Association of Bay Area Governments: Bay Area Regional Energy Network (BayREN)

Cost Effectiveness Analysis Title 24 2013 Reach Code Single Family Residential

Climate Zone 3

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1 Summary

This report presents the results of a supporting energy savings and cost-effectiveness analysis conducted for low-rise residential buildings in the San Francisco Bay Area, Climate Zone 3 under the Bay Area Regional Energy Network (BayREN) Codes and Standards Program.

For new single family residential projects in climate zone 3, 15% energy budget savings against the base code appears to be cost effective.

The purpose of this analysis is to demonstrate cost-effectiveness for single-family low-rise residential building permit applicants to exceed a performance level equivalent to the 2013 California Building Energy Efficiency Standards, also known as Title 24 Part 6 ("Title 24 2013"), by 15%. A 15% performance target aligns with Tier 1 of the Energy Efficiency Performance Standard for Residential Voluntary Measures for the 2013 California Green Building Standards Title 24 Part 11 ("CALGreen") Section A4.203.

In addition to the performance target, the Tiers include a set of prerequisites, such as lighting measures and quality insulation installation (QII), that are required if a jurisdiction elects to keep them as prerequisites at the time of adoption. This report, therefore, includes those prescriptive requirements of the Tiers (found in section A4.203.1.1) as listed in the summary tables.

This report is for new construction only and is not applicable to additions and alterations building renovation projects, which are found under code section A4.204 of CALGreen.

The result of this analysis is a list of cost-effective energy savings and energy generation measures that can be implemented on a performance basis to achieve these targets. This list is not an endorsement of any particular energy efficiency measure, nor is it necessary that the list be followed prescriptively to achieve energy savings against the baseline.

This report is intended to be included in applications to the California Energy Commission (CEC) for a Local Energy Ordinance. It is intended to meet the requirements specified in Section 10-106 of the Title 24, Part 6: Locally Adopted Energy Standards, for "findings and supporting analyses on the energy savings and cost effectiveness of the proposed energy standards."

2 Costs and Savings Analysis

2.1 Base Building Models

We performed a comparative analysis of energy savings and costs for measures using a representative single-family building energy prototype. The baseline prototype is compliant with Title 24 Part 6 2013. Values from this analysis are found in Table 1 under the section titled "Measures Analyzed for Code Compliance." Key building characteristics are described in Appendix A1.

2.2 Methods and Assumptions

Energy savings data was developed using energy modeling with an adapted meta-analysis version of EnergyPlus, the IOU "ZNE Tool", and the results in the report *The Technical Feasibility of Zero Net Energy Buildings in California* (the "ZNE Report"). ZNE Tool and Report results were cross-verified against results from Codes and Standards Enhancement (CASE) research done for the 2013 and 2016 code cycles. Energy savings were estimated for a set of sample measures for each model, in both real energy terms and in terms of the CEC approved 2013 Reach Time Dependent Value energy (Reach TDV)[1]. Where energy savings results differed significantly between these sources, the lower result was chosen in order to provide a conservative approach; where results did not differ significantly the average results is reported. All energy and cost savings were scaled to a per-square-foot basis.

Incremental first cost data was developed from existing CASE reports done for the 2013 and 2016 code cycles, and from RS Means where CASE data was not available. Cost data was scaled to a per-square-foot basis.

Detailed measure descriptions, and source energy savings and cost data, are described in Appendix A2.

Key notes and assumptions are as follows:

- The following measures were either not analyzed or not totaled towards savings as they do not apply towards compliance under the Title 24 performance compliance path. They are presented in Table 1 (titled "Additional Measures Analyzed") as possible prescriptive measures that can be implemented under a reach code path.
    - Plug load or electrical equipment measure upgrades, and water use upgrades, were analyzed but are not counted towards the performance compliance rating, as they are not regulated by the Title 24 performance compliance method (Alternative Calculation Method "ACM") at this time.
    - Lighting upgrades were analyzed but are not counted towards the performance compliance rating, as they are not regulated by the Title 24 residential performance compliance method (ACM) at this time.
        - High efficacy lighting was analyzed in consideration of CALGreen Section A4.203.1.1.3 provision.
    - HVAC equipment rated efficiency improvements (for furnaces, packaged and split AC units, chillers, boilers, water heaters) were not analyzed, as they are regulated by the U.S. Department of Energy and Title 20 and preempted from local regulation.

