applicant shall model the building envelope and mechanical system of the proposed design consistent with the 2008 Title 24 performance method rules. The applicant shall demonstrate that the TDV energy of the proposed design is less than the TDV energy of the standard design by the percentage required for minimum energy performance specified in the current GreenPoint Rated new "multi-family residential" construction guidelines. Compliance with this section shall constitute achievement of GreenPoint Rated's minimum energy prerequisite required for new "multi-family residential" construction as described in Table B of the "City of Palo Alto Green Building Standards for Compliance for Private Residential Construction and Renovation."

(3) Multi-family renovations, alterations, additions, and/or rebuilds to individual units greater than or equal to 250 square feet with a building permit valuation greater than or equal to $100,000 in a single unit. The applicant shall attain a HERS II rating prior to issuance of the building permit, although achievement of a particular rating is not required. Compliance with this section shall constitute achievement of the HERS rating requirement as described in Table B of the "City of Palo Alto Green Building Standards for Compliance for Private Residential Construction and Renovation". Compliance with this section is not required until January 1, 2011.

(4) Single-family or two-family residential new construction greater than or equal to 1,250 square feet. The performance approach specified in Section 151 of the 2008 Building Energy Efficiency Standards shall be used to demonstrate that the TDV energy of the proposed design is at least 15.0% less than the TDV energy of the standard design. Compliance with this section shall constitute achievement of GreenPoint Rated's minimum energy prerequisite for new "single-

family and two-family residential" construction, as described in Table B of the "City of Palo Alto Green Building Standards for Compliance for Private Residential Construction and Renovation".

(5) Single-family or two-family residential additions or rebuilds greater than or equal to 1,250 square feet. The performance approach specified in Section 151 of the 2008 Building Energy Efficiency Standards shall be used to demonstrate that the TDV energy of the proposed design is at least 15.0% less than the TDV energy of the standard design. Compliance with this section shall constitute achievement of GreenPoint Rated's minimum energy prerequisite for new "single-family and two-family residential" construction, as described in Table B of the "City of Palo Alto Green Building Standards for Compliance for Private Residential Construction and Renovation".

(6) Single-family or two-family renovations, rebuilds and/or additions that are between 250 square feet and 1,250 square feet, and that have greater than $100,000 in building permit valuation in a single unit. The applicant shall attain a HERS II rating prior to issuance of the building permit, although achievement of a specific HERS II rating is not required. Compliance with this section shall constitute achievement of the minimum energy requirement as described in Table B of the "City of Palo Alto Green Building Standards for Compliance for Private Residential Construction and Renovation". This section has an effective date of January 1, 2011.

(Ord. 5070 § 2, 2010: Ord. 5024 § 2, 2008)"

6. Appendix B – Additions and Alterations Analysis

Some of the energy efficiency measures that TRC analyzed for new construction may also be applicable to additions and alterations of buildings. The City of Palo may also choose to require Reach Codes for these types of permit applications. TRC assessed the relevance of each measure to additions and alterations, followed by a Reach Code recommendation.

6.1 Residential Measures

The T24 Standards sections relevant to residential additions and alterations are:

- 150.0: Low Rise Residential Building – Mandatory Features and Devices
- 150.1: Low Rise Residential Buildings – Performance and Prescriptive Compliance Approaches for Newly Constructed Residential Buildings
- 150.2: Low Rise Residential Buildings – Additions and Alterations in Existing Low Rise Residential Buildings

6.1.1 Relevance

The current language in Section 16.18.050 of the Palo Alto Municipal Code requires the following:

- Low rise multifamily alterations ≥ 50% of the existing floor area that include replacement or alteration of at least two systems (HVAC, envelope, domestic hot water, or lighting), must use the performance approach to demonstrate that the TDV energy of the proposed design is ≤ 15% the TDV energy of the standard design.
- Single family additions or rebuilds ≥ 1,250 ft^2 must use the performance approach to demonstrate that the TDV energy of the proposed design is ≤ 15% the TDV energy of the standard design.
- Single family renovations, rebuilds, or additions ≥ 250 ft^2 and ≤ 1,250 ft^2 must achieve a HERS II Rating.

