CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE)

Increased Wall Insulation

2013 California Building Energy Efficiency Standards

California Utilities Statewide Codes and Standards Team September 2011

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1. Purpose

The California Building Energy Efficiency Standards prescriptive U-factors for residential walls have not been adjusted since the 1992 code change. The purpose of this CASE report is to show the potential energy savings and benefits of increasing the prescriptive standards for wall insulation in residential wood-framed walls in the 2013 California Building Energy Efficiency Standards, and to propose expansion of the JA4 tables to include better performing insulation products that may be used with both conventional and advanced framing techniques.

2. Overview

<table>
<tr><td>a. Measure Title</td><td>Increased Wall Insulation</td></tr>
<tr><td>b. Description</td><td>The proposed measure will apply new prescriptive wall insulation requirements to all new low-rise residential buildings in all climate zones.</td></tr>
<tr><td>c. Type of Change</td><td>The proposed measure will decrease the U-factor for residential wall assemblies in Package D. It will set new prescriptive requirements in each climate zone and adjust the standard home that residential buildings using the performance approach are measured against. The proposed prescriptive standards are as follows:
<table>
<tr><th>Climate Zone</th><th>Maximum U-Factor</th></tr>
<tr><td>1, 11, 12, 14, 16</td><td>0.049</td></tr>
<tr><td>2-5, 9, 10</td><td>0.053</td></tr>
<tr><td>6-8</td><td>0.071</td></tr>
<tr><td>13, 15</td><td>0.045</td></tr>
</table>
In addition, JA4 tables for wood framed walls would be revised to include a larger range of insulation products and R-values listed as compliance options. Proposed 2013 JA4 tables are in section 5.2 of this report.
The proposed change does not modify or expand the scope of the Standards, but require modification of standards Table 151-C, and JA4 table 4.3.1. </td></tr>
</table>

d. Energy Benefits	The proposed measures for each climate zone will save from approximately 29 kWh per home in climate zone 7, up to 625 kWh in climate zone 15, and up to 0.53 kW (climate zone 13). Gas savings estimates range from 9 Therms in climate zone 15, up to 95 Therms in climate zone 2. These saving estimates are based on energy simulation runs using CALRES (MICROPAS 2013 r11), using the 2700 square foot Prototype D home with a 2008 Package D compliant home as the base case in each climate zone. The table below summarizes the energy savings from the proposed measures for each climate zone.

Wall Assembly Measure Name	Electricity Savings (kwh/yr)	Demand Savings (kw)	Natural Gas Savings (Therms/yr)	TDV Elec. Savings (million kBtu)	TDV Gas Savings (million kBtu)
CZ 01: 0.049 U-factor	71	0.00	57	1.30	9.56
CZ 02: 0.053 U-factor	195	0.14	95	8.18	16.69
CZ 03: 0.053 U-factor	84	0.01	73	2.10	13.04
CZ 04: 0.053 U-factor	185	0.16	80	7.50	14.26
CZ 05: 0.053 U-factor	111	0.00	90	2.08	15.61
CZ 06: 0.071 U-factor	58	0.06	26	2.65	4.70
CZ 07: 0.071 U-factor	29	0.04	11	1.81	1.90
CZ 08: 0.071 U-factor	95	0.12	20	4.64	3.70
CZ 09: 0.053 U-factor	245	0.29	44	11.75	7.86
CZ 10: 0.053 U-factor	293	0.40	50	14.58	9.02
CZ 11: 0.049 U-factor	272	0.22	49	11.31	8.88
CZ 12: 0.049 U-factor	138	0.13	49	6.37	8.75
CZ 13: 0.045 U-factor	335	0.53	53	19.52	9.61
CZ 14: 0.049 U-factor	185	0.16	37	7.32	6.83
CZ 15: 0.045 U-factor	625	0.40	9	21.44	1.65
CZ 16: 0.049 U-factor	71	0.00	71	1.13	12.40

The savings from this measure results in the following statewide first year savings:

Total Electric Energy Savings (GWh)	Total Gas Energy Savings (MMtherms)	Total TDV Savings (million kBtu)
10.54	2.31	908,455

e. Non-Energy Benefits	Non-energy benefits of added insulation include thermal comfort and sound insulation.

f. Environmental Impact

The proposed measure does not have substantial adverse impacts on the environment. The proposed measure will result less lumber consumption, for homes in climates zones 1 and 11-16, where 2x6 16-inch on center framing is the assumed baseline. However, the use of 2x6 framing in place of 2x4 framing will increase the board feet of lumber for framing in homes in climate zones 2 through 10, where 2x4 framing is the baseline. Based on the distribution of forecasted new construction, this measure will yield a statewide reduction in total residential lumber use for framing by 2.12%. This equates to 7,315,086 board feet, or 10,351 tons, of lumber material saved.

The assumptions behind the wood savings calculations match 2008 base case assumptions, but may not agree with current construction practice. This is discussed further in sections 3.4 and 4.3 of this report.

The measure does not increase or decrease use of mercury, lead, copper, steel or plastic, and does not affect water consumption or quality.

Material Increase (I), Decrease (D), or No Change (NC): (All units are lbs/year)

	Mercury	Lead	Copper	Steel	Plastic	Wood
Per Prototype Home	NA	NA	NA	NA	NA	(D) 20,707,693

Water Consumption:

	On-Site (Not at the Powerplant) Water Savings (or Increase) (Gallons/Year)
Per Prototype Home	NA

Water Quality Impacts:

	Mineralization (calcium, boron, and salts	Algae or Bacterial Buildup	Corrosives as a Result of PH Change	Others
Impact (I, D, or NC)	NA	NA	NA	NA

g. Technology Measures	The proposed measure will encourage the use of continuous exterior insulation on residential wall assemblies. One-Coat Stucco systems and External Insulation and Finishing Systems (EIFS) are two examples that are readily available for use, in residential construction. **Measure Availability:** Though it is not the base case assumption, many contractors currently use a One-Coat Stucco System to comply with 2008 Standards. The necessary products are therefore readily available in California, and the industry has the ability to supply materials in response to the proposed Standards change. One-Coat Stucco and/or EIFS products are available from the following distributors in California: ABC Supply Company, Inc. Allied Building Products AMS - Acoustical Material Services CALPLY Cal-Wal Gypsum Supply Great Western Building Materials Gypsum Drywall Supply Eagle Building Materials El Camino Building Supply Expo Stucco Parex USA, Inc. Redding Drywall and Stucco Sacramento Stucco Co. Sierra Building Materials Starr Building Supply Surface FX Westside Building Materials Wright Brothers Supply **Useful Life, Persistence, and Maintenance:** One-Coat Stucco and EIFS are low maintenance. Unlike cement stucco, synthetic stucco is unlikely to crack with building expansion or settling. Homes coated with synthetic stucco rarely need painting because the color is mixed in to the synthetic coating, and is fade resistant. Periodic maintenance includes checking all flashing and sealing to ensure that the building envelope remains watertight.[1] The energy savings related to insulation installation will persist for the lifetime of the building, assuming no change is made to the wall assembly.

[1]www.eima.com/abouteifs/maintenance/

h. Performance Verification of the Proposed Measure	This measure would require visual inspection by a building inspector to ensure that the wall assembly constructed, including framing spacing, wall cavity insulation value, and external insulation value is in compliance, or matches the performance run in the compliance software. Because visual inspections are standard practice prior to installation of drywall (for cavity insulation) and again at final inspection (f0r external insulation), there is no added cost burden for inspections for this measure.

i. Cost Effectiveness

The proposed change is cost effective using life cycle costing (LCC) methodology for the prototype building where the measure is installed. All materials needed to construct wall assemblies to meet the proposed standard are commonly used and readily available. Therefore the post adoption cost of the measure is assumed to be consistent with the current cost of the measure.

The following table summarizes the assumptions used to derive the LCC analysis:

A	B	C	D	E	F	G
Wall Assembly Measure Name	Measure Life (Years)	Additional Costs– Current Measure Costs per Prototype Home (Relative to Basecase) ($)	Additional Cost– Post-Adoption Measure Costs (Relative to Basecase) ($)	PV of Additional Maintenance Costs (Savings) per Prototype Home (Relative to Basecase) (PV$)	PV of Energy Cost Savings – Per Proto Building (PV$)	LCC Per Prototype Home Based on Current Costs ($)
CZ 01: 0.049 U-factor	30	$168	NA	0	$1,880	($1,711)
CZ 02: 0.053 U-factor	30	$2,558	NA	0	$4,307	($1,748)
CZ 03: 0.053 U-factor	30	$2,558	NA	0	$2,623	($65)
CZ 04: 0.053 U-factor	30	$2,558	NA	0	$3,769	($1,211)
CZ 05: 0.053 U-factor	30	$2,558	NA	0	$3,063	($504)
CZ 06: 0.071 U-factor	30	$804	NA	0	$1,272	($468)
CZ 07: 0.071 U-factor	30	$804	NA	0	$641	$163[1]
CZ 08: 0.071 U-factor	30	$804	NA	0	$1,445	($641)
CZ 09: 0.053 U-factor	30	$2,558	NA	0	$3,395	($836)
CZ 10: 0.053 U-factor	30	$2,558	NA	0	$4,087	($1,529)
CZ 11: 0.049 U-factor	30	$2,243	NA	0	$3,498	($1,255)
CZ 12: 0.049 U-factor	30	$2,243	NA	0	$2,619	($376)
CZ 13: 0.045 U-factor	30	$4,657	NA	0	$5,045	($389)
CZ 14: 0.049 U-factor	30	$168	NA	0	$2,450	($2,282)
CZ 15: 0.045 U-factor	30	$2,583	NA	0	$3,998	($1,415)
CZ 16: 0.049 U-factor	30	$168	NA	0	$2,343	($2,174)

1. The measure does not meet cost-effectiveness criteria using conservative cost assumptions, but is assumed to be cost-effective. See section 4.2.2 for further justification of this proposed requirement in climate zone 7.

More detailed analysis on methodology is included in section 3.3 of this report. Costs breakdowns are included in summary in section 4.2, and in more detail in section 7.1.

j. Analysis Tools	Energy savings can be quantified using CALRES. The wall assembly library will need to include all possible combinations of the following variables: • 2x4 framing with R-13, R-15, and R-17 cavity insulation, and 2x6 framing with R-19, R-21, R-24, R-26, and R-29 cavity insulation • 16-inch, 24-inch, and advanced wall framing options • R-0, R-2, R-4, R-6, R-7, R-8, R-10, and R-14 external insulation values
k. Relationship to Other Measures	This measure does not directly impact other measures, but will have an interactive energy savings affect with other HVAC and envelope measures.

3. Methodology

This section describes the methodology and assumptions used in quantifying energy and costs savings associated with increasing the prescriptive standards for residential wall insulation in the 2013 Building Energy Efficiency Standards.

3.1 Look-up Tables: U-factor and Heat Capacity Calculations

In order to propose more efficient envelope assemblies as compliance options in the 2013 California Building Energy Efficiency Standards HMG revised the JA4 look-up tables for wood framed walls to reduce bias towards specific insulation types and include higher R-value/inch insulation products. HMG also created a new table to include advanced framing techniques as a compliance option. More information on methodology and assumptions for advanced wall framing calculations can be found in the Advanced Wall Assembly CASE Report.[2]

U-factor values for walls with each included combination of cavity and continuous insulation were calculated using EZFRAME effective U-value calculation software (CEC, V 2.0B). This approach is consistent with the parallel heat flow calculation method mentioned in the 2008 Joint Appendices for calculating U-factors for wood frame walls. HMG updated the U-factors for assemblies already existing in the 2008 JA4 table for wood-framed walls as well, for consistency in use of the parallel path method.

The modeled construction assemblies assume an exterior air film of R-0.17, a 7/8 inch layer of stucco of R-0.18, building paper of R-0.06, continuous insulation (where applicable), cavity insulation in the faming layer, ½ inch gypsum board of R-0.45, and an interior air film of R 0.68. All framing members were modeled at 1.5" in width and depths corresponding to the following nominal sizes:

2x4: 3.5"

2x6: 5.5"

2x8: 7.25"

2x10: 9.25"

2x12: 11.25"

3.2 Energy Analysis Prototypes and Assumptions

The baseline condition for this study is a home that complies with 2008 California Building Energy Efficiency Standards for Residential buildings in each climate zone. The base case wall assemblies used in this study are:

- Climate zones 2 through 10: A U-factor of 0.102 achieved with 2x4, 16-inc on center framing

[2] *Advanced Wall Assemblies: 2013 Building Energy Efficiency Standards CASE Report*. May 2011

with R-13 batt cavity insulation and a 3-coat stucco exterior finish.

