CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE)

Residential Window Efficiency

2013 California Building Energy Efficiency Standards

California Utilities Statewide Codes and Standards Team October 2011

This report was prepared by the California Statewide Utility Codes and Standards Program and funded by the California utility customers under the auspices of the California Public Utilities Commission.

Table of Contents

Table of Figures

1. Purpose

This Codes and Standards Enhancement (CASE) report regards potential changes to the 2008 California Building Energy Efficiency Standards for adoption into the 2013 Standards. It proposes revisions to the prescriptive U- factor and Solar Heat Gain Coefficient (SHGC) requirements for residential fenestration and summarizes the research supporting these revisions.

2. Overview

a. Measure Title	Residential Window Efficiency
b. Description	This CASE report proposes revisions to the fenestration requirements in the residential Prescriptive Packages C, D, and E. Code language revisions detailed in Sections 5.1, 5.2, 5.3, and 5.4 are briefly summarized below: Section 151, Table 151-C (Package D): Max U-factor = 0.32, all climate zones Max Solar Heat Gain Coefficient (SHGC) = 0.25, all climate zones except 1, 3, and 5, which have No Requirement (NR) Section 151, Table 151-B (Package C): TBD (see Section 5.2) Section 151, Table 151-D (Package E): Recommend removing this prescriptive package from the Standards Section 151(f): Add exception enabling the below prescriptive fenestration performance requirements for up to 8 square feet of skylight area (when complying using the prescriptive method): max U-factor = 0.55, max SHGC = 0.30
c. Type of Change	This CASE report proposes modifications to low-rise residential prescriptive requirements, which must be met when using the prescriptive compliance method. When using performance compliance, prescriptive requirements define the standard design (which sets the energy budget). Adoption of this proposal would result in changes to Standards Tables 151-B, C, and E (Packages C, D, and E) and Section 151(f). Changes to the Residential Alternative Calculation Manual (ACM) would be necessary only to the extent that the standard design would change to reflect the proposed revised prescriptive requirements.
d. Energy Benefits	Relative to current code-compliant residential construction, buildings built to the proposed prescriptive revisions would yield positive annual TDV savings in all climate zones, kWh savings in all climate zones, and therm savings in four climate zones. Cooling TDV and energy savings would lower peak electrical demand due to reduced air conditioning loads in all but one climate zone. This study shows that updating window prescriptive requirements as recommended is highly cost effective and results in statewide TDV savings on the order of 14% and 9% for the single-family and multi-family building prototypes, respectively. Calculated savings by evaluated prototype building and climate zone are summarized in Figure 1 and Figure 2, below. Following, Figure 3 and Figure 4 summarize calculated annual

statewide savings based on projected construction starts for the building type representing the modeled CEC prototypes. Details and the methodology behind development of the statewide construction forecast used for this CASE study are provided in the Appendix, Section 7.4.

Climate Zone	Electricity Savings (kwh/yr)	Demand Savings (kw)	Natural Gas Savings (Therms/yr)	TDV Electricity Savings (mTDV/yr)	TDV Gas Savings (mTDV/yr)
01	44.8	0.0	36.5	0.0	7.0
02	150.3	0.4	(20.8)	15.9	(3.9)
03	39.6	0.0	19.2	1.8	3.9
04	300.6	0.7	(22.1)	25.3	(4.3)
05	89.7	(0.0)	80.2	(1.0)	15.6
06	316.4	0.7	(20.0)	22.4	(4.0)
07	224.1	0.5	(13.5)	17.0	(2.6)
08	461.5	0.8	(14.6)	27.0	(2.9)
09	561.7	0.9	(15.9)	34.9	(3.2)
10	601.2	1.0	(17.6)	37.6	(3.4)
11	796.4	1.3	(14.6)	51.1	(2.7)
12	577.5	0.9	(11.9)	36.1	(2.1)
13	846.5	1.4	(7.8)	51.7	(1.5)
14	754.2	1.0	(25.9)	41.3	(5.0)
15	957.2	0.8	0.5	38.0	0.1
16	643.4	1.6	(93.2)	55.4	(18.0)