The current Palo Alto Municipal Code require the use of the performance approach for low rise multifamily alterations and single family additions that exceed a floor area threshold. Single family alterations do not require a T24-based calculation.

Additions: The performance approach for additions and alterations uses the prescriptive requirements in Section 150.1 to establish the performance budget for Section 150.2. TRC's new construction costs and energy savings analysis compared measures relative to the T24 prescriptive requirements, therefore the new construction findings hold true for all additions.

Alterations: For alterations, the relevance of the new construction analysis completed for each residential measure is discussed below in Table 21.

Table 21. Residential Measures Relevance to Alterations

Measure	Relevant?	Justification
High Performance Attics	No	TRC's analysis included adding above-deck insulation and duct improvements, which would not normally be triggered during an insulation alteration. The cost of improving duct leakage and adding duct insulation to existing ducts, and adding roof deck insulation, is not included in TRC's new construction analysis.
High Performance Walls	No	TRC's analysis calculates cost effectiveness for installing 2x6 studs, while most wall insulation alterations likely contain 2x4 studs. The cost of wall insulation assemblies other than R19 + R6, or replacing 2x4 studs with 2x6 studs, is not included in TRC's new construction analysis.
Cool Roofs	Yes	TRC's new construction analysis includes the cost of adding a cool roof beyond the prescriptive minimum solar reflectance, which are the only costs relevant to an alteration of a roof.
Instantaneous Water Heaters	Yes	TRC's new construction analysis includes the cost of adding the new instantaneous water heater compared to the prescriptive storage tank water heater, but does not include alteration costs. TRC reviewed the 2013 CASE Report "High-Efficiency Water Heater Ready" for estimates on costs for alterations.[24] The costs for a new venting system, electrical connection, condensate disposal, and upgraded gas supply line (1/2" to 3/4" diameter) are estimated to be $1,357 for retrofits in the CASE report. These costs are added to the incremental cost of -$349 per dwelling, from Table 8, to result in a net cost of $1,008 per dwelling.
Solar Ready	No	Palo Alto did not request TRC to apply this measure to alterations.

The costs and savings related to the Cool Roof and Instantaneous Water Heaters measures are relevant to single family and multifamily alterations.

6.1.2 Cost Effectiveness

As described earlier, TRC's new construction cost effectiveness analysis is relevant to additions.

[24] California Utilities Statewide Codes and Standards Team. (October 2011) High-efficiency Water Heater Ready Codes and Standards Enhancement Initiative. Available at: http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/current/Reports/Residential/Water_Heating/2013_CASE_WH2.WH5_WaterHeaterReady-10.28.2011.pdf

The single family alterations package is cost-effective by over 10% when applying the instantaneous water heater and cool roof new construction analysis results, as shown in Table 22.

Table 22. Single Family Alterations Cost Effective Package

Single Family Residential Alterations					
Measure	**TDV kBTU/ft²**	**% Above Title 24**	**Present Value of Energy Savings**	**Cost**	**Benefit to Cost Ratio**
Code Compliant Building	30.9	0%	$0	$0	-
+ Instantaneous Water Heaters	27.9	9.6%	$1,452	$1,008	1.4
+ Cool Roof	27.5	11.0%	$1,738	$1,146	1.5

The multifamily alterations package is cost-effective by over 20% when applying only the instantaneous water heater analysis, as shown in Table 23.

Table 23. Multifamily Alterations Cost Effective Package

Multifamily Residential Alterations					
Measure	**TDV kBTU/ft²**	**% Above Title 24**	**Present Value of Energy Savings**	**Cost**	**Benefit to Cost Ratio**
Code Compliant Building	44	0%	$0	$0	-
+ Instantaneous Water Heaters	34	23%	$12,041	$10,856	1.1

6.1.3 Recommendation

When considering these recommendations for alterations, please note the analysis findings are derived from a specific set of measures that do not apply to all alterations. Applying these findings to all alteration scenarios is an aggressive Reach Code requirement. Furthermore, not all alterations building permit applicants would be completing a performance approach, and requiring them to do so may be unnecessarily burdensome. This is a contrast to new construction, where all building systems are designed and built as one unit and the performance approach is used by the majority of applicants.

With this in consideration, TRC recommends that Palo Alto require the following Reach Code measures for residential additions and alterations. The underlined sections emphasize the changes from the original language.