- Climate zones 11 through 13: A U-factor of 0.074 achieved with 2x6, 16-inch on center framing with R-19 batt cavity wall insulation and a 3-coat stucco exterior finish
- Climate zones 1 and 14 through 16: A U-factor of 0.069 achieved with 2x6, 16-inch on center framing with R-21 high-density batt cavity wall insulation and a 3-coat stucco exterior finish

To assess the energy savings, demand costs, and environmental impacts HMG used the 2,700 square foot, two-story Prototype D building, pictured in Figure 4-11 of the 2008 Title 24 Residential ACM Manual.

	Occupancy Type (Residential, Retail, Office, etc)	Area (Square Feet)	Number of Stories	Other Notes
Prototype D	Residential	2700	2	

Projected energy savings from increased U-factor requirements for residential walls in each climate zone were estimated based on energy simulation runs performed using CALRES (MICROPAS 2013) software. The data set and energy savings include results from analysis in all sixteen (16) California climate zones.

Because the base case assumed 2x6 constructions in many climate zones, and because 24-inch on-center framing reduces materials costs over 16-inch on-center framing, while increasing energy savings, in most climate zones, the energy analysis in this study focused on 2x6 wall assemblies with 24-inch on-center framing as a target for all climate zones.

3.3 Cost Effectiveness

HMG determined cost effectiveness through collection of wall assembly costs, and use of life cycle cost methodology developed for the 2013 California Building Energy Efficiency Standards, prepared for the CEC by AEC.[3] Cost collection and LCC methodology are discussed in this section.

3.3.1 Market Pricing

Using R.S. Means cost data, HMG estimated the total cost, including materials, equipment, labor, and contractor overhead and profit of each 2x4 and 2x6 wood-framed wall assembly in JA4 Table 4.3.1. For each component in the assembly we averaged costs for similar products in representative regions across the state to find a statewide estimated cost per unit reported in R.S. Means. Cost data was collected for the following building components in the wall assembly:

[3] Architectural Energy Corporation, Life Cycle Cost Methodology 2013 California Building Energy Efficiency Standards, December 14, 2010.

- Exterior Insulation and Finishing Systems (insulation and synthetic stucco finish), or 3-coat cement stucco if no external insulation
- Weather barrier
- OSB sheathing
- Wall framing, including window buck, king studs, jack studs, rough sill, cripples, header and accessories
- Window flashing
- Cavity wall insulation
- ½-inch unfinished interior gypsum board

The per-unit costs were multiplied by the number of units in the Prototype D building to get a cost per home for each wall assembly. Gypsum board, OSB sheathing, weather barrier, and flexible window flashing were constant across all wall assemblies. Framing, flashing, cavity insulation, continuous exterior insulation and stucco costs varied by assembly. The costs per home of all wall assembly components in the proposed assembly were compared to a base case assembly cost to find the incremental cost of increasing the prescriptive requirements for insulation in residential buildings. The base case for each climate zone is described in section 3.2 of this report.

Most R.S. Means costs were reported in square feet of wall area and easily multiplied by the wall area in the Prototype D home. To estimate window flashing costs, we assumed standard window dimensions of 3 feet wide by 5 feet tall, or 15 square feet with a perimeter dimension of 16 linear feet. The prototype home includes 540 square feet of glazing, distributed equally among four orientations. Using the standard window dimension of 3 feet by 5 feet, the prototype building has 576 linear feet of total window perimeter that must be flashed, and 108 linear feet of window sill and 108 of window header that require additional metal flashing.

Though cavity insulation values can be reached with multiple types of insulation, the assumed insulation types for the purposes of this study are shown in Figure 1 below.

Nominal Framing Size	Cavity Insulation R-value	
2x4	R-11	R-11 batt
2x4	R-13	R-13 batt
2x4	R-15	R-15 batt
2x4	R-17	3" med-density foam
2x6	R-19	R-19 batt
2x6	R-21[3]	R-21 batt
2x6	R-24[5]	2" med-density foam, plus R-13 batt
2x6	R-26[5]	2" med-density foam, plus R-15 batt
2x6	R-29[5]	5" closed cell

Figure 1: Cavity Insulation Type Assumptions

A few cavity insulation costs were not available in R.S. Means. For high density R-15 and R-21 batt insulation, we assumed $0.13 per R-value per square foot. This figure is based on sampling of building material supply companies. For flash and batt insulation, we added the cost of two inches of medium density foam and the cost of batt insulation.

Metal flashing costs also were not available in R.S. Means. HMG used sheet metal window casing costs, in square feet, and estimated the amount of square feet of sheet metal needed for a 3-foot window sill and 3-foot header at varying wall thickness.

One-Coat Stucco costs and EIFS costs for an R-4 (1-inch EPS) cladding system in R.S. Means were inconsistent with cost estimates reported by practicing contractors. Contractors consulted reported a 20-25 percent reduction in the cost of One-Coat Stucco systems over traditional cement stucco, due to reduced labor costs. For the cost analysis of this measure, we assumed 20% reduction in cost from a three-coat cement stucco system. One contractor quoted $3.50 to $5.00 per square foot for One-Coat Stucco System materials and installation, which is significantly lower than our assumed cost of $7.07 per square foot. The cost estimates therefore err on the high side, yielding a more conservative life cycle cost calculation to prove cost effectiveness.

All materials for which costs were collected as part of this analysis are readily available and common in residential construction. Therefore no cost reduction is predicted with this measure over time.

3.3.2 Maintenance Costs

Maintenance costs for synthetic stucco systems are negligible and generally less than three-coat stucco, used in the base case assumptions, if installed correctly. Because the saved maintenance cost is not substantial or easily quantified, a maintenance cost of zero, when compared to base case, was used in the LCC calculations.

3.3.3 Lifecycle Cost (LCC) Analysis

HMG calculated lifecycle cost analysis using methodology explained in the California Energy Commission report Life Cycle Cost Methodology 2013 California Building Energy Efficiency Standards, written by Architectural Energy Corporation, using the following equation:

$$\Delta LCC = \text{Cost Premium} - \text{Present Value of Energy Savings}$$

$$\Delta LCC = \Delta C - (PVTDV\text{-}E * \Delta TDVE + PVTDV\text{-}G * \Delta TDVG)$$

Where:

- ΔLCC change in life-cycle cost
- ΔC cost premium associated with the measure, relative to the basecase
- PVTDV-E present value of a TDV unit of electricity
- PVTDV-G present value of a TDV unit of gas
- ΔTDVE TDV of electricity
- ΔTDVG TDV of gas

We used a 30-year lifecycle as per the LCC methodology for all residential measures.

LCC calculations were completed for each wall assembly in all sixteen (16) climate zones.

3.4 Environmental Impact

Stakeholder feedback from CASE workshops indicated a concern within the building industry that deviation from framing practices used for compliance with the 2008 Building Energy Efficiency Standards may have a negative environmental impact in terms of deforestation and wood waste. HMG conducted literature review and interviews with the National Research Defense Council to define the environmental impact of increased insulation requirements.

HMG also calculated the change in board feet of lumber needed to build a home meeting the proposed wall insulation requirements, as compared to the 2008 base case. The assumptions used in this calculation match those used in the energy analysis and include:

- 2700 square foot prototype D home
- Base case (2008) framing assumptions:

  2x4 framing in climate zones 2 through 10

  2x6 framing (to accommodate R-19 or R-21 cavity insulation) in climate zones 1 and 11-16

Builders have the option of meeting the 2008 prescriptive u-factor requirements, which assume 2x6 construction and R-19 or R-21 cavity wall insulation with 2x4 framing, R-13 cavity insulation, and R-4 external insulation. This base case was also researched. Findings are reported in section 4.3.

3.5 Statewide Savings Estimates

The statewide energy savings associated with the proposed measures will be calculated by multiplying the per unit estimate with the statewide estimate of new construction in 2014. Details on the method and data source of the residential construction forecast are in 7.3.

4. Analysis and Results

This section describes the analysis and results on which the 2013 code change recommendations for residential wall insulation in this report are based.

4.1 Energy Analysis

This section summarizes the energy analysis results. Methodology and assumptions used in the energy analysis are in section 3.2 of this report.

The Figure 2 summarizes the kTDV savings expected over 2008 baseline with each 2x6 wall assembly, 24-inches on-center, with R-0, R-4, or R-8 external insulation, in each climate zone. The highlighted cells indicate the proposed prescriptive standard in each climate zone. The values in the table are from initial energy simulation runs performed to see relative savings of different insulation combinations in each climate zone.

Exterior Insulation	**R-0**				**R-4**				**R-8**			
Cavity Insulation	**R-19**	**R-21**	**R-24**	**R-26**	**R-19**	**R-21**	**R-24**	**R-26**	**R-19**	**R-21**	**R-24**	**R-26**
U-factor	0.071	0.066	0.062	0.060	0.053	0.049	0.046	0.045	0.043	0.040	0.038	0.037
CZ 01		0.41	1.42	1.99		4.18	4.78	5.17		6.24	6.68	6.95
CZ 02	5.89	6.64	7.54	8.05	9.45	9.91	10.49	10.84	11.35	11.68	12.09	12.33
CZ 03	3.69	4.13	4.64	4.92	5.76	6.03	6.33	6.51	6.76	6.92	7.07	7.20
CZ 04	5.26	5.90	6.67	7.12	8.26	8.66	9.17	9.46	9.81	10.09	10.44	10.66
CZ 05	4.15	4.67	5.31	5.68	6.71	7.05	7.46	7.71	8.13	8.36	8.65	8.83
CZ 06	2.83	3.15	3.51	3.71	4.20	4.37	4.60	4.73	4.81	4.92	5.07	5.16
CZ 07	1.41	1.55	1.69	1.77	1.98	2.05	2.12	2.16	2.15	2.20	2.24	2.26
CZ 08	3.22	3.60	4.03	4.28	4.86	5.08	5.35	5.50	5.61	5.75	5.94	6.05
CZ 09	4.75	5.36	6.07	6.47	7.40	7.76	8.28	8.53	8.80	9.07	9.43	9.61
CZ 10	5.78	6.52	7.40	7.90	8.97	9.43	10.67	10.99	11.32	11.63	12.06	12.29
CZ 11	0.39	1.65	3.15	3.97	6.13	6.92	7.95	8.50	9.27	9.82	10.55	10.96
CZ 12	0.24	1.21	2.33	2.97	4.56	5.16	5.91	6.33	6.91	7.32	7.85	8.17
CZ 13	0.38	1.58	3.00	3.81	8.16	8.92	9.95	10.44	11.15	11.68	12.42	12.81
CZ 14		0.37	1.82	2.65		5.47	6.44	6.99		8.27	8.97	9.36
CZ 15		0.59	2.30	3.27		6.86	8.18	8.81		10.31	11.28	11.75
CZ 16		0.40	1.67	2.40		5.20	6.01	6.49		7.74	8.30	8.65

Figure 2: kTDV per Sq. Ft. Savings for Increased Wall Insulation with 24-inch o.c. Framing

The savings for the selected requirements, highlighted in the table were refined through subsequent simulation runs, and influenced the final life-cycle cost values shown in Figure 5.

The graph in Figure 3 illustrates the steep climb in energy savings as the U-factor decreases in the more extreme climate zones (1, and 11-16). The baseline for these climate zones is R-19 in 11 through 13 and R-21 in 1 and 14 through 16, as compared to the baseline R-13 in climate zones 2 through 10. Climate zone 7 stands apart from all other climate zones with a much lower and flatter increase in energy savings as the U-factor decreases.