Figure 1: Energy Benefits, Single-Family Prototype D

Climate Zone	Electricity Savings (kwh/yr)	Demand Savings (kw)	Natural Gas Savings (Therms/yr)	TDV Electricity Savings (mTDV/yr)	TDV Gas Savings (mTDV/yr)
01	81.6	0.0	64.0	0.0	12.5
02	482.6	1.1	(21.6)	41.3	(4.0)
03	68.0	0.1	32.0	4.2	6.6
04	788.5	1.5	(21.6)	54.7	(4.2)
05	13.6	(0.3)	103.0	(11.9)	20.6
06	897.3	1.3	(9.7)	48.1	(2.0)
07	720.5	1.1	0.0	40.7	(0.1)
08	1,033.2	1.3	(6.3)	51.6	(1.2)
09	1,176.0	1.6	(10.4)	65.2	(2.2)
10	1,237.2	1.6	(13.2)	66.5	(2.6)
11	1,665.4	1.9	(8.4)	80.1	(1.5)
12	1,230.4	1.7	(4.2)	67.7	(0.6)
13	1,692.6	1.8	0.7	77.4	0.1
14	1,577.0	1.7	(30.6)	75.1	(5.9)
15	1,869.3	1.3	0.0	67.2	0.0
16	1,631.4	3.2	(131.5)	115.9	(25.7)

Figure 2: Energy Benefits, Multi-Family Prototype E

Climate Zone	Electricity Savings (gwh/yr)	Natural Gas Savings (million-therms/yr)	TDV Savings (mTDV/yr)
01	0.02	0.01	2,654
02	0.18	(0.02)	14,181
03	0.05	0.02	6,940
04	0.81	(0.06)	56,246
05	0.05	0.04	7,611
06	0.38	(0.02)	21,844
07	0.48	(0.03)	30,998
08	0.91	(0.03)	47,243
09	1.27	(0.04)	71,984
10	5.32	(0.16)	302,442
11	2.57	(0.05)	156,184
12	5.65	(0.12)	332,350
13	5.86	(0.05)	347,372
14	1.24	(0.04)	59,565
15	1.84	0.00	73,441
16	0.97	(0.14)	56,174
STATEWIDE	27.57	(0.68)	1,587,226

Figure 3: Statewide Energy Benefits, Single-Family

Climate Zone	Electricity Savings (gwh/yr)	Natural Gas Savings (million-therms/yr)	TDV Savings (mTDV/yr)
01	0.00	0.00	147
02	0.04	(0.00)	3,190
03	0.01	0.00	1,171
04	0.06	(0.00)	3,891
05	0.00	0.00	293
06	0.14	(0.00)	7,211
07	0.17	0.00	9,714
08	0.21	(0.00)	10,275
09	0.29	(0.00)	15,654
10	0.41	(0.00)	21,125
11	0.17	(0.00)	8,054
12	0.33	(0.00)	18,139
13	0.37	0.00	17,009
14	0.14	(0.00)	6,278
15	0.17	0.00	6,286
16	0.12	(0.01)	6,573
STATEWIDE	2.65	(0.02)	135,010

Figure 4: Statewide Energy Benefits, Low-Rise Multi-Family

e. Non-Energy Benefits	Non-energy benefits from increased window performance can include increased occupant comfort.

f. Environmental Impact

The proposed revisions promote fenestration of the same range of materials, general manufacturing and construction practices currently typical in the market. As such, and as summarized in Figure 5 below, their implementation would result in no known adverse environmental impacts, including any related to contaminants, water consumption, or water quality.