- Low rise multifamily alterations, additions, or rebuilds $\geq$ 50% of the existing floor area that include replacement or alteration of at least two systems (HVAC, envelope, domestic hot water, or lighting), must use the performance approach to demonstrate that the TDV energy of the proposed design is 15% below the TDV energy of the standard design.

- Single family additions, or rebuilds ≥ 1,250 ft^2 must use the performance approach to demonstrate that the TDV energy of the proposed design is 15% below the TDV energy of the standard design.
- Single family alterations or renovations ≥ 1,250 ft^2 that include alteration, replacement, or installation of at least two systems (HVAC, envelope, domestic hot water, or lighting) must use the performance approach to demonstrate that the TDV energy of the proposed design is 10% below the TDV energy of the standard design.
- Water heater change-outs present a unique situation for residential alterations and renovations. Our analysis showed that instantaneous water heaters (IWH) (or the solar-assist equivalent) were cost effective for both multi-family and single family new construction, saving 23% and almost 10% (9.6%) of the whole building energy use, respectively.[25] However, the new construction analysis allows the applicant to use the performance approach to model other DHW systems, such as "standard" tank-style gas water heaters. In the case of water heater change-out only alterations it is unlikely that the applicant would use the whole building performance approach, and less likely that the otherwise unaltered existing building would meet the current Title 24 code requirements. The City **may** want to include IWH, or the solar-assist equivalent, to the residential Reach Code requirements, but should recognize that this requirement would limit home-owner choices, with few alternatives. An exception to this requirement is an existing permanently installed domestic solar water-heating system.

6.2 Nonresidential Measures

The T24 Standards sections relevant to nonresidential additions and alterations are:

- 120.0 – 130.5: Nonresidential Mandatory Requirements
- 140.0 – 140.9: Nonresidential Performance and Prescriptive Compliance Approaches for Achieving Energy Efficiency
- 141.0: Additions, Alterations, and Repairs to Existing Buildings that Will be Nonresidential Occupancies and to Existing Outdoor Lighting for these Occupancies

6.2.1 Relevance

The current language in Section 16.18.050 of the Palo Alto Municipal Code requires the following:

- Nonresidential additions meet the new construction Reach Code.

[25] The solar fraction proposed in the Instantaneous Water Heating CASE report is 0.55.

- Nonresidential tenant improvements, alterations, or renovations ≥ 5,000 ft² that include replacement or alteration of at least two systems (HVAC, envelope, hot water, or lighting) meet the T24 Standards. (There is no Reach Code).

TRC assumes that building permit applicants will use the performance approach for additions or alterations ≥ 5,000 ft² that include multiple systems. The performance approach for additions and alterations of nonresidential buildings, as defined in T24 Section 141.0(a)2 and 141.0(b)3, requires the added and altered components meet the mandatory requirements in T24 Sections 120.0-130.5, as well as the energy budget for a prescriptive building defined in Sections 140.2-140.9.

Additions: Because the standard energy budget for additions is the same as for prescriptive buildings, and TRC's analysis compared costs and energy savings compared to the T24 prescriptive requirements, the costs and energy savings in TRC's analysis remain relevant to additions.

Alterations: For alterations, the relevance of the new construction analysis completed for each nonresidential measure is described below in Table 24.

Table 24. Nonresidential Measures Relevance to Alterations

Measure	Relevant?	Justification
Outdoor LPA	No	The lighting power allowance required by this measure may not be achievable without major renovations to existing outdoor lighting systems (e.g., digging into hardscape and moving wiring). TRC's new construction analysis does not include the costs of these renovations.
Indoor Lighting – Indoor LPDs	Yes	The lighting power density required by this measure is achievable for renovations to existing indoor lighting systems. Generally for large lighting renovations, T24 would require contractors to install multilevel dimming ballasts and efficient fixtures, which are capable of achieving the LPDs required in this measure. TRC's new construction analysis does not anticipate costs for going beyond the T24 minimum, which are relevant alterations.
Indoor Lighting – Partial-ON Occupancy Sensors	Yes	This measure may be achieved through simple control changes in equipment. Generally, large lighting renovations to achieve the 2013 T24 minimum would require contractors to install and/or reconfigure occupancy sensor controls where needed. Thus, this measure does not result in costs beyond what is required in the T24 minimum for alterations, which was also the assumption for TRC's new construction analysis.
Indoor Lighting – Open Office Occupancy Sensors	Yes	This measure requires additional occupancy sensors. The costs of the materials and labor beyond the current T24 minimum requirement were included in TRC's new construction analysis for this measure.
Indoor Lighting	Yes	This measure may be achieved through simple control changes in existing equipment. Generally, large lighting renovations to achieve the 2013 T24 minimum would require contractors to