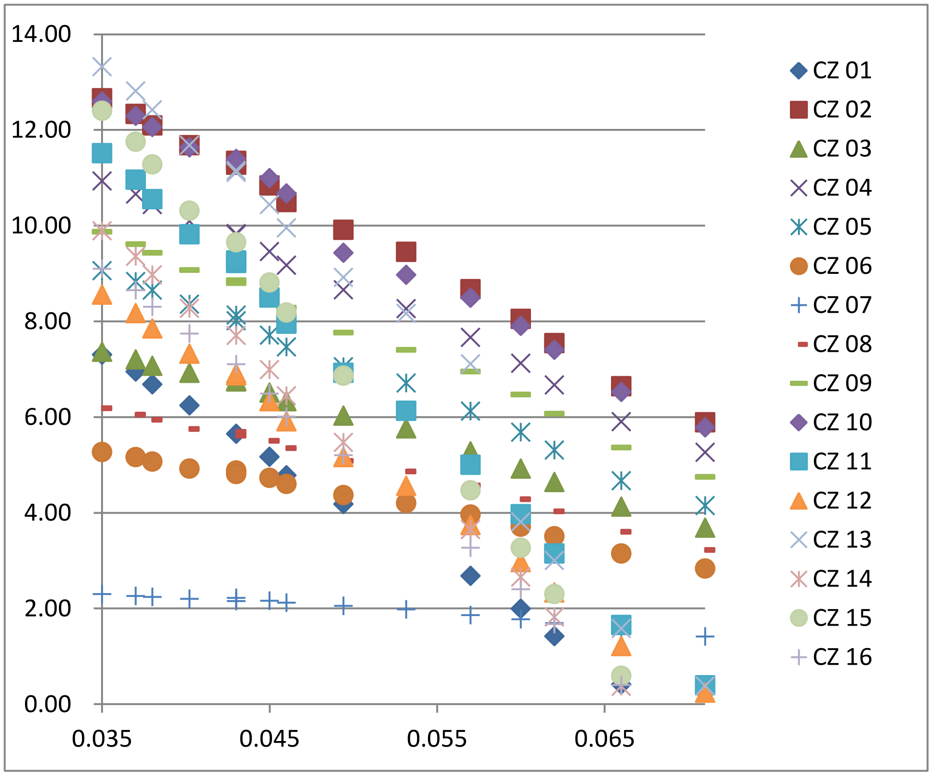

Figure 3: U-factor vs. kTDV/Sq. ft. Savings

In the milder climate zones, such as climate zone 7, the energy savings was higher for 16-inch on-center framing. This is likely due to a decrease in thermal mass and most extreme in climate zone 7, as shown in Figure 4.

			Rated R-value of Continuous Insulation [1]		
Std.	**Nominal Framing Size**	**Cavity Insulation R-value** [2]	**R-0**	**R-4**	**R-8**
16 in. OC	2x4	R-13	0.00	1.49	1.89
	2x4	R-15[3]	0.32	1.61	1.95
	2x4	R-17[5]	0.54	1.70	1.99
	2x6	R-19	1.44	2.05	2.23
	2x6	R-21[3]	1.57	2.12	2.25
	2x6	R-24[5]	1.73	2.19	2.30
	2x6	R-26[5]	1.80	2.23	2.32
	2x6	R-29[5]	1.89	2.28	2.37
24 in OC	2x6	R-19	1.41	1.98	2.15
	2x6	R-21[3]	1.55	2.05	2.20
	2x6	R-24[5]	1.69	2.12	2.24
	2x6	R-26[5]	1.77	2.16	2.26
	2x6	R-29[5]	1.86	2.22	2.30

Figure 4: kTDV/sq. ft. Energy Savings Over 2008 Base Case in Climate Zone 7

For consistency, the recommended prescriptive U-factor requirement assumes 24-inch on-center framing in all climate zones. Only in the case of climate zone 7 would 16-inches on-center save more energy. Because of the material cost savings with 24-inch o.c. framing, it is more cost effective, even in climate zone 7 to use 24-inch o.c., even though the energy savings may be slightly lower.

Following cost-effectiveness analysis and determination of the proposed prescriptive requirement for each climate zone, HMG reran the energy analysis for only the proposed assemblies in the most recent version of the software (MICROPAS 2013 r11). The results differ slightly from the initial analysis and are shown in Figure 5.

PKG D	Climate Zone	2x	Cavity Ins.	Exterior Ins.	Stud Spacing, in.	Annual Savings per Prototype Home					TDV savings	
						KW	KWH	THERMS	MTDVElec	MTDVGas	kTDV/sf/yr	%
PKGD 2008	01	6	21	0	16							
Proposed 2013	01	6	21	4	24	0.00	71	57	1.30	9.56	4.0	9.1%
PKGD 2008	02	4	13	0	16							
Proposed 2013	02	6	19	4	24	0.14	195	95	8.18	16.69	9.2	16.8%
PKGD 2008	03	4	13	0	16							
Proposed 2013	03	6	19	4	24	0.01	84	73	2.10	13.04	5.6	14.6%
PKGD 2008	04	4	13	0	16							
Proposed 2013	04	6	19	4	24	0.16	185	80	7.50	14.26	8.1	14.4%
PKGD 2008	05	4	13	0	16							
Proposed 2013	05	6	19	4	24	0.00	111	90	2.08	15.61	6.6	17.8%
PKGD 2008	06	4	13	0	16							
Proposed 2013	06	6	19	0	24	0.06	58	26	2.65	4.70	2.7	6.7%
PKGD 2008	07	4	13	0	16							
Proposed 2013	07	6	19	0	24	0.04	29	11	1.81	1.90	1.4	4.3%
PKGD 2008	08	4	13	0	16							
Proposed 2013	08	6	19	0	24	0.12	95	20	4.64	3.70	3.1	5.9%
PKGD 2008	09	4	13	0	16							
Proposed 2013	09	6	19	4	24	0.29	245	44	11.75	7.86	7.3	9.7%
PKGD 2008	10	4	13	0	16							
Proposed 2013	10	6	19	4	24	0.40	293	50	14.58	9.02	8.7	10.8%
PKGD 2008	11	6	19	0	16							
Proposed 2013	11	6	21	4	24	0.22	272	49	11.31	8.88	7.5	6.1%
PKGD 2008	12	6	19	0	16							
Proposed 2013	12	6	21	4	24	0.13	138	49	6.37	8.75	5.6	6.5%
PKGD 2008	13	6	19	0	16							
Proposed 2013	13	6	26	4	24	0.53	335	53	19.52	9.61	10.8	8.9%
PKGD 2008	14	6	21	0	16							
Proposed 2013	14	6	21	4	24	0.16	185	37	7.32	6.83	5.2	4.8%
PKGD 2008	15	6	21	0	16							
Proposed 2013	15	6	26	4	24	0.40	625	9	21.44	1.65	8.6	5.3%
PKGD 2008	16	6	21	0	16							
Proposed 2013	16	6	21	4	24	0.00	71	71	1.13	12.40	5.0	5.3%

Figure 5: Energy Analysis Results for Proposed 2013 Standards

4.2 Cost Effectiveness

This section summarizes the measure cost and life cycle cost analysis results associated with the proposed prescriptive wall insulation standards.

4.2.1 Measure Costs

As described in section 3.3.1, HMG used primarily R.S. Means costs in the life cycle cost calculations. These costs are detailed in the appendix section 7.1, of this report and summarized per prototype home in the figures below.

Figure 6 demonstrates the increased cost of 2x6 over 2x4 wall construction. Framing represents the highest cost, except when medium-density foam insulation is used. Medium density foam is necessary to for achieving an R-17 cavity insulation value within 2x4 framing and R-29 in 2x6 framing. 2 inches of medium-density foam is also included in the flash and batt assumptions for R-24 and R-26.

Stud Spacing	**Nominal Framing Size**	**Cavity Insulaiton Value**	Cavity Insulation	Basic sill (no external insulation)	Wall Framing	1/2-inch Gyp board	Total Interior Cost
16 in. o.c.	2x4	R-13	$1,712.14	$358.20	$2,966.49	$1,629.63	$6,666.46
	2x4	R-15[3]	$3,001.05	$358.20	$2,966.49	$1,629.63	$7,955.37
	2x4	R-17[5]	$4,764.06	$358.20	$2,966.49	$1,629.63	$9,718.38
	2x6	R-19	$2,127.24	$515.22	$3,537.89	$1,629.63	$7,809.98
	2x6	R-21[3]	$4,201.47	$515.22	$3,537.89	$1,629.63	$9,884.21
	2x6	R-24[5]	$4,868.80	$515.22	$3,537.89	$1,629.63	$10,551.54
	2x6	R-26[5]	$8,758.62	$515.22	$3,537.89	$1,629.63	$14,441.36
	2x6	R-29[5]	$7,937.82	$515.22	$3,537.89	$1,629.63	$13,620.56
24 in. o.c.	2x6	R-19	$2,212.33	$515.22	$3,113.34	$1,629.63	$7,470.52
	2x6	R-21[3]	$4,369.53	$515.22	$3,113.34	$1,629.63	$9,627.72
	2x6	R-24[5]	$5,063.55	$515.22	$3,113.34	$1,629.63	$10,321.74
	2x6	R-26[5]	$9,108.96	$515.22	$3,113.34	$1,629.63	$14,367.16
	2x6	R-29[5]	$8,255.33	$515.22	$3,113.34	$1,629.63	$13,513.53

Figure 6: Wall Assembly Costs Reliant on Framing Size and Spacing per Prototype Home

Figure 7 shows that the cladding system, whether three-coat cement stucco or one-coat synthetic stucco represents the highest cost within the wall assembly.

	Rated R-value of Continuous Insulation		
	R-0	R-4	R-8
OSB	$2,600.91	$2,600.91	$2,600.91
Weather barrier	$560.03	$560.03	$560.03
Additional sill flashing	$0.00	$78.51	$157.02
Three-coat cement stucco	$14,090.40	$0.00	$0.00
One-coat synthetic stucco	$0.00	$11,272.32	$11,723.21
Total Exterior Cost	$17,251.34	$14,511.77	$15,041.17

Figure 7: Wall Assembly Costs Reliant on Exterior Finishing per Prototype Home

Figure 8 combines the totals from Figure 6 and Figure 7 to show a total wall cost for each assembly. The range starts at just over $21,000 and escalates to over $31,000.

			Rated R-value of Continuous Insulation		
Stud Spacing	**Nominal Framing Size**	**Cavity Insulaiton Value**	**R-0**	**R-4**	**R-8**
16 in. o.c.	2x4	R-13	$23,917.80	$21,178.23	$21,707.63
	2x4	R-15[3]	$25,206.71	$22,467.14	$22,996.54
	2x4	R-17[5]	$26,969.72	$24,230.15	$24,759.55
	2x6	R-19	$25,061.32	$22,321.75	$22,851.15
	2x6	R-21[3]	$27,135.55	$24,395.98	$24,925.38
	2x6	R-24[5]	$27,802.87	$25,063.30	$25,592.71
	2x6	R-26[5]	$31,692.70	$28,953.13	$29,482.53
	2x6	R-29[5]	$30,871.90	$28,132.33	$28,661.73
24 in. o.c.	2x6	R-19	$24,721.86	$21,982.29	$22,511.69
	2x6	R-21[3]	$26,879.06	$24,139.49	$24,668.89
	2x6	R-24[5]	$27,573.08	$24,833.51	$25,362.91
	2x6	R-26[5]	$31,618.49	$28,878.92	$29,408.33
	2x6	R-29[5]	$30,764.86	$28,025.29	$28,554.70

Figure 8: Total Wall Assembly Costs per Prototype Home

Figures Figure 9 through Figure 11 show the total incremental cost increase from the 2008 baselines. In some cases, the incremental cost is negative due to the cost savings associated with 24-in. o.c. framing.