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

	Mercury	Lead	Copper	Steel	Plastic	Others (Indentify)
Per Unit Measure[1]	NC	NC	NC	NC	NC	NC
Per Prototype Building[2]	NC	NC	NC	NC	NC	NC

**For description of prototype buildings refer to Methodology, Section 3.3.2*

Figure 5: Environmental Impact, Materials

g. Technology Measures	Window products meeting the proposed prescriptive performance values are readily available from a large majority of window manufacturers and from common retail outlets. The proposed performance levels are regularly met by currently installed products in both new California homes and in the replacement window market. Vinyl, wood, fiberglass or other non- metal frame windows with low-E glass can meet the proposed prescriptive requirements. The proposed revisions will not directly affect the maintenance, longevity, or useful life of residential fenestration products available in California.
h. Performance Verification of the Proposed Measure	The currently required National Fenestration Rating Council (NFRC) labels can continue to serve as an effective performance verification tool. Builders and enforcement personnel are already trained to rely on the NFRC label to verify the U-factor and SHGC values of residential fenestration products.

i. Cost Effectiveness

The proposed prescriptive requirement revisions are calculated to be cost effective in all climate zones for the residential new construction prototype buildings evaluated. Figure 6 and
Figure 7 below summarize this study's cost-effectiveness analysis for the single and multi-family prototype buildings, respectively. Additional information is presented in Sections 3 and 4 of this report.

a	b	c		d		e		f	g	
Measure: Fenestration Prescriptive Performance Requirements, by Climate Zone	Measure Life (Years)	Additional Costs[1]– Current Measure Costs (Relative to Basecase) ($)		Additional Cost[2]– Post-Adoption Measure Costs (Relative to Basecase) ($)		PV of Additional[3] Maintenance Costs (Savings, Relative to Basecase) (PV$)		PV of[4] Energy Cost Savings – Per Proto Building (PV$)	LCC Per Prototype Building ($)	
		Per Unit (sf of window area)	Per Proto Building	Per Unit (sf of window area)	Per Proto Building	Per Unit	Per Proto Building		(c+e)-f Based on Current Costs	(d+e)-f Based on Post-Adoption Costs
1	30	$0.71	$383	$0.36	$192	$0	$0	$1,216	($833)	($1,024)
2	30	$0.71	$383	$0.36	$192	$0	$0	$2,090	($1,707)	($1,899)
3	30	$0.71	$383	$0.36	$192	$0	$0	$982	($599)	($790)
4	30	$0.71	$383	$0.36	$192	$0	$0	$3,624	($3,241)	($3,432)
5	30	$0.71	$383	$0.36	$192	$0	$0	$2,525	($2,142)	($2,334)
6	30	$0.71	$383	$0.36	$192	$0	$0	$3,184	($2,801)	($2,993)
7	30	$0.71	$383	$0.36	$192	$0	$0	$2,488	($2,105)	($2,296)
8	30	$0.71	$383	$0.36	$192	$0	$0	$4,162	($3,779)	($3,970)
9	30	$0.71	$383	$0.36	$192	$0	$0	$5,494	($5,111)	($5,303)
10	30	$0.71	$383	$0.36	$192	$0	$0	$5,920	($5,537)	($5,728)
11	30	$0.71	$383	$0.36	$192	$0	$0	$8,380	($7,997)	($8,188)
12	30	$0.71	$383	$0.36	$192	$0	$0	$5,887	($5,504)	($5,696)
13	30	$0.71	$383	$0.36	$192	$0	$0	$8,698	($8,315)	($8,506)
14	30	$0.71	$383	$0.36	$192	$0	$0	$6,294	($5,911)	($6,102)
15	30	$0.71	$383	$0.36	$192	$0	$0	$6,607	($6,224)	($6,416)
16	30	$0.71	$383	$0.36	$192	$0	$0	$6,486	($6,103)	($6,294)