– Daylight Dimming-Plus-Off		install or reconfigure daylight sensor controls where needed. Thus, this measure does not result in costs beyond what is required in the T24 minimum for alterations, which was also the assumption for TRC's new construction analysis.
Cool Roof	Yes	TRC's analysis includes the cost of adding a cool roof beyond the prescriptive T24 minimum aged solar reflectance (SR=0.63), which is the same solar reflectance required for roofing alterations.
Roof Insulation	No	TRC's analysis calculates the incremental cost of going from R-25 insulation to R-30 insulation. R-values lower than R-25 are required for roof insulation alterations, and would result in different incremental costs than those provided in TRC's analysis.
HVAC Efficiency	No	TRC's analysis calculates the incremental cost of replacing HVAC equipment with higher efficiency units. HVAC systems have varying lifetimes, and alterations of existing HVAC systems may not happen simultaneously. Many owners choose to alter components of systems rather than replacing systems to improve efficiency. TRC's analysis does not include the variation in alteration scenarios for the types of HVAC systems studied.

6.2.2 Cost Effectiveness

As described earlier, TRC's new construction cost effectiveness analysis is relevant to additions.

The nonresidential alterations package is cost-effective by over 5% when applying the Indoor Lighting and Cool Roof measures, as shown in Table 25.

Table 25. Nonresidential Alterations Cost Effective Package

Nonresidential Alterations					
Measure	**TDV kBTU/ft²**	**% Above Title 24**	**Present Value of Energy Savings**	**Cost**	**Benefit to Cost Ratio**
Code Compliant Building	152.3	0%	$0	$0	-
+ Indoor Lighting	144.1	5%	$22,201	$3,832	5.8
+ Cool Roof	143.5	6%	$22,709	$4,299	5.3

Additionally, the energy impact of the lighting improvements alone exceed the standard lighting design TDV budget by 21%, as shown in Table 26.

Table 26. Nonresidential Lighting Alterations Cost Effective Package

Nonresidential Indoor Lighting Alterations					
Measure	**TDV kBTU/ft²**	**% Above Title 24**	**Present Value of Energy Savings**	**Cost**	**Benefit to Cost Ratio**
Lighting for Code Compliant Building	35	0%	$0	$0	-
+ Indoor Lighting	27	22%	$20,170	$3,832	5.3

6.2.3 Recommendation

When considering these recommendations for alterations, please note the analysis findings are derived from a specific set of measures applied to an office building prototype model that do not apply to all alterations. Applying these findings to all alteration scenarios is an aggressive Reach Code requirement. Furthermore, not all alterations building permit applicants would be completing a performance approach, and requiring them to do so may be unnecessarily burdensome.

With this in consideration, TRC recommends that Palo Alto require the following for nonresidential additions and alterations. The underlined sections emphasize the changes from the original language.

- Nonresidential additions meet the new construction Reach Code.
- Tenant improvements, alterations, or renovations ≥ 5,000 ft² that include replacement or alteration of at least two systems (HVAC, envelope, hot water, or lighting) must use the performance approach to demonstrate that the TDV energy of the proposed design is ≤ 5% the TDV energy of the standard design.
- Nonresidential lighting alterations alone must demonstrate that the proposed lighting design is 15% below the standard lighting energy allowance.