Stud Spacing	**Nominal Framing Size**	**Cavity Insulation R-value[2]**	**R-value of Continuous Insulation**		
			R-0	**R-4**	**R-8**
16 in. o.c	2x4	R-13	$0.00	($2,739.57)	($2,210.17)
	2x4	R-15[3]	$1,288.91	($1,450.66)	($921.26)
	2x4	R-17[5]	$3,051.92	$312.35	$841.75
	2x6	R-19	$1,143.52	($1,596.05)	($1,066.65)
	2x6	R-21[3]	$3,217.75	$478.18	$1,007.58
	2x6	R-24[5]	$3,885.08	$1,145.51	$1,674.91
	2x6	R-26[5]	$7,774.90	$5,035.33	$5,564.73
	2x6	R-29[5]	$6,954.10	$4,214.53	$4,743.93
24 in. o.c.	2x6	R-19	$804.06	($1,935.51)	($1,406.10)
	2x6	R-21[3]	$2,961.26	$221.69	$751.09
	2x6	R-24[5]	$3,655.28	$915.71	$1,445.12
	2x6	R-26[5]	$7,700.70	$4,961.13	$5,490.53
	2x6	R-29[5]	$6,847.07	$4,107.50	$4,636.90

Figure 9: Incremental Cost over R-13 Wall (2008 Base Case for Climate Zones 2-10)

Stud Spacing	Nominal Framing Size	Cavity Insulation R-value[2]	R-value of Continuous Insulation		
			R-0	R-4	R-8
16 in. o.c	2x4	R-13	($1,143.52)	($3,883.09)	($3,353.69)
	2x4	R-15[3]	$145.39	($2,594.18)	($2,064.78)
	2x4	R-17[5]	$1,908.40	($831.17)	($301.77)
	2x6	R-19	$0.00	($2,739.57)	($2,210.17)
	2x6	R-21[3]	$2,074.23	($665.34)	($135.94)
	2x6	R-24[5]	$2,741.56	$1.99	$531.39
	2x6	R-26[5]	$6,631.38	$3,891.81	$4,421.21
	2x6	R-29[5]	$5,810.58	$3,071.01	$3,600.41
24 in. o.c.	2x6	R-19	($339.46)	($3,079.03)	($2,549.62)
	2x6	R-21[3]	$1,817.74	($921.83)	($392.43)
	2x6	R-24[5]	$2,511.76	($227.81)	$301.60
	2x6	R-26[5]	$6,557.18	$3,817.61	$4,347.01
	2x6	R-29[5]	$5,703.55	$2,963.98	$3,493.38

Figure 10: Incremental Cost over R-19 Wall (2008 Base Case for Climate Zones 11-13)

Stud Spacing	Nominal Framing Size	Cavity Insulation R-value[2]	R-value of Continuous Insulation		
			R-0	R-4	R-8
16 in. o.c	2x4	R-13	($3,217.75)	($5,957.32)	($5,427.92)
	2x4	R-15[3]	($1,928.84)	($4,668.41)	($4,139.01)
	2x4	R-17[5]	($165.83)	($2,905.40)	($2,376.00)
	2x6	R-19	($2,074.23)	($4,813.80)	($4,284.40)
	2x6	R-21[3]	$0.00	($2,739.57)	($2,210.17)
	2x6	R-24[5]	$667.33	($2,072.24)	($1,542.84)
	2x6	R-26[5]	$4,557.15	$1,817.58	$2,346.98
	2x6	R-29[5]	$3,736.35	$996.78	$1,526.18
24 in. o.c.	2x6	R-19	($2,413.69)	($5,153.26)	($4,623.85)
	2x6	R-21[3]	($256.49)	($2,996.06)	($2,466.66)
	2x6	R-24[5]	$437.53	($2,302.04)	($1,772.63)
	2x6	R-26[5]	$4,482.95	$1,743.38	$2,272.78
	2x6	R-29[5]	$3,629.32	$889.75	$1,419.15

Figure 11: Incremental Cost over R-21 Wall (2008 Base Case for Climate Zones 1 and 14-16)

4.2.2 Lifecycle Cost Calculations

Using the energy analysis results shown in section 4.1, the costs in section 4.2.1, and the methodology described in section 3.3.3, we calculated the life cycle cost of each wall assembly. The results for 2x6 assemblies with 24-in o.c. framing are displayed in Figure 12, with the proposed prescriptive requirement for each climate zone is highlighted.

Exterior Insulation	R-0				R-4				R-8			
Cavity Insulation	**R-19**	**R-21**	**R-24**	**R-26**	**R-19**	**R-21**	**R-24**	**R-26**	**R-19**	**R-21**	**R-24**	**R-26**
U-factor	0.071	0.066	0.062	0.060	0.053	0.049	0.046	0.045	0.043	0.040	0.038	0.037
CZ 01		(448)	(226)	3,552		(4,951)	(4,537)	(674)		(5,385)	(4,896)	(977)
CZ 02	(1,950)	(144)	130	3,936	(6,354)	(4,412)	(3,989)	(108)	(6,713)	(4,711)	(4,208)	(275)
CZ 03	(921)	1,030	1,486	5,400	(4,629)	(2,598)	(2,044)	1,917	(4,567)	(2,485)	(1,861)	2,124
CZ 04	(1,656)	202	536	4,371	(5,798)	(3,828)	(3,372)	538	(5,993)	(3,967)	(3,437)	506
CZ 05	(1,137)	778	1,172	5,045	(5,073)	(3,075)	(2,573)	1,356	(5,208)	(3,158)	(2,600)	1,362
CZ 06	(519)	1,488	2,014	5,966	(3,899)	(1,822)	(1,235)	2,749	(3,655)	(1,550)	(926)	3,078
CZ 07	145	2,236	2,865	6,873	(2,861)	(737)	(76)	3,951	(2,411)	(278)	398	4,434
CZ 08	(702)	1,278	1,771	5,699	(4,208)	(2,154)	(1,586)	2,389	(4,029)	(1,938)	(1,332)	2,662
CZ 09	(1,417)	455	817	4,675	(5,396)	(3,407)	(2,956)	972	(5,521)	(3,490)	(2,964)	997
CZ 10	(1,899)	(88)	195	4,007	(6,130)	(4,188)	(4,074)	(178)	(6,699)	(4,687)	(4,194)	(256)
CZ 11	(522)	1,046	1,039	4,701	(5,945)	(4,158)	(3,945)	(157)	(6,884)	(4,984)	(4,632)	(778)
CZ 12	(452)	1,252	1,422	5,168	(5,211)	(3,335)	(2,991)	858	(5,781)	(3,815)	(3,369)	527
CZ 13	(517)	1,079	1,109	4,776	(6,895)	(5,093)	(4,881)	(1,064)	(7,763)	(5,854)	(5,506)	(1,643)
CZ 14		(430)	(414)	3,244		(5,554)	(5,313)	(1,525)		(6,334)	(5,967)	(2,104)
CZ 15		(532)	(638)	2,954		(6,204)	(6,127)	(2,376)		(7,288)	(7,047)	(3,222)
CZ 16		(444)	(343)	3,361		(5,428)	(5,112)	(1,291)		(6,086)	(5,654)	(1,772)

Figure 12: Life Cycle Cost Summary of Increased Insulation and 24-inch o.c. Framing

The life cycle costs in Figure 12 suggest that R-8 external insulation is cost-effective in most climate zones. However, HMG was unable to find sufficient data to suggest that R-8 installation techniques are commonly understood for residential construction. For this reason, we capped the proposed prescriptive requirements with assumptions of R-4 external insulation. Additionally, though R-21 cavity insulation with R-4 external insulation proves cost-effective in climate zones 2, 4, 9, and 10, we capped the proposed requirement at a U-factor that could be achieved in a 2x4 assembly.

In climate zone 7, using the conservative cost estimates in section 4.2.1, an upgrade to 2x6, 24-in. o.c. construction is not cost effective. However, the proposed U-factor requirement of 0.071 may alternatively be met by adding R-4 exterior insulation to a 2x4, R-13 assembly, which is cost-effective.

Figure 13 summarizes the change from 2008 standard to the proposed 2013 standard for wood-framed wall assemblies.

	2008 Prescriptive Std. (Base Case)					Proposed Prescriptive Standard				
Climate Zone	**Cavity Insulation**	**External Insulation**	**Wall Framing**	**2008 U-factor**	**Base case cost per home**	**Cavity Insulation**	**External Insulation**	**Wall Framing**	**Proposed 2013 U-factor**	**Proposed cost per home**
1	R-21	R-0	2x6 16" oc	0.069	$27,136	R-21	R-4	2x6 24" oc	0.049	$27,304
2	R-13	R-0	2x4 16" oc	0.102	$23,918	R-19	R-4	2x6 24" oc	0.053	$26,476
3	R-13	R-0	2x4 16" oc	0.102	$23,918	R-19	R-4	2x6 24" oc	0.053	$26,476
4	R-13	R-0	2x4 16" oc	0.102	$23,918	R-19	R-4	2x6 24" oc	0.053	$26,476
5	R-13	R-0	2x4 16" oc	0.102	$23,918	R-19	R-4	2x6 24" oc	0.053	$26,476
6	R-13	R-0	2x4 16" oc	0.102	$23,918	R-19	R-0	2x6 24" oc	0.071	$24,722
7	R-13	R-0	2x4 16" oc	0.102	$23,918	R-19	R-0	2x6 24" oc	0.071	$24,722
8	R-13	R-0	2x4 16" oc	0.102	$23,918	R-19	R-0	2x6 24" oc	0.071	$24,722
9	R-13	R-0	2x4 16" oc	0.102	$23,918	R-19	R-4	2x6 24" oc	0.053	$26,476
10	R-13	R-0	2x4 16" oc	0.102	$23,918	R-19	R-4	2x6 24" oc	0.053	$26,476
11	R-19	R-0	2x6 16" oc	0.074	$25,061	R-21	R-4	2x6 24" oc	0.049	$27,304
12	R-19	R-0	2x6 16" oc	0.074	$25,061	R-21	R-4	2x6 24" oc	0.049	$27,304
13	R-19	R-0	2x6 16" oc	0.074	$25,061	R-26	R-4	2x6 24" oc	0.045	$29,718
14	R-21	R-0	2x6 16" oc	0.069	$27,136	R-21	R-4	2x6 24" oc	0.049	$27,304
15	R-21	R-0	2x6 16" oc	0.069	$27,136	R-26	R-4	2x6 24" oc	0.045	$29,718
16	R-21	R-0	2x6 16" oc	0.069	$27,136	R-21	R-4	2x6 24" oc	0.049	$27,304

Figure 13: 2008 Prescriptive Wall Insulation Standard Compared to Proposed 2013 Standard

Figure 14 lists the alternatives to meet the proposed prescriptive U-factor requirement in each climate zone.

Climate Zone	2008 Prescriptive Baseline	Proposed 2013 Prescriptive Baseline	U-Factor	Alternative 1: Upgrade Exterior Insulation Only	Alternative 2: Upgrade Cavity Insulation and Exterior Insulation	Alternative 3: Upgrade Framing and Insulation
1	2x6 16" OC, R-21	2x6 **24" OC**, R-21 + **R-4**	0.049	2x6 16" OC, R-21 + **R-8**	2x6 16" OC, **R-24** + **R-4**	
2	2x4 16" OC, R-13	**2x6 24" OC, R-19** + **R-4**	0.053	2x4 16" OC, R-13 + **R-8**		**2x6** 16" OC, **R-21** + **R-4**
3	2x4 16" OC, R-13	**2x6 24" OC, R-19** + **R-4**	0.053	2x4 16" OC, R-13 + **R-8**		**2x6** 16" OC, **R-21** + **R-4**
4	2x4 16" OC, R-13	**2x6 24" OC, R-19** + **R-4**	0.053	2x4 16" OC, R-13 + **R-8**		**2x6** 16" OC, **R-21** + **R-4**
5	2x4 16" OC, R-13	**2x6 24" OC, R-19** + **R-4**	0.053	2x4 16" OC, R-13 + **R-8**		**2x6** 16" OC, **R-21** + **R-4**
6	2x4 16" OC, R-13	**2x6 24" OC, R-19**	0.071	2x4 16" OC, R-13 + **R-4**		**2x6** 16" OC, **R-21**
7	2x4 16" OC, R-13	**2x6 24" OC, R-19**	0.071	2x4 16" OC, R-13 + **R-4**		**2x6** 16" OC, **R-21**
8	2x4 16" OC, R-13	**2x6 24" OC, R-19**	0.071	2x4 16" OC, R-13 + **R-4**		**2x6** 16" OC, **R-21**
9	2x4 16" OC, R-13	**2x6 24" OC, R-19** + **R-4**	0.053	2x4 16" OC, R-13 + **R-8**		**2x6** 16" OC, **R-21** + **R-4**
10	2x4 16" OC, R-13	**2x6 24" OC, R-19** + **R-4**	0.053	2x4 16" OC, R-13 + **R-8**		**2x6** 16" OC, **R-21** + **R-4**
11	2x6 16" OC, R-19	2x6 **24" OC, R-21** + **R-4**	0.049	2x6 16" OC, R-19 + **R-8**	2x6 16" OC, **R-24** + **R-4**	
12	2x6 16" OC, R-19	2x6 **24" OC, R-21** + **R-4**	0.049	2x6 16" OC, R-19 + **R-8**	2x6 16" OC, **R-24** + **R-4**	
13	2x6 16" OC, R-19	2x6 **24" OC, R-21** + **R-4**	0.045	2x6 16" OC, R-19 + **R-8**	2x6 16" OC, **R-29** + **R-4**	
14	2x6 16" OC, R-21	2x6 **24" OC**, R-21 + **R-4**	0.049	2x6 16" OC, R-21 + **R-8**	2x6 16" OC, **R-24** + **R-4**	
15	2x6 16" OC, R-21	2x6 **24" OC**, R-21 + **R-4**	0.045	2x6 16" OC, R-21 + **R-8**	2x6 16" OC, **R-29** + **R-4**	
16	2x6 16" OC, R-21	2x6 **24" OC**, R-21 + **R-4**	0.049	2x6 16" OC, R-21 + **R-8**	2x6 16" OC, **R-24** + **R-4**	

Figure 14: Wall Assembly Compliance Alternatives

Figure 15 shows the proposed decrease in prescriptive U-factor requirements from 2008 Standards.