Figure 6: Summary of Cost-effectiveness, Single-Family Prototype D

a	b	c		d		e		f	g	
Measure: Fenestration Prescriptive Performance Requirements, by Climate Zone	Measure Life (Years)	Additional Costs[1]– Current Measure Costs (Relative to Basecase) ($)		Additional Cost[2]– Post-Adoption Measure Costs (Relative to Basecase) ($)		PV of Additional[3] Maintenance Costs (Savings, Relative to Basecase) (PV$)		PV of[4] Energy Cost Savings – Per Proto Building (PV$)	LCC Per Prototype Building ($)	
		Per Unit (sf of window area)	Per Proto Building	Per Unit (sf of window area)	Per Proto Building	Per Unit	Per Proto Building		(c+e)-f Based on Current Costs	(d+e)-f Based on Post-Adoption Costs
1	30	$0.71	$741	$0.36	$371	$0	$0	$2,170	($1,428)	($1,799)
2	30	$0.71	$741	$0.36	$371	$0	$0	$6,461	($5,720)	($6,090)
3	30	$0.71	$741	$0.36	$371	$0	$0	$1,880	($1,139)	($1,510)
4	30	$0.71	$741	$0.36	$371	$0	$0	$8,751	($8,010)	($8,381)
5	30	$0.71	$741	$0.36	$371	$0	$0	$1,507	($765)	($1,136)
6	30	$0.71	$741	$0.36	$371	$0	$0	$7,980	($7,238)	($7,609)
7	30	$0.71	$741	$0.36	$371	$0	$0	$7,039	($6,298)	($6,669)
8	30	$0.71	$741	$0.36	$371	$0	$0	$8,739	($7,998)	($8,368)
9	30	$0.71	$741	$0.36	$371	$0	$0	$10,921	($10,180)	($10,550)
10	30	$0.71	$741	$0.36	$371	$0	$0	$11,065	($10,324)	($10,695)
11	30	$0.71	$741	$0.36	$371	$0	$0	$13,609	($12,868)	($13,238)
12	30	$0.71	$741	$0.36	$371	$0	$0	$11,608	($10,867)	($11,237)
13	30	$0.71	$741	$0.36	$371	$0	$0	$13,428	($12,687)	($13,057)
14	30	$0.71	$741	$0.36	$371	$0	$0	$11,982	($11,240)	($11,611)
15	30	$0.71	$741	$0.36	$371	$0	$0	$11,644	($10,903)	($11,273)
16	30	$0.71	$741	$0.36	$371	$0	$0	$15,622	($14,881)	($15,251)

Figure 7: Summary of Cost-effectiveness, Multi-Family Prototype E

Incremental costs to meet the proposed prescriptive requirements vary somewhat by window type (slider, fixed, sliding glass door, etc.), but across types they range from low to zero. The same incremental costs were used in analysis of both single-family and multi-family prototypes and are listed in Column c of Figure 6 and Figure 7, above. It is worth noting that as standard practice many California builders already install, and retail outlets already stock, fenestration products meeting the proposed requirements. The authors of this report estimate incremental costs after adoption in 2013 will, for the large majority of installed windows, will be at or near zero as manufacturers tailor performance of their California baseline products to even more fully align with the proposed prescriptive requirements. Conservatively, post-adoption incremental costs listed in Column d are estimated to be half of the current ones. The proposed requirements entail no known additional maintenance costs, as reflected in Column e of both above figures.

This section, as well as most of this report, regards new construction. Due to the varying vintages of existing buildings and the varying nature of their window types, quantifying expected savings for fenestration retrofits of a ‘typical’ existing prototype single or multi-family building is less feasible.