7. APPENDIX C – COST DETAILS

Table 27. Residential HPA 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**
Below Deck Insulation	none	R-13	$0.32	ft^2 roof area	2520	$806	1740	$557	4176	$1,336
Ceiling Insulation	R-30	R-38	$0.14	ft^2 ceiling area	2100	$294	1450	$203	3480	$487
Duct Insulation	R-6	R-8	$0.66	Linear ft ducts	217	$143	278	$183	718	$474
Duct Leakage	8%	5%	(Proper care during field installation can achieve 5% duct leakage without adding a low leakage air handler or other additional costs)							
Netting	None	Present	$0.32	ft^2 roof area	2520	$806	1740	$557	4176	$1,336
Radiant Barrier	Present	None	-$0.14	ft^2 ceiling area	2100	-$353	1450	-$244	3480	-$585
				Totals	-	$1,697	-	$1,256	-	$3,049

Table 28. Residential HPW 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**
Batt Insulation	R-15	R-19	-$0.19	ft² wall area	1288	-$245	2172	-$413	3762	-$715
Rigid Insulation	R-4	R-6	$0.21	ft² exterior wall area	1018	$214	1902	$399	3762	$790
Wood Framing	2x4	2x6	$0.29	linear board ft of framing	1642	$476	2594	$752	4919	$1,427
Sill Flashing (additional)	1"	1.5"	$2.16	ft² sill flashing area	32	$69	32	$69	32	$69
				Totals	-	$514	-	$808	-	$1,571

Table 29. Residential Cool Roof Detailed Costs

					Single Story		Two Story		Multifamily	
Material	**Base Case**	**Proposed Update**	**Incremental $/Unit**	**Unit**	**Units/ Home**	**$/Home**	**Units/ Home**	**$/Home**	**Units/ Building**	**$/ Building**
Steep Slope Asphalt Shingles	ASR=0.10, TE=0.85	ASR=0.28, TE=0.85	$0.13	ft² roof area	2520	$328	1740	$226	4176	$543
Steep Slope Tile	ASR=0.10, TE=0.85	ASR=0.28, TE=0.85	$0.00	ft² roof area	2520	$0	1740	$0	4176	$0
				Average	-	$164	-	$113	-	$271

Table 30. 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		

Table 31. Nonresidential HVAC Efficiency - 40-Ton AHU Costs

Source	Cost for 9.8 EER	Cost for 11 EER	Incremental $/unit	Average Inc. $/unit	+ 25% Contractor Markup and 10% Taxes
Trane #1	$38,000	$48,000	$10,000	$6,667	$9,167
Trane #2	$48,000	$53,000	$5,000		
Norman S Wright	$38,000	$43,000	$5,000		

Table 32. Nonresidential HVAC Efficiency – 400 MBH Boiler Costs

Source	Efficiency	Price	Average $/unit
Online - Burnham Series 8H steam boiler	80-84%	$4,678	$5,407
Online - Burnham 5007B Nonresidential Atmospheric Gas-Fired Steam Boiler		$6,309	
Online - AO Smith HW-399 Conservationist Burkay		$5,531	
Online - AO Smith HW-399 Conservationist Burkay		$5,110	
Online - Lochinvar Knight XL Boiler	> 90%	$10,819	$10,828
Online - Lochinvar Knight Kbn400 High Efficiency		$9,665	
Clyde Equipment - MLX EXT 481		$12,000	
		Incremental $/unit	$5,421
		+ 25% Contractor Markup and 10% Taxes	$7,454

Table 33. Nonresidential HVAC Efficiency Detailed Costs

					Small Office		Medium Office	
Component	**Base Case**	**Proposed Update**	**Incremental $/Unit**	**Units**	**Units/ Building**	**$/ Building**	**Units/ Building**	**$/ Building**
Five SZACs 2.5 Tons Cooling Capacity 38 MBH Heating Capacity	No Economizer 13 SEER 78% AFUE	Economizer 14 SEER 90% AFUE	$1,444	SZAC	5	$7,219	-	-
Three AHUs 40 Tons Cooling Capacity	9.8 EER	11 EER	$9,167	AHU	-	-	3	$27,500
Two Boilers 400 MBH Heating Capacity	80% TE	90% TE	$7,454	Boiler	-	-	2	$14,908
			Totals		-	$7,219	-	$42,408

8. APPENDIX D – SPREADSHEET ANALYSIS ENERGY SAVINGS

The energy impact of the Outdoor LPA measure, described in Section 3.2.1, and the Proximity Sensors measure, described in Section 3.2.2, could not be calculated using CBECC-Com. TRC estimated the energy impact using spreadsheet analysis using information from the respective CASE reports.