[1] Reach TDV are a set of TDV scalars intended for use in reach code analysis specifically. Used as defined in http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/general_cec_documents/Title24_2013_TDV_Methodology_Report_23Feb2011.pdf

- Reach Time-dependent valuation of savings (Reach TDV) provided using the CEC approved 2013 Reach TDV numbers. All percent savings targets are based on Reach TDV.
- The cost-benefit calculation evaluated energy savings against incremental first costs of measures. Replacement costs and maintenance costs not considered.
- Savings provided in terms of standard TDV kBtu were translated to Reach TDV kBtu and reach TDV dollars ($) via standard multipliers provided as a part of the TDV development. See Appendix A2.

3 Results

3.1 Single Family Residence

Table 1 shows the cost-effective and feasible energy savings measures beyond code that could be implemented for performance compliance in the single-family residence prototype in Climate Zone 3.

The table also lists, for interest, additional measures analyzed that were either found not cost-effective or are uncovered under performance code compliance.

Percent savings are based off of a building code compliance baseline energy consumption of 127,970 Reach TDV kbtu. The code compliance baseline excludes plug load and lighting energy, as these are not covered by performance compliance in the residential code. However they provide insight into the areas in which total energy use in buildings are expected to be reduced by designing with more energy conserving features in the building. This can help guide possible measure-specific reach codes.

Total whole building baseline energy consumption including all end-uses totaled 238,208 Reach TDV kbtu.

Baseline energy consumption is reported for the building prototype developed by the IOU ZNE Tool and presented in the report “The Technical Feasibility of Zero Net Energy Buildings in California”.

Table 1: Single-Family Residence Energy Results

Prescriptive Measure List Description	Lifecycle Savings			First Costs	Lifecycle Benefit : Cost Ratio
	Reach TDV kbtu	Reach TDV %	Reach TDV $ / sq. ft.	$ / sq. ft.	
Measures Analyzed for Code Compliance					
Improved Wall Insulation From R-15 w/R-4ci on 2x4, to R-21 w/R-4ci on 2x6 (w/o QII: 70% of maximum savings)[2]	2,143	1.7%	$0.18	$0.19	0.9
DHW Heater Tankless 40 gal Gas Storage to Gas Tankless Instantaneous (Federal Minimum equivalent of 0.62 EF to 074 EF equivalent) [3]	4,256	3.3%	$0.32	$0.29	1.1
HVAC Technology Change PTAC to Heat Pump (11.0 SEER, 9.5 EER, 2.9 COP)	6,942	5.4%	$1.00	$0.57	1.7
Ducts in conditioned space	1,522	1.2%	$0.13	$0.46	0.3
QII (Quality Insulation Inspection)[4] Brings savings from wall and ceiling insulation up to 100%[5]	1,247	1.0%	$0.10	$0.35	0.3
Reduced Infiltration: 5 ACH50 to 3 ACH50	5,326	4.2%	$0.44	$0.32	1.4
Total Savings for Title 24 Part 6 Energy Budget Compliance	21,435	16.8%	$2.16	$2.18	1.0
Code Compliance Baseline	127,970	-	$10.55	-	-
Additional Measures Analyzed					
Showerheads 2.5 to 1.8 GPM	1,486	-	$0.12	$0.01	9.8
Kitchen Sinks 2.2 to 1.8 GPM	2,676	-	$0.22	$0.48	0.5
All Building LED High-Efficacy Lighting[6] Equivalent to upgrade from 55 lm/W to 75 lm/W	3,629	-	$0.30	$0.02	16.9
Plug Load Controls One major home circuit on a timer to shut off major standby/vampire loads at night, midnight-6am, daily	3,511	-	$0.29	$0.27	1.1
Ceiling Insulation From R-30 to R-38 blown-in insulation w/Raised Heel Trusses (w/o QII: (96-0.347*R)% of maximum savings)[7]	2,400	-	$0.17	$0.68	0.3
Solar Domestic Water Heating: Solar Savings Fraction 50%, Gas Water Heater	10,534	-	$0.87	$2.81	0.3
Whole Building Savings	45,672	-	$4.13	$6.45	-
Whole Building Baseline	238,208	-	$19.65	-	-

[2] CASE report for *Residential High Performance Walls and QII*
[3] Using updated Federal standards for small water heaters effective starting April 16, 2015.
[4] Per CALGreen Section A4.203.1.1.2.
[5] Title 24 Residential Reference ACM, section 2.2.6
[6] Per CALGreen Section A4.203.1.1.3.
[7] Title 24 Residential Reference ACM, section 2.2.6

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References

Arup. The Technical Feasibility of Zero Net Energy Buildings in California. Prepared for Pacific Gas and Electric Company. December 31, 2012. http://www.energydataweb.com/cpucFiles/pdaDocs/904/California_ZNE_Technical_Feasibility_Report_Final.pdf