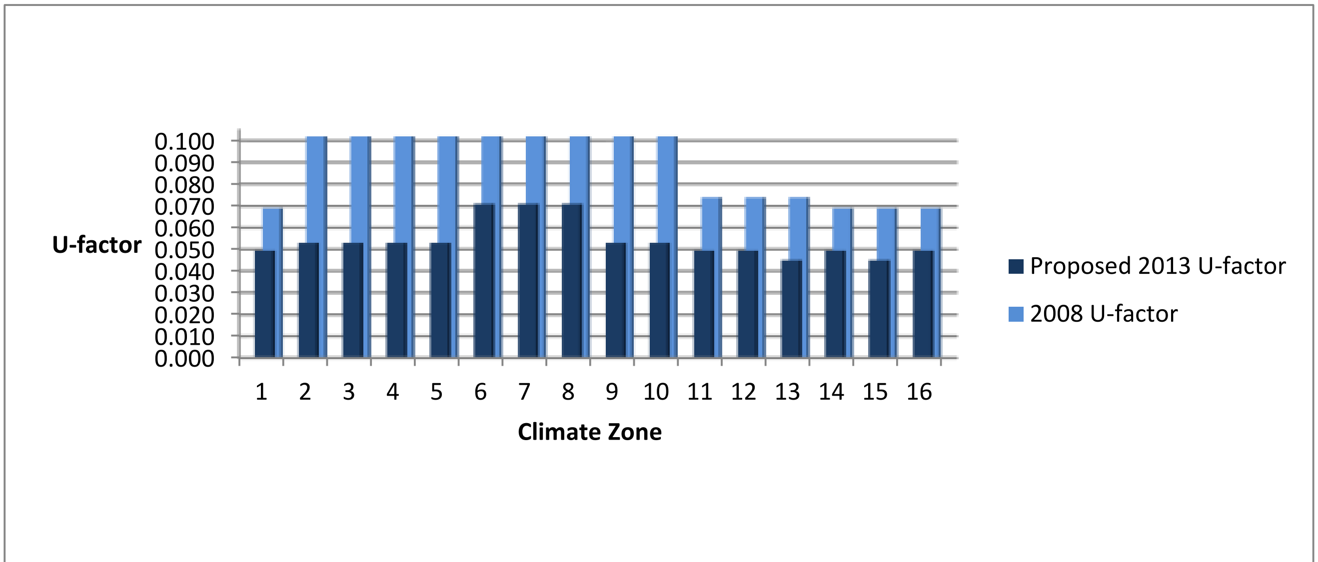

Figure 15: Proposed 2013 vs. 2008 Prescriptive U-factor Requirements

4.3 Environmental Impact

A shift to 2x6, 24-inch on center framing was shown to have a very small environmental impact, with regard to lumber consumption. Review of USDA-published literature confirmed that milling 2x6 framing members, alongside other nominal framing sizes results in maximum board foot yield from a standard 9-inch log, and does not require more or larger trees to be cut.[4] Regardless, the wood remnants, not milled into lumber, are never wasted, but used to make composite materials. The milling of 2x6 framing members is therefore not an environmental concern.

The estimated amount of lumber consumed by 2x6 framing at 24 inches on center, as compared to the 2008 base case assumptions, outlined in section 3.4, is lower. Though the proposed measure increases framing size from 2x4 to 2x6 in climate zones 2 through 10, the shift to 24-in on center from 16-inch on center in climate zones 1 and 11 through 16 reduces lumber consumption, as demonstrated in Figure 16and Figure 17.

Description	**2x4 @16"OC**	**2x6 @16" OC**	**2x6 @24" OC**
Double top plate (board feet)	48.0	72.0	72.0
Sole plate	24.0	36.0	36.0
Studs - center of wall	138.7	208.0	136.0
3 studs total for two ends of wall (California corners)	16.0	24.0	24.0
Total board feet for 36' wall	**226.7**	**340.0**	**268.0**
	Delta from 2x4, 16-inch on center	50%	-21%
	Delta from 2x6, 16-inch on center		18%

Figure 16: Nominal framing size and spacing comparison in board feet per 36-foot wall

The total board feet of lumber in a 36-foot wall was extrapolated to a whole-home value, and the delta (in board feet) between base cases of 2x4 16-inch on center and 2x6 16-inch on center, and the proposed case of 2x6 24-inch on center framing was calculated. Results, shown in Figure 17, estimate a 1.7% increase in total lumber use per home in climate zones 2 through 10, and a 3% decrease in climate zones 1 and 11 through 16. If 35% of all lumber consumed is for residential new construction[5], using new construction estimates as outlined in detail in section 7.3, the measure will reduce total lumber consumption in California by 2.12%.

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[4] Steele, Phillip H., "Factors Determining Lumber Recovery in Sawmilling," April 1984.

[5] Howard, James L., "U.S. Timber Production, Trade, Consumption and Price Statistics 1965 to 2005."

	2 x6" @16" OC	2 x6" @24" OC
Board feet delta for a 2700 sq.ft home **from 2x4 16-inch on cente**r	906.67	330.67
Total board feet per standard home	18,900.00	18,900.00
Percent increase per house	4.8%	1.7%
Percent impact on lumber	1.68%	0.61%
Board feet delta for a 2700 sq.ft. home **from 2x6 16-inch on center**		-576.00
Total board feet per standard home		18,900.00
Percent increase per house		-3.0%
Percent impact on lumber		-1.07%

Figure 17: Change in board feet from base case framing to proposed framing

Alternatively, if we assume that all homes are currently built with 2x4 framing - using external insulation, rather than increased cavity insulation to meet prescriptive requirements in climates zones 1 and 11-16 - we estimate a 1.7% increase in lumber per home, and a small increase of 0.61% in annual lumber demand statewide.

Based on a very small sample of homes receiving incentives for exceeding 2008 standards by 15% through the California New Homes Program, HMG observed that many builders are using a combination of 2x6 and 2x4 framing. Of the 548 homes in the sample, by 9 builders, 67% included some 2x6 exterior wall framing. The 2x6 framed wall area was, on average, only 23% of the total exterior wall area in the homes using some 2x6 framing. In no case was 24-inch on center framing specified.

4.4 Statewide Savings Estimates

The total energy and energy cost savings potential for this measure, per prototype home, range from 29 to 625 kWh, 9 to 95 therms/ft2, and 3.71 to 29.13 TDV million kBtu, depending on climate zone.

Applying these unit estimates to the statewide single family residential estimate of new construction of 47,402 single family homes per year results in first year statewide energy savings of 10.54 GWh, 2.31 MMtherms, and 908,455 TDV million kBtu. Estimated new construction and resulting savings per climate zone are shown in Figure 18 below.

Climate Zone	Number of Homes	Electricity Savings (kwh/yr)	Natural Gas Savings (Therms/yr)	Total TDV (million kBtu)
CZ 1	378	26,838	21,546	4,105
CZ 2	1,175	229,125	111,625	29,222
CZ 3	1,224	102,816	89,352	18,531
CZ 4	2,688	497,280	215,040	58,491
CZ 5	522	57,942	46,980	9,234
CZ 6	1,188	68,904	30,888	8,732
CZ 7	2,158	62,582	23,738	8,006
CZ 8	1,966	186,770	39,320	16,396
CZ 9	2,269	555,905	99,836	44,495
CZ 10	8,848	2,592,464	442,400	208,813
CZ 11	3,228	878,016	158,172	65,173
CZ 12	9,777	1,349,226	479,073	147,828
CZ 13	6,917	2,317,195	366,601	201,492
CZ 14	1,639	303,215	60,643	23,192
CZ 15	1,925	1,203,125	17,325	44,448
CZ 16	1,500	106,500	106,500	20,295
Statewide Total	47,402	10,537,903	2,309,039	908,455

Figure 18: Statewide Savings Estimates by Climate Zone

5. Recommended Language for the Standards Document, ACM Manuals, and the Reference Appendices

This section provides complete language for code change recommendations for the Standards Reference Appendices. There is no recommended change to the ACM Manuals associated with this measure.

5.1 Residential Prescriptive Package

This measure requires updating row three (3) of Table 151-C Component Package D with the values in Figure 19, below, and editing associated footnotes. Package D may be renamed Package A in the 2013 Standards.

Wood-Frame Walls **Maximum U-factor**	~~R21~~ R21/R4 0.049	~~R13~~ R19/R4 0.053	~~R13~~ R19/R4 0.053	~~R13~~ R19/R4 0.053	~~R13~~ R19/R4 0.053	~~R13~~ R19 0.071	~~R13~~ R19 0.071	~~R13~~ R19 0.071	~~R13~~ R19/R4 0.053	~~R13~~ R19/R4 0.053	~~R19~~ R21/R4 0.049	~~R19~~ R21/R4 0.049	~~R19~~ R26/R4 0.045	~~R21~~ R21/R4 0.049	~~R21~~ R26/R4 0.045	~~R21~~ R21/R4 0.049

Figure 19: Proposed Changes to 2008 Standards Table 151-C Component Package D

Footnote requirements to TABLE 151-B, TABLE 151-C and TABLE 151-D.

[1] The R-values shown for ceiling, ~~wood frame wall~~ and raised floor are for wood-frame construction with insulation installed between the framing members. For alternative construction assemblies, see Section 151(f)1A.

5.2 JA4 Look-up Tables

Figure 20 and Figure 21 will replace Joint Appendix Table 4.3.1 of the 2008 Standards.

Table 4.3.1a - U-Factors of Wood Framed Walls 16 in. OC

			Rated R-value of Continuous Insulation [1]							
			R-0	**R-2**	**R-4**	**R-6**	**R-7**	**R-8**	**R-10**	**R-14**
			A	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Any	R-0	1	0.356	0.247	0.144	0.111	0.109	0.091	0.082	0.061
2x4	R-11	2	0.110	0.087	0.073	0.063	0.059	0.056	0.050	0.041
2x4	R-13	3	0.102	0.081	0.068	0.059	0.056	0.052	0.047	0.039
2x4	R-15[3]	4	0.095	0.076	0.064	0.056	0.053	0.050	0.045	0.038
2x4	R-17[5]	5	0.090	0.072	0.061	0.053	0.050	0.047	0.043	0.036
2x6	R-19	6	0.072	0.061	0.053	0.048	0.045	0.043	0.039	0.034
2x6	R-21[3]	7	0.069	0.058	0.051	0.046	0.043	0.041	0.038	0.032
2x6	R-24[5]	8	0.065	0.055	0.048	0.042	0.040	0.039	0.036	0.031
2x6	R-26[5]	9	0.063	0.053	0.047	0.042	0.040	0.038	0.035	0.030
2x6	R-29[5]	10	0.060	0.051	0.044	0.040	0.038	0.036	0.033	0.029
2x8	R-19	11	0.065	0.057	0.050	0.045	0.043	0.041	0.038	0.033
2x8	R-22	12	0.061	0.053	0.047	0.042	0.040	0.039	0.036	0.031
2x8	R-25	13	0.057	0.050	0.044	0.040	0.038	0.037	0.034	0.030
2x8	R-27[4]	14	0.055	0.048	0.043	0.039	0.037	0.035	0.033	0.029
2x8	R-30[3]	15	0.052	0.046	0.041	0.038	0.036	0.034	0.032	0.028
2x8	R-33[5]	16	0.050	0.044	0.039	0.035	0.034	0.033	0.030	0.026
2x8	R-35[5]	17	0.049	0.043	0.038	0.035	0.033	0.032	0.029	0.026
2x8	R-37[5]	18	0.048	0.042	0.037	0.034	0.032	0.031	0.029	0.025
2x10	R-30	19	0.047	0.042	0.038	0.035	0.034	0.032	0.030	0.027
2x10	R-33	20	0.045	0.040	0.036	0.033	0.032	0.031	0.029	0.026
2x10	R-36	21	0.043	0.039	0.035	0.032	0.031	0.030	0.028	0.025
2x10	R-38	22	0.042	0.038	0.034	0.031	0.030	0.029	0.027	0.025
2x10	R-41[5]	23	0.041	0.037	0.033	0.030	0.029	0.028	0.026	0.023
2x10	R-43[5]	24	0.040	0.036	0.032	0.030	0.029	0.028	0.026	0.023
2x10	R-45[5]	25	0.039	0.035	0.032	0.029	0.028	0.027	0.025	0.023
2x10	R-47[5]	26	0.039	0.035	0.031	0.029	0.028	0.027	0.025	0.022
2x10	R-49[5]	27	0.038	0.034	0.031	0.028	0.027	0.026	0.024	0.022
2x12	R-38	28	0.039	0.035	0.032	0.030	0.029	0.028	0.026	0.023
2x12	R-41[4]	29	0.037	0.034	0.031	0.029	0.028	0.027	0.025	0.023
2x12	R-44[5]	30	0.036	0.033	0.030	0.028	0.027	0.026	0.025	0.022
2x12	R-47[5]	31	0.035	0.032	0.029	0.027	0.026	0.025	0.024	0.021
2x12	R-49[5]	32	0.035	0.031	0.029	0.027	0.026	0.025	0.023	0.021
2x12	R-52[5]	33	0.034	0.031	0.028	0.026	0.025	0.024	0.023	0.020