However, following the reasonable assumption that existing California buildings, including their windows, are less energy efficient than new construction, retrofit / replacement windows would therefore result in a greater savings for the same incremental cost. Thus the proposed revisions are deemed cost-effective for the retrofit/replacement market as well.	
j. Analysis Tools	The CALRES energy software tool, revised for the 2013 Standards, was used to quantify energy savings and peak reduction for the proposed revisions. No additional software enhancements are required to support this proposal.
k. Relationship to Other Measures	U-factor and SHGC values in the 2008 Standards' prescriptive packages are higher than those of the most commonly installed window products. This differential between prescriptive requirements and the typical installed products enables using the performance compliance approach to increase the project compliance margin by increasing glass area or, alternatively, to use this built in "window credit" to trade off other efficiency measures and still achieve compliance. Adoption of this CASE proposal would address both of these concerns, enabling the standard energy budget in the performance approach to reflect typically installed residential window products. The revisions proposed here will result in increased envelope efficiency and thus lower the TDV and annual energy use of a typical low-rise residential building. Thus, the extent of potential savings and cost-effectiveness of other, concurrent proposals to update envelope efficiency for the 2013 Standards will be affected by the adoption of this proposal. Vice versa is also true.

3. Methodology

The research supporting this proposal can be divided into four categories: context, market research, building energy simulations, and analysis integrating the above. The research process and methodology are outlined in this section.

3.1 Existing Requirements Review

3.1.1 2008 Title 24

The core of this CASE report addresses the prescriptive fenestration requirements found in Standards Table 151-C, also referred to as prescriptive Package D. The team evaluated the structure and content of the existing 2008 Title 24 requirements on fenestration specifications to provide a context for proposed improvements. These 2008 Title 24 requirements are explained in more detail in Section 2008 Title 24 Requirement4.1.

3.1.2 Relevant National Efficiency Standards

Nationally recognized codes and criteria that establish levels of fenestration energy efficiency were identified and reviewed, for comparison to the existing California 2008 Standards and to document movement on a national level towards more efficient windows. We sought such relevant national standards also to inform the extent of performance requirements that would be proposed through this CASE report. Details of the relevant national standards are provided in Section 4.1.

3.2 Market Study

To supplement the contextual information as well as our team's existing knowledge of the industry and market, research was carried out through the following channels.

3.2.1 Window Industry Surveys

Window product manufacturer and dealer contacts were identified via a combination of channels, including *Window and Door* Top 100 Manufacturers of 2010, CASE stakeholder lists, and industry contacts familiar to the research team. Distinct market surveys were developed for both manufacturers and dealer representatives. Effort was made to collect information from such industry contacts across company size, window frame type, and California's varied climates. Identified persons were contacted via email and/or phone to introduce the goals of the CASE research and to solicit input regarding their company's available products, performance, and costs as well as the current California market as a whole. If receptive to participating, industry contacts were emailed a link to the online survey, estimated to take 15 – 20 minutes to complete. This manufacturer and dealer/distributor survey link is provided in the Appendix, Section 7.1.1. Names of specific company and representative contacted and participating are not included in this report due to agreed upon confidentiality.

3.2.2 Retail Site Visits

The research team visited a sample of retail home improvement stores and window showrooms in late 2010 and early 2011. Specific locations are identified in the Appendix, Section 7.2.1. These visits informed research questions relating to window type and performance availability, complemented data collected in the industry and energy consultant surveys, and supported determination of appropriate code change proposals and the corresponding incremental costs of achieving them. Recorded variables collected included window size, frame material, operator type, glass type (e.g. low-e, clear), U-factor, SHGC, certifications/rating (e.g., Energy Star), manufacturer, and cost.

3.2.3 Energy Consultant Interviews

Phone interviews were conducted in March, 2011, with energy consultant contacts/companies serving large-volume home builders in California. Effort was made to include consultants working in a variety of California locations / climate zones. Nine energy consultant contacts/companies that work with production builders were identified and contacted for data on typical window specifications. Seven of these provided input by phone regarding typical window types and performance ranges being installed by their clients. The CASE team focused on consultants serving larger volume builders rather than those of custom or one-off homes, as they would likely better represent ‘typical’ California market-rate residential construction as well as a larger percentage of constructed homes. A list of contacted consultants is included in Section 7.2.2.

3.2.4 Building Department Survey

The IOU Codes and Standards team led by HMG coordinated a one-time survey of receptive California building department officials, including questions from across the range of code change proposal topics. A handful of questions relevant to residential fenestration compliance patterns were included by the authors of this report in order to better understand the typical compliance path relevant to windows.