8.1 Outdoor LPA

To determine the potential energy savings associated with this measure, TRC calculated the area of general hardscape relevant to each prototype. Using Figures 39 and 40 in the Outdoor LPA CASE report, TRC determined that there is 1 ft^2 of general hardscape for each 1 ft^2 of office conditioned floor area. [26] Since the measure applies to several lighting zones, all of which could be included in the City of Palo Alto, Table 15 from the CASE report was used to estimate the likely construction activity within the respective lighting zones. Tables 24 and 25 from the CASE report provide the effective lighting power density impacts and energy impacts per square foot of general hardscape. The 15-year factor of 0.089 was used to convert from TDV dollars to TDV kBtu.

All of this information was used to arrive at the estimates provided in Table 34, and validated by the lead author of the Outdoor LPA CASE report.[27] For simplicity, not all of the steps necessary to determine the standard and proposed TDV savings are presented. It is important to note the highlighted cell containing the weighted average 9.8 TDV kBtu/ft^2-yr is the value used in Table 4 to determine the TDV energy usage of the prototypes, including outdoor lighting.

[26] TRC Energy Services and Clanton & Associates (December 2014) Nonresidential Outdoor Lighting Power Allowance Codes and Standards Enhancement Initiative. California Utilities Statewide Codes and Standards Team. Available at: http://www.energy.ca.gov/title24/2016standards/prerulemaking/documents/2014-06-24_workshop/final_case_reports/2016_T24_CASE_Report-Outdoor_LPA-Dec_2014-V3.pdf

[27] Communication with Michael Mutmansky (TRC Energy Services). January 2015.

Table 34. Nonresidential Outdoor Lighting TDV Energy Savings

Source	Item	1	2	3	4	Total
Table 15 of CASE report	% Construction	0.1%	10%	90%	0.0%	
Table 24 of CASE report	2013 LPA (W/ft^2)	0.056	0.080	0.139	0.183	
	2016 LPA (W/ft^2)	0.037	0.053	0.068	0.089	
Calculation	Power Reduction (W/ft^2)	0.019	0.026	0.072	0.094	
	% Reduction	34%	33%	52%	51%	
	Weighted % Reduction	0%	3%	47%	0%	50%
Table 25 of CASE report	TDV \$/ft^2 Savings	0.130	0.170	0.470	0.620	
Calculation	Weighted Standard TDV kBtu/ft^2-yr	0.0043	0.5819	9.1759	0.0000	9.8
	Weighted Proposed TDV kBtu/ft^2-yr	0.0028	0.3928	4.4229	0.0000	4.8
	Weighted Savings TDV kBtu/ft^2-yr	0.0015	0.1891	4.7530	0.0000	4.9

8.2 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 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-daylighted 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%. The summary of findings is provided in Table 35.

[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

Table 35. 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*	$1,732*	$14,596*
TDV kBtu Savings*	19,458*	164,004*
Percent Savings	1.9%	2.6%

* Accounting for overlap with potential daylight sensor savings.

9. APPENDIX E – REACH CODE PRESCRIPTIVE WALLS PATH

During the drafting of this study, the Reach Code ordinance included the residential walls measure as a prescriptive path (as an alternative to the performance path). The CEC's proposed revisions to the 2016 Title 24 code, released in early March 2015, includes a wall U-factor of 0.051 in climate zone 4.[29] TRC recommends that Palo Alto's prescriptive U-factor requirement for walls be 0.051 in order to align with the CEC's revisions, rather than 0.048 as per the measure included in the compliance packages. Aligning the 2013 Reach Code with the 2016 Standards will serve to better prepare the Palo Alto regional building industry of future statewide changes. (This change would have no bearing on the results and recommendations from the 15% residential package in the body of the report, as that package was shown to be cost effective).

The primary difference between a U-0.051 wall assembly and a U-0.048 wall assembly described in the body of the report is that the exterior insulation can be R-5 rather than R-6. R-5 insulation is slightly less expensive than R-6 insulation, and is also manufactured in 1" thickness, which negates the incremental costs necessary for additional sill flashing at wall openings. These two changes are reflected in the incremental costs for a U-0.051 wall presented in Table 36.