Figure 20. JA4 table for U-factor of Wood Framed Walls 16 in. OC

Table 4.3.1b - U-Factors of Wood Framed Walls 24 in. OC

			Rated R-value of Continuous Insulation [1]							
			R-0	R-2	R-4	R-6	R-7	R-8	R-10	R-14
			A	B	C	D	E	F	G	H
Any	R-0	34	0.547	0.251	0.165	0.123	0.110	0.099	0.082	0.062
2x4	R-11	35	0.106	0.085	0.072	0.062	0.058	0.055	0.049	0.041
2x4	R-13	36	0.098	0.079	0.067	0.058	0.055	0.052	0.046	0.039
2x4	R-15[3]	37	0.091	0.073	0.062	0.055	0.051	0.049	0.044	0.037
2x4	R-17[5]	38	0.086	0.069	0.059	0.052	0.049	0.046	0.042	0.036
2x6	R-19	39	0.069	0.059	0.052	0.046	0.044	0.042	0.038	0.033
2x6	R-21[3]	40	0.066	0.056	0.049	0.044	0.042	0.040	0.037	0.032
2x6	R-24[5]	41	0.062	0.053	0.046	0.042	0.040	0.038	0.035	0.030
2x6	R-26[5]	42	0.060	0.051	0.045	0.040	0.038	0.037	0.034	0.029
2x6	R-29[5]	43	0.057	0.048	0.043	0.038	0.037	0.035	0.032	0.028
2x8	R-19	44	0.063	0.055	0.049	0.044	0.042	0.040	0.037	0.032
2x8	R-22	45	0.058	0.051	0.046	0.041	0.040	0.038	0.035	0.030
2x8	R-25	46	0.055	0.048	0.043	0.039	0.037	0.036	0.033	0.029
2x8	R-27[4]	47	0.053	0.046	0.041	0.038	0.036	0.035	0.032	0.028
2x8	R-30[3]	48	0.050	0.044	0.039	0.038	0.034	0.033	0.031	0.027
2x8	R-33[5]	49	0.048	0.042	0.038	0.034	0.033	0.031	0.029	0.026
2x8	R-35[5]	50	0.047	0.041	0.037	0.033	0.032	0.031	0.029	0.025
2x8	R-37[5]	51	0.045	0.040	0.036	0.032	0.031	0.030	0.028	0.025
2x10	R-30	52	0.045	0.041	0.037	0.034	0.033	0.031	0.029	0.026
2x10	R-33	53	0.043	0.039	0.035	0.032	0.031	0.030	0.028	0.025
2x10	R-36	54	0.041	0.037	0.034	0.031	0.030	0.029	0.027	0.024
2x10	R-38	55	0.040	0.036	0.033	0.030	0.029	0.029	0.026	0.023
2x10	R-41[5]	56	0.039	0.035	0.032	0.029	0.028	0.027	0.025	0.023
2x10	R-43[5]	57	0.038	0.034	0.031	0.029	0.028	0.027	0.025	0.022
2x10	R-45[5]	58	0.037	0.033	0.030	0.028	0.027	0.026	0.024	0.022
2x10	R-47[5]	59	0.037	0.033	0.030	0.027	0.026	0.026	0.024	0.021
2x10	R-49[5]	60	0.036	0.032	0.029	0.027	0.026	0.025	0.024	0.021
2x12	R-38	61	0.037	0.034	0.031	0.029	0.028	0.027	0.025	0.023
2x12	R-41[4]	62	0.036	0.033	0.030	0.028	0.027	0.026	0.025	0.022
2x12	R-44[5]	63	0.034	0.031	0.029	0.027	0.026	0.025	0.024	0.021
2x12	R-47[5]	64	0.033	0.030	0.028	0.026	0.025	0.024	0.023	0.021
2x12	R-49[5]	65	0.033	0.030	0.027	0.026	0.025	0.024	0.023	0.020
2x12	R-52[5]	66	0.032	0.029	0.027	0.025	0.024	0.023	0.022	0.020

Figure 21. JA4 Table for U-factor of Wood Framed Walls 24 in. OC

Notes

1. Continuous insulation may be installed on either the interior or the exterior of the wall, or both.

2. R-values can be met using one or multiple insulation types within a cavity.

Low-density (open cell) spray-in insulation shall fill the entire cavity, when used independent of medium-density (closed cell) spray foam insulation.

When used alone or in combination with another insulation type, medium-density insulation must be applied as a first layer and need not fill the thickness of the cavity.

The R-value of low-density insulation shall be 3.6 per inch thickness. Cellulose shall have a binder to prevent sagging.

The R-value of medium-density insulation shall be 5.8 per inch thickness.

3. Requires high-density batt insulation or medium-density spray-in insulation. Medium density insulation may be used in combination with batt or spray-in cellulose insulation to reach cavity insulation R-value

4. Requires spray-in insulation (low or medium density). Medium-density insulation may be used in combination with batt or spray-in cellulose insulation to reach cavity insulation R-value.

5. Requires use of medium-density spray foam insulation. May be used in combination with batt or spray-in cellulose insulation to reach cavity insulation R-value.

6. Bibliography and Other Research

This section lists documents and experts referenced in development of this CASE report, and similar research projects in progress.

6.1 Referenced Documents

Architectural Energy Corporation, "Life Cycle Cost Methodology 2013 California Building Energy Efficiency Standards," December 14, 2010.

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6.2 List of Experts Consulted

Ken Allison, Demilec USA

Jamy Bacchus, National Resource Defense Council (NRDC)

Kevin Downey, United Sub Contractor

Rick Duncan, Spray Polyurethane Foam Alliance (SPFA)

Rob Hammon, Consol

Mike Hodgson, Consol

Steve Johnson, Anderson Windows

Mike Moore, Newport Ventures, Inc.

Robert Niney, Engineering Manager, Demilec USA

Ken Nittler, P.E., Enercomp, Inc

Roger Morrison, Deer Ridge Consulting

James Morshead, Project Manager, SDI Insulation, Inc.

Kurt Riesenberg, Spray Polyurethane Foam Alliance (SPFA)

Sami Yassa, National Resource Defense Council (NRDC)

7. Appendices

7.1 Cost Tables

The tables in this section include cost information used to calculate total wall assembly costs for use in the Life-cycle cost calculations.

RS Means Description	Bakersfield	Eureka	Oakland	Redding	Sacramento	San Diego	O&P Mean Across Regions per square foot	O&P Mean across products per square foot	Number of units in Prototype Home	Cost per Prototype Home
Gypsum wallboard, on walls, standard, 1/2" thick	$ 0.72	$ 0.79	$ 0.85	$ 0.77	$ 0.77	$ 0.69	$ 0.77	$ 0.79	2,052	$ 1,629.63
Gypsum wallboard, on walls, fire resistant, 1/2" th	$ 0.77	$ 0.86	$ 0.90	$ 0.83	$ 0.83	$ 0.75	$ 0.82			

Figure 22: Table of R.S. Means Cost Information for ½" Gypsum Board

Batt Insulation R-value	RS Means Description	Palo Alto	Richmond	Sacramento	San Jose	O&P Mean Across Regions per square foot	O&P Mean across products per square foot	Number of units in Prototype Home	Cost per Prototype Home
R-13	Kraft faced fiberglass, 3-1/2" thick, 11" wide	$ 0.78	$ 0.78	$ 0.78	$ 0.78	$ 0.78	$ 0.83	1,539	$ 1,712.14
	Foil faced fiberglass, 3-1/2" thick, 11" wide	$ 1.10	$ 1.12	$ 1.04	$ 1.05	$ 1.08			
	Unfaced 3-1/2" thick, 11" wide	$ 0.80	$ 0.83	$ 0.77	$ 0.80	$ 0.80			
	Unfaced, 3-1/2" thick, incl. spring type wire	$ 0.68	$ 0.68	$ 0.68	$ 0.68	$ 0.68			
R-19	Kraft faced fiberglass, 6" thick, 11" wide	$ 0.90	$ 0.90	$ 0.90	$ 0.90	$ 0.90	$ 1.04	1,539	$ 2,127.24
	Foil faced fiberglass, 6" thick, 15" wide	$ 1.27	$ 1.27	$ 1.27	$ 1.27	$ 1.27			
	Unfaced fiberglass, 6" thick, 15" wide	$ 0.94	$ 0.94	$ 0.94	$ 0.94	$ 0.94			

Figure 23: Table of R.S. Means Cost Data for Batt Insulation

High-Density Batt Insulation R-value		Cost per square foot	Number of units in Prototype Home	Cost per Prototype Home
R-15	$0.13 per R-value per square foot assumed per industry research by CEC	$1.95	1,539	$3,001.05
R-21	$0.13 per R-value per square foot assumed per industry research by CEC	$2.73	1,539	$4,201.47

Figure 24: Table of High-Density Batt Insulation Costs

Flash & Batt		Cost per square foot	Number of units in Prototype Home	Cost per Prototype Home
R-24	2" foam, plus R-13 batt	$ 2.37	1,539	$ 4,868.80
R-26	2" foam, plus R-15 batt	$ 4.27	1,539	$ 8,758.62

Figure 25: Table of Flash and Batt Insulation Costs

Description	Square Feet	Bakersfield	Eureka	Oakland	Redding	Sacramento	San Diego	Average Cost per wall	O&P Mean Across Regions per square foot	O&P Mean across products per square foot	Number of units in Prototype Home	Cost per Prototype Home
Wall framing, door buck, king studs, jack studs, header and accessories, 2" x 4" wall, 3' wide, 8' high	24	$ 29.06	$ 36.06	$ 34.75	$ 32.09	$ 32.87	$ 29.27	$ 32.35	$ 1.35			
Wall framing, door buck, king studs, jack studs, header and accessories, 2" x 4" wall, 4' wide, 8' high	32	$ 30.07	$ 37.51	$ 35.92	$ 33.24	$ 34.04	$ 30.42	$ 33.53	$ 1.05			
Wall framing, door buck, king studs, jack studs, header and accessories, 2" x 4" wall, 5' wide, 8' high	40	$ 33.10	$ 41.84	$ 39.44	$ 36.68	$ 37.56	$ 33.88	$ 37.08	$ 0.93			
Wall framing, door buck, king studs, jack studs, header and accessories, 2" x 4" wall, 6' wide, 8' high	48	$ 34.42	$ 43.72	$ 40.97	$ 38.18	$ 39.09	$ 35.38	$ 38.63	$ 0.80			
Wall framing, door buck, king studs, jack studs, header and accessories, 2" x 4" wall, 8' wide, 8' high	64	$ 44.70	$ 58.04	$ 52.96	$ 49.79	$ 50.96	$ 46.85	$ 50.55	$ 0.79			
Wall framing, door buck, king studs, jack studs, header and accessories, 2" x 4" wall, 10' wide, 8' high	80	$ 53.93	$ 71.23	$ 63.67	$ 60.27	$ 61.67	$ 57.38	$ 61.36	$ 0.77			
Wall framing, door buck, king studs, jack studs, header and accessories, 2" x 4" wall, 12' wide, 8' high	96	$ 67.11	$ 90.07	$ 78.97	$ 75.24	$ 76.97	$ 72.42	$ 76.80	$ 0.80			
Wall framing, window buck, king studs, jack studs, rough sill, cripples, header and accessories, 2" x 4" wall, 2' wide, 8' high	16	$ 34.94	$ 42.64	$ 41.90	$ 38.46	$ 39.40	$ 34.68	$ 38.67	$ 2.42	$1.14	2,592	$2,966.49
Wall framing, window buck, king studs, jack studs, rough sill, cripples, header and accessories, 2" x 4" wall, 3' wide, 8' high	24	$ 37.44	$ 46.22	$ 44.81	$ 41.30	$ 42.31	$ 37.54	$ 41.60	$ 1.73			
Wall framing, window buck, king studs, jack studs, rough sill, cripples, header and accessories, 2" x 4" wall, 4' wide, 8' high	32	$ 39.16	$ 48.67	$ 46.80	$ 43.25	$ 44.30	$ 39.49	$ 43.61	$ 1.36			
Wall framing, window buck, king studs, jack studs, rough sill, cripples, header and accessories, 2" x 4" wall, 5' wide, 8' high	40	$ 42.24	$ 53.06	$ 50.37	$ 46.74	$ 47.87	$ 43.00	$ 47.21	$ 1.18			
Wall framing, window buck, king studs, jack studs, rough sill, cripples, header and accessories, 2" x 4" wall, 6' wide, 8' high	48	$ 44.43	$ 56.20	$ 52.92	$ 49.24	$ 50.42	$ 45.51	$ 49.79	$ 1.04			
Wall framing, window buck, king studs, jack studs, rough sill, cripples, header and accessories, 2" x 4" wall, 8' wide, 8' high	64	$ 57.33	$ 73.96	$ 68.02	$ 63.77	$ 65.28	$ 59.75	$ 64.69	$ 1.01			
Wall framing, window buck, king studs, jack studs, rough sill, cripples, header and accessories, 2" x 4" wall, 10' wide, 8' high	80	$ 67.44	$ 88.41	$ 79.75	$ 75.25	$ 77.01	$ 71.28	$ 76.52	$ 0.96			
Wall framing, window buck, king studs, jack studs, rough sill, cripples, header and accessories, 2" x 4" wall, 12' wide, 8' high	96	$ 82.82	$ 110.39	$ 97.60	$ 92.71	$ 94.86	$ 88.84	$ 94.54	$ 0.98			