California Energy Commission. Title 24 Residential Alternative Calculation Method (ACM) Reference Manual 2013. June 2013. http://www.energy.ca.gov/2013publications/CEC-400-2013-003/CEC-400-2013-003-CMF-REV.pdf

Codes and Standards Enhancement Initiative (CASE). Residential Lighting: 2013 California Building Energy Efficiency Standards California Utilities Statewide Codes and Standards Team. October 2011. http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/current/Reports/Residential/Lighting/2013_CASE_R_Residential_Lighting_Oct_2011.pdf

Codes and Standards Enhancement Initiative (CASE). Multi-Head Showers and Lower-Flow Shower Heads: 2013 California Building Energy Efficiency Standards California Utilities Statewide Codes and Standards Team. September 2011. http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/current/Reports/Residential/Water_Heating/2013_CASE_R_Shower_Heads_Sept_2011.pdf

Codes and Standards Enhancement Initiative (CASE). Residential High Performance Walls and QII: 2016 California Building Energy Efficiency Standards California Utilities Statewide Codes and Standards Team. September 2014. http://title24stakeholders.com/wp-content/uploads/2014/10/2016-T24-CASE-Report-High-Perf-Walls-Sep2014.pdf

Codes and Standards Enhancement Initiative (CASE). Residential Ducts in Conditioned Space / High Performance Attics: 2016 California Building Energy Efficiency Standards California Utilities Statewide Codes and Standards Team. October 2014. http://title24stakeholders.com/wp-content/uploads/2014/10/2016-T24-CASE-Report-HPA-DCS-Oct2014.pdf

Codes and Standards Enhancement Initiative (CASE). Residential Instantaneous Water Heaters: 2016 California Building Energy Efficiency Standards California Utilities Statewide Codes and Standards Team. September 2014. http://title24stakeholders.com/wp-content/uploads/2014/10/2016-T24-CASE-Report-HPA-DCS-Oct2014.pdf

Codes and Standards Enhancement Initiative (CASE). Residential Plug-load Controls: 2013 California Building Energy Efficiency Standards California Utilities Statewide Codes and Standards Team. October 2011. http://www.energy.ca.gov/title24/2013standards/prerulemaking/docum

ents/current/Reports/Residential/Lighting/2013_CASE_PowerDist2_ResPlugLoads_10.7.2011.pdf

Codes and Standards Enhancement Initiative (CASE). Residential Roof Envelope Measures: 2013 California Building Energy Efficiency Standards California Utilities Statewide Codes and Standards Team. October 2011. http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/current/Reports/Residential/Envelope/2013_CASE_R_Roof_Measures_Oct_2011.pdf

Codes and Standards Enhancement Initiative (CASE). Solar Water Heating – Residential and Specialty Commercial. 2013 California Building Energy Efficiency Standards California Utilities Statewide Codes and Standards Team. October 2011. http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/current/Reports/Residential/Water_Heating/2013_CASE_Res_Comm_SolarHotWater_10.28.2011.pdf

Database for Energy Efficient Resources (DEER). California Public Utilities Commission. Accessed October 2014. http://www.deeresources.com/

Energy + Environmental Economics (E3). Time Dependent Valuation of Energy for Developing Building Efficiency Standards 2013 Time Dependent Valuation (TDV) Data Sources and Inputs. February 2011. http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/general_cec_documents/Title24_2013_TDV_Methodology_Report_23Feb2011.pdf

National Renewable Energy Laboratory (NREL). National Residential Efficiency Measures Database. Accessed October 2014. http://www.nrel.gov/ap/retrofits/measures.cfm

RS Means Online. Accessed October and November 2014. www.rsmeansonline.com

A1 Baseline Building Models

Representative Baseline Building for Energy Reach Code Analysis.

Table 2: Prototype Building Characteristics

Representative Single-Family Baseline Building	
Conditioned Floor Area	2,100 sq. ft.
Number of Levels	1
Ceiling	2,100 sq. ft., vented attic R-30 insulation
Walls	2'x 4', 16" o.c., R-15 w/R-4 rigid c.i. U = 0.065
Windows	20 % WWR 0.32 U-factor
DHW System	Gas Water Heater w/ 40 gal tank 0.62 EF
Heating System	Gas-Fired Furnace, 0.80 EF
Cooling System	DX PTAC (11.0 SEER, 9.5 EER, 2.9 COP)
Interior Lighting Power Density (LPD)	High-efficacy lighting mandatory in many spaces per Title 24 Dimming or vacancy sensor mandatory in many spaces per Title24
Exterior Lighting Power Density (LPD)	None
Code Compliance Total EUI (kbtu / sq. ft.) (excl. plug loads & lighting)	18.9
Total EUI (kbtu / sq. ft.)	35.1

A2 Measure References and Data

The following tables contain the measure savings and costs references, and notes, to detail how measure results were developed.