Table 36. Incremental Costs of U-0.051 Residential Walls

Component/Material	Base Case	Proposed Update	1-story	2-story	Multifamily
Batt Insulation	R-15	R-19	-$245	-$413	-$715
Rigid Insulation	R-4	R-5	$153	$285	$564
Wood Framing	2x4	2x6	$476	$752	$1,427
Sill Flashing	1"	1"	$0	$0	$0
Total Incremental Costs			$384	$625	$1,276
Average Incremental Costs			$505		-

Table 37 shows that U-0.051 residential walls are cost effective as a standalone measure for both single family and multifamily new construction buildings, and acceptable to pursue as a prescriptive measure in the Reach Code.

Table 37. Cost Effectiveness of U-0.051 Residential Walls

Residential U-0.051 Walls					
Measure	**TDV kBTU/ft²**	**% Above Title 24**	**Present Value of Energy Savings**	**Cost**	**Benefit to Cost Ratio**
Single Family	30	4.5%	$726	$505	1.4
Multifamily	43	2.5%	$1,349	$1,276	1.1

[29] Proposed Revisions to the California Building Energy Efficiency Standards. 45-Day Language. Available at: http://www.energy.ca.gov/title24/2016standards/rulemaking/documents/express_terms/01_2016%20T24%20Standards%20Parts%201%20and%206%20-%2045%20Day%20Language.pdf

For a diagram of wall assemblies and associated U-factors, please refer to the CEC's 2013 Joint Appendices, section JA4.3 – Walls, reproduced in Figure 3.

Table 4.3.1 – U-factors of Wood Framed Walls

Spacing	Cavity Insulation	Nominal Framing Size		Rated R-value of Continuous Insulation [2] R-0	R-2	R-4	R-5	R-6	R-7	R-8
				A	B	C	D	E	F	G
16 in. OC	None	Any	1	0.356	0.209	0.146	0.127	0.113	0.101	0.092
	R-11	2x4	2	0.110	0.088	0.074	0.068	0.064	0.060	0.056
	R-13	2x4	3	0.102	0.082	0.069	0.064	0.060	0.056	0.053
	R-15 [1]	2x4	4	0.095	0.077	0.065	0.060	0.056	0.053	0.050
	R-19	2x6	5	0.074	0.063	0.055	0.051	0.049	0.046	0.044
	R-21 [1]	2x6	6	0.069	0.059	0.051	0.048	0.046	0.043	0.041
	R-22	2x6	7	0.072	0.062	0.054	0.051	0.048	0.045	0.043
	R-19	2x8	8	0.065	0.057	0.051	0.048	0.045	0.043	0.041
	R-22	2x8	9	0.061	0.053	0.047	0.045	0.043	0.041	0.039
	R-25	2x8	10	0.057	0.050	0.044	0.042	0.040	0.038	0.037
	R-30 [1]	2x8	11	0.056	0.049	0.044	0.041	0.040	0.038	0.036
24 in. OC	None	Any	12	0.362	0.211	0.148	0.128	0.114	0.102	0.092
	R-11	2x4	13	0.106	0.086	0.072	0.067	0.062	0.059	0.055
	R-13	2x4	14	0.098	0.079	0.067	0.062	0.058	0.055	0.052
	R-15	2x4	22	0.091	0.074	0.063	0.059	0.055	0.052	0.049
	R-19	2x6	15	0.071	0.061	0.053	0.050	0.048	0.045	0.043
	R-21 [1]	2x6	16	0.066	0.057	0.050	0.047	0.045	0.042	0.040
	R-22	2x6	17	0.069	0.060	0.052	0.049	0.047	0.044	0.042
	R-19	2x8	18	0.063	0.055	0.049	0.047	0.045	0.043	0.041
	R-22	2x8	19	0.058	0.051	0.046	0.044	0.042	0.040	0.038
	R-25	2x8	20	0.055	0.048	0.043	0.041	0.039	0.037	0.036
	R-30 [1]	2x8	21	0.054	0.047	0.042	0.040	0.038	0.037	0.035

Notes

1. Higher density fiberglass batt is required in these cases.
2. Continuous insulation may be installed on either the inside or the exterior of the wall, or both.

Figure 3. JA4 – U-factors of Wood Framed Walls (courtesy of CEC)