Figure 26: Table of R.S. Means 2x4 Framing Costs

Description	Square Feet	Bakersfield	Eureka	Oakland	Redding	Sacramento	San Diego	Average Cost per wall	O&P Mean Across Regions per square foot	O&P Mean across products per square foot	Number of units in Prototype Home	Cost per Prototype Home
Wall framing, door buck, king studs, jack studs, header and accessories, 2" x 6" wall, 3' wide, 8' high	24	$ 35.30	$ 44.98	$ 41.99	$ 39.18	$ 40.11	$ 36.39	$ 39.66	$ 1.65			
Wall framing, door buck, king studs, jack studs, header and accessories, 2" x 6" wall, 4' wide, 8' high	32	$ 36.18	$ 46.24	$ 43.01	$ 40.17	$ 41.13	$ 37.39	$ 40.69	$ 1.27			
Wall framing, door buck, king studs, jack studs, header and accessories, 2" x 6" wall, 5' wide, 8' high	40	$ 39.25	$ 50.63	$ 46.58	$ 43.67	$ 44.70	$ 40.90	$ 44.29	$ 1.11			
Wall framing, door buck, king studs, jack studs, header and accessories, 2" x 6" wall, 6' wide, 8' high	48	$ 40.57	$ 52.52	$ 48.11	$ 45.16	$ 46.23	$ 42.41	$ 45.83	$ 0.95			
Wall framing, door buck, king studs, jack studs, header and accessories, 2" x 6" wall, 8' wide, 8' high	64	$ 50.85	$ 66.83	$ 60.10	$ 56.77	$ 58.10	$ 53.87	$ 57.75	$ 0.90			
Wall framing, door buck, king studs, jack studs, header and accessories, 2" x 6" wall, 10' wide, 8' high	80	$ 59.64	$ 79.39	$ 70.30	$ 66.75	$ 68.30	$ 63.90	$ 68.05	$ 0.85			
Wall framing, door buck, king studs, jack studs, header and accessories, 2" x 6" wall, 12' wide, 8' high	96	$ 73.27	$ 98.86	$ 86.11	$ 82.22	$ 84.11	$ 79.44	$ 84.00	$ 0.88			
Wall framing, window buck, king studs, jack studs, rough sill, cripples, header and accessories, 2" x 6" wall, 2' wide, 8' high	16	$ 42.68	$ 53.69	$ 50.88	$ 47.24	$ 48.38	$ 43.51	$ 47.73	$ 2.98	$1.36	2,592	$3,537.89
Wall framing, window buck, king studs, jack studs, rough sill, cripples, header and accessories, 2" x 6" wall, 3' wide, 8' high	24	$ 45.31	$ 57.46	$ 53.94	$ 50.23	$ 51.44	$ 46.51	$ 50.82	$ 2.12			
Wall framing, window buck, king studs, jack studs, rough sill, cripples, header and accessories, 2" x 6" wall, 4' wide, 8' high	32	$ 47.07	$ 59.97	$ 55.98	$ 52.23	$ 53.48	$ 48.52	$ 52.88	$ 1.65			
Wall framing, window buck, king studs, jack studs, rough sill, cripples, header and accessories, 2" x 6" wall, 5' wide, 8' high	40	$ 50.59	$ 64.99	$ 60.06	$ 56.22	$ 57.56	$ 52.53	$ 56.99	$ 1.42			
Wall framing, window buck, king studs, jack studs, rough sill, cripples, header and accessories, 2" x 6" wall, 6' wide, 8' high	48	$ 53.22	$ 68.76	$ 63.12	$ 59.22	$ 60.62	$ 55.54	$ 60.08	$ 1.25			
Wall framing, window buck, king studs, jack studs, rough sill, cripples, header and accessories, 2" x 6" wall, 8' wide, 8' high	64	$ 67.44	$ 88.41	$ 79.75	$ 75.25	$ 77.01	$ 71.28	$ 76.52	$ 1.20			
Wall framing, window buck, king studs, jack studs, rough sill, cripples, header and accessories, 2" x 6" wall, 10' wide, 8' high	80	$ 77.99	$ 103.48	$ 91.99	$ 87.22	$ 89.25	$ 83.32	$ 88.88	$ 1.11			
Wall framing, window buck, king studs, jack studs, rough sill, cripples, header and accessories, 2" x 6" wall, 12' wide, 8' high	96	$ 94.25	$ 126.71	$ 110.86	$ 105.69	$ 108.12	$ 101.87	$ 107.92	$ 1.12			

Figure 27: Table of R.S. Means 2x6 Framing Costs

Description	Bakersfield	Eureka	Oakland	Redding	Sacramento	San Diego	O&P Mean Across Regions per square foot	O&P Mean across products per square foot	Number of units in Prototype Home	Cost per Prototype Home
Sheathing, oriented strand board, 7/16" thick	$ 1.04	$ 1.22	$ 1.24	$ 1.13	$ 1.15	$ 1.00	$ 1.13	$1.27	2,052	$2,600.91
Sheathing, oriented strand board, 7/16" thick,	$ 0.90	$ 1.07	$ 1.07	$ 0.98	$ 1.00	$ 0.88	$ 0.98			
Sheathing, oriented strand board, 1/2" thick	$ 1.07	$ 1.26	$ 1.28	$ 1.17	$ 1.19	$ 1.03	$ 1.17			
Sheathing, oriented strand board, 1/2" thick, pneumatic nailed	$ 0.92	$ 1.10	$ 1.10	$ 1.01	$ 1.03	$ 0.90	$ 1.01			
Sheathing, oriented strand board, 5/8" thick	$ 1.56	$ 1.95	$ 1.86	$ 1.73	$ 1.77	$ 1.58	$ 1.74			
Sheathing, oriented strand board, 5/8" thick, pneumatic nailed	$ 1.40	$ 1.78	$ 1.67	$ 1.56	$ 1.59	$ 1.44	$ 1.57			

Figure 28: Table of OSB Sheathing Costs

Description	Cost per roll	Cost per Linear Foot	Average Cost per Linear Foot	Number of Units in Prototype Home	Cost per Prototype Home
6" X 75' Co Fair Tight Seal	$ 44.90	$ 0.60	$0.58	648	$376.34
6" X 75' Co Fair Tight Seal	$ 31.79	$ 0.42			
6" X 75' Co Fair Tight Seal	$ 32.51	$ 0.43			
6" X 75' Co Fair Tight Seal	$ 39.76	$ 0.53			
6" X 75' Co Fair Tight Seal	$ 49.89	$ 0.67			
6" X 75' Co Fair Tight Seal	$ 47.82	$ 0.64			
6" X 75' Co Fair Tight Seal	$ 33.99	$ 0.45			
6" X 75' Co Fair Tight Seal	$ 40.22	$ 0.54			
6" X 75' Co Fair Tight Seal	$ 60.07	$ 0.80			
9" x 75' 40 mil Fortfiber/Fortiflash	$ 54.63	$ 0.73	$0.75	648	$486.85
9" x 75' 40 mil Fortfiber/Fortiflash	$ 68.11	$ 0.91			
9" x 75' 40 mil Fortfiber/Fortiflash	$ 70.86	$ 0.94			
9" x 75' 40 mil Fortfiber/Fortiflash	$ 54.63	$ 0.73			
9" x 75' 40 mil Fortfiber/Fortiflash	$ 72.24	$ 0.96			
9" x 75' 40 mil Fortfiber/Fortiflash	$ 68.80	$ 0.92			
9" x 75' 40 mil Fortfiber/Fortiflash	$ 55.00	$ 0.73			
9" x 75' 40 mil Fortfiber/Fortiflash	$ 57.36	$ 0.76			
9" x 75' 25 mil Fortfiber/Fortiflash	$ 41.85	$ 0.56			
9" x 75' 25 mil Fortfiber/Fortiflash	$ 55.24	$ 0.74			
9" x 75' 25 mil Fortfiber/Fortiflash	$ 57.47	$ 0.77			
9" x 75' 25 mil Fortfiber/Fortiflash	$ 45.50	$ 0.61			
9" x 75' 25 mil Fortfiber/Fortiflash	$ 58.59	$ 0.78			
9" x 75' 25 mil Fortfiber/Fortiflash	$ 55.80	$ 0.74			
9" x 75' 25 mil Fortfiber/Fortiflash	$ 42.00	$ 0.56			
9" x 75' 25 mil Fortfiber/Fortiflash	$ 43.50	$ 0.58			
12" x 75' 40 mil Fortfiber/Fortiflash	$ 110.04	$ 1.47	$1.03	648	$670.25
12" x 75' 40 mil Fortfiber/Fortiflash	$ 90.78	$ 1.21			
12" x 75' 40 mil Fortfiber/Fortiflash	$ 94.45	$ 1.26			
12" x 75' 40 mil Fortfiber/Fortiflash	$ 69.23	$ 0.92			
12" x 75' 40 mil Fortfiber/Fortiflash	$ 96.29	$ 1.28			
12" x 75' 40 mil Fortfiber/Fortiflash	$ 91.70	$ 1.22			
12" x 75' 40 mil Fortfiber/Fortiflash	$ 69.00	$ 0.92			
12" x 75' 25 mil Fortfiber/Fortiflash	$ 64.35	$ 0.86			
12" x 75' 25 mil Fortfiber/Fortiflash	$ 66.95	$ 0.89			
12" x 75' 25 mil Fortfiber/Fortiflash	$ 68.25	$ 0.91			
12" x 75' 25 mil Fortfiber/Fortiflash	$ 61.01	$ 0.81			
12" x 75' 25 mil Fortfiber/Fortiflash	$ 65.00	$ 0.87			
12" x 75' 25 mil Fortfiber/Fortiflash	$ 61.00	$ 0.81			
12" x 75' 25 mil Fortfiber/Fortiflash	$ 78.00	$ 1.04			

Figure 29: Table of Flexible Flashing Costs

Weather Barrier	Description	Bakersfield	Eureka	Oakland	Redding	Sacramento	San Diego	O&P Mean Across Regions per	O&P Mean across products per	Number of units in Prototype	Cost per Prototype Home
	Weather barriers, building paper, asphalt felt sheathing paper, 15#, per square foot	$ 0.18	$ 0.16	$ 0.21	$ 0.19	$ 0.19	$ 0.17	$ 0.18	$ 0.27	2,052	$ 560.03
	Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, small roll	$ 0.34	$ 0.35	$ 0.42	$ 0.38	$ 0.39	$ 0.37	$ 0.38			
	Weather barriers, building paper, housewrap, exterior, spun bonded polypropylene, large roll	$ 0.24	$ 0.24	$ 0.30	$ 0.27	$ 0.27	$ 0.25	$ 0.26			
	Weather barriers, building paper, spunbonded polyethylene	$ 0.25	$ 0.25	$ 0.31	$ 0.28	$ 0.28	$ 0.26	$ 0.27			

Figure 30: Table of R.S. Means Weather Barrier Costs

	Description	Bakersfield	Eureka	Oakland	Redding	Sacramento	San Diego	O&P Mean Across Regions per square foot	O&P Mean across products per square foot	Number of units in Prototype Home	Cost per Prototype Home
Concrete Stucco	Stucco, 3 coats, float finish, with mesh, on wood frame, 1" thick	$ 6.48	$ 7.02	$ 7.76	$ 6.96	$ 7.04	$ 5.94	$ 6.87	$ 6.87	2,052	$ 14,090.40
R-4 EIFS	Polymer based exterior insulation and finish system, field applied, 1" EPS insulation	$ 7.20	$ 6.85	$ 8.76	$ 8.01	$ 8.20	$ 7.08	$ 7.68	$ 7.68		$ 15,766.20
R-8 EIFS	Polymer based exterior insulation and finish system, field applied, 2" EPS insulation	$ 7.49	$ 7.18	$ 9.13	$ 8.34	$ 8.54	$ 7.43	$ 8.02	$ 8.02		$ 16,453.62

Figure 31: Table of R.S. Means Stucco and EIFS Costs

Note that EIFS costs were researched, but not used in the cost analysis for this CASE report. Though EIFS may be used to meet the prescriptive requirements, the costs used in the study assumed use of a One-Coat Stucco System.