Table 3: Measure Data References

Measure	**Data Sources**
Improved Wall Insulation From R-15 w/R-4ci on 2x4, to R-21 w/R-4ci on 2x6 (w/o QII: 70% of maximum savings)	• Savings directly from the ZNE Report, and directly from the CASE report for *Residential High Performance Walls and QII* • Costs directly from the same CASE report
DHW Heater Tankless 40 gal Gas Storage to Gas Tankless Instantaneous	• Savings from the IOU ZNE Tool, and directly from the CASE report for *Residential Instantaneous Water Heaters* • Costs directly from the same CASE reports

(Federal Minimum equivalent of 0.62 EF to 0.74 EF equivalent)	
HVAC Technology Change PTAC to Heat Pump (11.0 SEER, 9.5 EER, 2.9 COP)	• Savings from the IOU ZNE Tool • Costs developed from RS Means Online for 5 ton cooling unit
QII (Quality Insulation Inspection) Brings savings from wall and ceiling insulation up to 100%	• Savings from the IOU ZNE Tool, and calculated from wall and ceiling insulation savings calculations per Residential ACM method • Costs developed from the CASE report for *Residential High Performance Walls and QII*
Reduced Infiltration: 5 ACH50 to 3 ACH50	• Savings directly from the ZNE Report • Costs from NREL's National Residential Efficiency Measures Database
Showerheads 2.5 to 1.8 GPM	• Savings from the IOU ZNE Tool, and calculated from the CASE report for *Multi-Head Showers and Lower-Flow Shower Heads* (linear interpolation between GPMs provided from annual energy consumption data) • Costs from the DEER database
Kitchen Sinks 2.2 to 1.8 GPM	• Savings from the IOU ZNE Tool, and calculated from the CASE report for *Multi-Head Showers and Lower-Flow Shower Heads* (linear interpolation between GPMs provided from annual energy consumption data, assuming half the usage time of showerheads) • Costs from the DEER database
All Building LED High-Efficacy Lighting Equivalent to upgrade from 55 lm/W to 75 lm/W	• Savings from the IOU ZNE Tool, and calculated from the CASE report for *Residential Lighting* (CASE report reliant calculations developed based on CASE reported average daily hours of use, average room type quantities, average permanently installed Watts per room type, and typical lamp and fixture types and rated efficacies) • Costs directly from the same CASE report (assuming Pin-base CFL downlight as baseline and LED downlight as proposed lamp type)
Plug Load Controls One major home circuit on a timer to shut off major standby/vampire loads midnight-6am and 10am-1pm, on weekdays	• Savings from the ZNE Report, and directly from the CASE report for *Residential Plug-load Controls* (average savings scenario") • Costs directly from the same CASE report
Ceiling Insulation From R-30 to R-38 blown-in insulation w/Raised Heel Trusses	• Savings directly from the ZNE Report, and directly from the CASE report for *Residential Roof Envelope Measures*

(w/o QII: (96-0.347*R)% of maximum savings)	• Costs directly from the same CASE report, checked against RS Means Online
Ducts in conditioned space	• Savings from the IOU ZNE Tool and from the CASE report for *Residential Ducts in Conditioned Space / High Performance Attics* • Costs directly from the same CASE report
Solar Water Heating: SSF 50%	• Savings from the IOU ZNE Tool, and the CBECC-Residential 2013 software assuming a standard single-family default model and default gas storage water heater with 60% efficiency. CASE report *Solar Water Heating – Residential and Specialty Commercial* reviewed but not used due to CASE analysis use of electric water heat for analysis baseline. • Costs directly from the same CASE report and checked against RS Means Online

Table 4: TDV PV Adjustment Factors

	(2013 $/TDVkBtu)	**(2008 $/TDVkBtu)**
Non-Res (15-yr)	$ 0.089	$ 0.084
Non-Res (30-yr)	$0.154	$ 0.146
Res (30-yr)	$ 0.173	$ 0.164

Convert TDV kBtu to TDV $.

Table 5: Average TDV Scalars

	2013 Reach	**2013**	**2008**
TDV kbtu/therm	203.09	159.51	148.12
TDV kbtu/kWh	27.3	21.26	13.95

Approximately convert standard therms and kWh to TDV kBtu; averages of the annual 8760 scalar values.

Table 6: Reach TDV Multipliers

	Electricity	**Gas**	**Propane**
Non-Res (15-yr)	1.253	1.375	1.197
Non-Res (30-yr)	1.27	1.354	1.182
Res (30-yr)	1.259	1.331	1.152

Convert standard TDV to reach TDV.