Pan width	Description	Bakersfield	Eureka	Oakland	Redding	Sacramento	San Diego	O&P Mean Across Regions per square foot	Average Cost Per Square Foot	Number of units in Prototype Home	Cost per Prototype Home
6-9/16 inches	Sheet Metal Cladding, aluminum, window casing, up to 6 bends, .024" thick	$ 4.05	$ 4.87	$ 5.05	$ 4.12	$ 4.29	$ 3.79	$ 4.36	$ 4.36	118.125	$ 515.22
7-9/16 inches	Sheet Metal Cladding, aluminum, window casing, up to 6 bends, .024" thick	$ 4.05	$ 4.87	$ 5.05	$ 4.12	$ 4.29	$ 3.79	$ 4.36	$ 4.36	136.125	$ 593.73
8-9/16 inches	Sheet Metal Cladding, aluminum, window casing, up to 6 bends, .024" thick	$ 4.05	$ 4.87	$ 5.05	$ 4.12	$ 4.29	$ 3.79	$ 4.36	$ 4.36	154.125	$ 672.24

Figure 32: Table of R.S. Means Window Sill and Header Flashing Costs

7.2 *Energy and Cost Analysis Tables*

PKG D	Climate Zone	2x	Cavity Ins.	Exterior Ins.	Stud Spacing, in.	PROPOSED	PROPOSED	PROPOSED	PROPOSED	PROPOSED	PROP	PROP	PROP	PROP	PROP	Annual Savings per Prototype Home					TDV savings	
						TOTAL	**HEATING**	**COOLING**	FAN	DHW	KW	KWH	THERMS	MTDVElec	MTDVGas	KW	KWH	THERMS	MTDVElec	MTDVGas	kTDV/sf/yr	%
PKGD 2008	01	6	21	0	16	44.28	26.67	0	1.11	16.5	0.02	596	643	11.64	107.92							
Proposed 2013	01	6	21	4	24	40.26	22.65	0	1.11	16.5	0.02	525	586	10.34	98.36	0.00	71	57	1.30	9.56	4.0	9.1%
PKGD 2008	02	4	13	0	16	54.88	26.36	11.4	1.11	16.01	0.8	891	621	42.2	105.98							
Proposed 2013	02	6	19	4	24	45.67	19.36	9.19	1.11	16.01	0.66	696	526	34.02	89.29	0.14	195	95	8.18	16.69	9.2	16.8%
PKGD 2008	03	4	13	0	16	38.4	14.85	6.47	1.11	15.97	0.5	538	464	25.24	78.43							
Proposed 2013	03	6	19	4	24	32.79	9.37	6.34	1.11	15.97	0.49	454	391	23.14	65.39	0.01	84	73	2.10	13.04	5.6	14.6%
PKGD 2008	04	4	13	0	16	56.1	20.1	19.11	1.11	15.78	1.64	1121	532	60.99	90.48							
Proposed 2013	04	6	19	4	24	48.04	14.12	17.03	1.11	15.78	1.48	936	452	53.49	76.22	0.16	185	80	7.50	14.26	8.1	14.4%
PKGD 2008	05	4	13	0	16	36.75	19.71	0	1.11	15.93	0.02	475	536	9.29	89.94							
Proposed 2013	05	6	19	4	24	30.2	13.16	0	1.11	15.93	0.02	364	446	7.21	74.33	0.00	111	90	2.08	15.61	6.6	17.8%
PKGD 2008	06	4	13	0	16	40.61	7.17	16.86	1.07	15.51	1.42	886	354	50.6	59.05							
Proposed 2013	06	6	19	0	24	37.89	5.21	16.1	1.07	15.51	1.36	828	328	47.95	54.35	0.06	58	26	2.65	4.70	2.7	6.7%
PKGD 2008	07	4	13	0	16	32.06	1.89	13.96	1.12	15.09	1.09	617	283	41.34	45.23							
Proposed 2013	07	6	19	0	24	30.69	1.09	13.39	1.12	15.09	1.05	588	272	39.53	43.33	0.04	29	11	1.81	1.90	1.4	4.3%
PKGD 2008	08	4	13	0	16	52.08	5.42	30.27	1.08	15.31	2.51	1577	328	86.32	54.3							
Proposed 2013	08	6	19	0	24	48.99	3.87	28.73	1.08	15.31	2.39	1482	308	81.68	50.6	0.12	95	20	4.64	3.70	3.1	5.9%
PKGD 2008	09	4	13	0	16	74.54	8.22	50.05	1.07	15.2	3.92	2389	364	140.51	60.75							
Proposed 2013	09	6	19	4	24	67.28	4.94	46.07	1.07	15.2	3.63	2144	320	128.76	52.89	0.29	245	44	11.75	7.86	7.3	9.7%
PKGD 2008	10	4	13	0	16	81	9.15	55.57	1.07	15.21	4.5	2798	380	154.98	63.72							
Proposed 2013	10	6	19	4	24	72.26	5.51	50.47	1.07	15.21	4.1	2505	330	140.4	54.7	0.40	293	50	14.58	9.02	8.7	10.8%
PKGD 2008	11	6	19	0	16	122.67	20.8	85.23	1.11	15.53	5.44	4660	544	238.06	93.15							
Proposed 2013	11	6	21	4	24	115.19	17.2	81.35	1.11	15.53	5.22	4388	495	226.75	84.27	0.22	272	49	11.31	8.88	7.5	6.1%
PKGD 2008	12	6	19	0	16	86.31	21.12	48.37	1.11	15.71	3.46	2284	551	138.64	94.39							
Proposed 2013	12	6	21	4	24	80.71	17.57	46.32	1.11	15.71	3.33	2146	502	132.27	85.64	0.13	138	49	6.37	8.75	5.6	6.5%
PKGD 2008	13	6	19	0	16	121.17	18.97	85.98	1.11	15.11	5.74	4950	510	239.68	87.48							
Proposed 2013	13	6	26	4	24	110.38	15.07	79.09	1.11	15.11	5.21	4615	457	220.16	77.87	0.53	335	53	19.52	9.61	10.8	8.9%
PKGD 2008	14	6	21	0	16	109.97	18.81	74.53	1.07	15.56	5.19	4267	515	208.28	88.64							
Proposed 2013	14	6	21	4	24	104.73	16.06	72.04	1.07	15.56	5.03	4082	478	200.96	81.81	0.16	185	37	7.32	6.83	5.2	4.8%
PKGD 2008	15	6	21	0	16	161.15	1.71	144.56	1.07	13.81	8.05	10669	254	393.58	41.53							
Proposed 2013	15	6	26	4	24	152.6	1.05	136.67	1.07	13.81	7.65	10044	245	372.14	39.88	0.40	625	9	21.44	1.65	8.6	5.3%
PKGD 2008	16	6	21	0	16	94.87	38.23	38.48	1.06	17.1	3	2210	806	118.23	137.92							
Proposed 2013	16	6	21	4	24	89.86	33.08	38.62	1.06	17.1	3	2139	735	117.1	125.52	0.00	71	71	1.13	12.40	5.0	5.3%

Figure 33: Final Energy Simulation Run Results for Proposed Prescriptive Standard

7.3 *Residential Construction Forecast Details*

The Residential construction forecast dataset is data that is published by the California Energy Commission's (CEC) demand forecast office. This demand forecast office is charged with calculating the required electricity and natural gas supply centers that need to be built in order to meet the new construction utility loads. Data is sourced from the California Department of Finance and California Construction Industry Research Board (CIRB) building permits. The Department of Finance uses census years as independent data and interpolates the intermediate years using CIRB permits.

CASE stakeholders expressed concern that the Residential forecast was inaccurate compared with other available data (in 2010 CEC forecast estimate is 97,610 new units for single family and the CIRB estimate is 25,526 new units). In response to this discrepancy, HMG revised the CEC construction forecast estimates. The CIRB data projects an upward trend in construction activity for 2010-2011 and again from 2011-2012. HMG used the improvement from 2011-2012 and extrapolated the trend out to 2014. The improvement from 2011-2012 is projected to be 37%. Instead of using the percent improvement year on year to generate the 2014 estimate, HMG used the conservative value of the total units projected to be built in 2011-2012 and added this total to each subsequent year. This is the more conservative estimate and is appropriate for the statewide savings estimates. Based on this trend, the new construction activity is on pace to regain all ground lost by the recession by 2021. The multi-family construction forecasts are consistent between CEC and CIRB and no changes were made to the multi-family data.

Residential New Construction Estimate (2014)			
	Single Family	Multi-family Low Rise	Multi-family High Rise
CZ 1	378	94	-
CZ 2	1,175	684	140
CZ 3	1,224	863	1,408
CZ 4	2,688	616	1,583
CZ 5	522	269	158
CZ 6	1,188	1,252	1,593
CZ 7	2,158	1,912	1,029
CZ 8	1,966	1,629	2,249
CZ 9	2,269	1,986	2,633
CZ 10	8,848	2,645	1,029
CZ 11	3,228	820	81
CZ 12	9,777	2,165	1,701
CZ 13	6,917	1,755	239
CZ 14	1,639	726	-
CZ 15	1,925	748	-

CZ 16	1,500	583	-
Total	47,400	18,748	13,845

Figure 34: Residential construction forecast for 2014, in total dwelling units

The demand generation office publishes this dataset and categorizes the data by demand forecast climate zones (FCZ). These 16 climate zones are organized by the generation facility locations throughout California, and differ from the Title 24 building climate zones (BCZ). HMG has reorganized the demand forecast office data using 2000 Census data (population weighted by zip code) and mapped FCZ and BCZ to a given zip code. The construction forecast data is provided to CASE authors in BCZ in order to calculate Title 24 statewide energy savings impacts. Though the individual climate zone categories differ between the demand forecast published by the CEC and the construction forecast, the total construction estimates are consistent; in other words, HMG has not added to or subtracted from total construction area.

The demand forecast office provides two (2) independent data sets: total construction and decay rate. Total construction is the sum of all existing dwelling units in a given category (Single family, Multi-family low rise and Multi-family high rise). Decay rate is the number of units that were assumed to be retrofitted, renovated or demolished. The difference in total construction between consecutive years (including each year's decay rate) approximates the new construction estimate for a given year.

In order to further specify the construction forecast for the purpose of statewide energy savings calculation for Title 24 compliance, HMG has segmented all multi-family buildings into low rise and high rise space (where high rise is defined as buildings 4 stories and higher). This calculation is based on data collected by HMG through program implementation over the past 10 years. Though this sample is relatively small (711), it is the best available source of data to calculate the relative population of high rise and low rise units in a given FCZ.

Most years show close alignment between CIRB and CEC total construction estimates, however the CEC demand forecast models are a long-term projection of utility demand. The main purpose of the CEC demand forecast is to estimate electricity and natural gas needs in 2022, and this dataset is much less concerned about the inaccuracy at 12 or 24 month timeframe.

It is appropriate to use the CEC demand forecast construction data as an estimate of future years construction (over the life of the measure), however to estimate next year's construction, CIRB is a more reliable data set.

Citation

"Res Construction Forecast by BCZ v4"; Developed by Heschong Mahone Group with data sourced September, 2010 from Sharp, Gary at the California Energy Commission (CEC).