3.2.5 Stakeholder Outreach

Stakeholder outreach and requests for input were made at official CASE stakeholder meetings in April 2010 and April 2011. The proposed code changes and request for industry input also occurred through the author’s presentation at the American Architectural Manufacturers Association (AAMA) 2010 Western Region Spring Meeting, May 5 – 6, 2010. In addition, the CEC held a public staff workshop including discussion of this proposal on May 31, 2011.

Links to documents and meeting notes from the above activities are provided in the Appendix, Section 7.2.

3.3 Energy Savings and Cost-effectiveness

3.3.1 Criteria for Evaluating Cost-Effective Solution

Energy simulation analysis was utilized to evaluate various potential proposals for revising fenestration performance requirements within the context of the following parameters/goals:

High Statewide TDV Savings

The concept of Time Dependent Valuation (TDV) was incorporated into the Standards in 2005 as means to appropriately assign value to energy savings based on the time of day and year it was saved, as well as its source (electricity or natural gas). As a metric TDV addresses the important issue of peak demand in California and serves to encourage and reward measures that save energy when it is most valuable on a statewide basis. For these reasons, TDV savings relative to the 2008 Standards was a key parameter in our analysis.

Low Life Cycle Cost (LCC)

Consultants to the CEC developed economic metrics and methodology used across the proposed CASE topics to estimate value, in present dollars, of calculated annual TDV savings resulting from proposed changes to the 2008 Standards. The variables considered, their process, and the resulting methodology are documented in their report for the CEC entitled Life-Cycle Cost Methodology (Architectural Energy Corporation, 2010).

This methodology and its factor for converting estimated annual TDV savings to 30-year present value $ savings was used to calculate the LCC of this report's proposed Standards revisions in each climate zone. Resulting LCC values below zero are cost effective. The greater the negative LCC magnitude, the greater the net savings in present dollars (or net present value, NPV) over the evaluated 30-year period.

Minimized Impact on Heating TDV Increases

The primary energy performance variables for windows are U-factor, which identifies its insulating value and its solar heat gain coefficient (SHGC) which signifies the level of incident solar radiation it prevents from entering a conditioned space. Both values are important in California climates, but SHGC has more direct impact on peak demand reduction in California's cooling climates. Lower SHGC's provide higher cooling TDV savings in hotter climates due to reducing the air conditioning loads that are a significant percentage of California's peak period electricity demand on warm days. However, low SHGC values also increase heating equipment loads and TDV, blocking wintertime solar radiation that would otherwise provide passive heating to conditioned space. Thus this CASE report's recommendations necessitated, as does window performance selection in general, balancing the TDV benefits of cooling demand savings with the heating TDV penalty in milder climates.

Consistency of Proposed Requirements across Climate Zones

To optimize theoretical potential savings one could recommend fenestration performance requirement packages specific to each climate zone. However, such an approach would not be consistent or practical with the nature of California's window product manufacturing and supply channels. Therefore this report seeks, within the context of the above goals, to recommend a small, feasible number of Package D U-factor/SHGC performance requirement package variations.

Achievable Performance Requirements across the Range of Typical Window Types

The authors recognize that fenestration operator and use types vary in their achievable energy performance. This CASE report seeks to propose requirements that can be met across the range of typical windows installed in California residential buildings.

3.3.2 Building Prototypes

Figure 8 below, describes the new construction prototype buildings used in building energy simulations for this CASE report. Neither of these prototypes includes skylights.

Prototype Building Occupancy Type	Area (Square Feet)	Number of Stories	Other Notes
Residential, Single-Family	2,700	2	Per 2008 Per Section 4.2 of Residential ACM Prototype D (see Bibliography, Section 6.1)
Residential, Multi-Family	6,960	2	8 units. Per Section 4.2 of 2008 Residential ACM Prototype E (see Bibliography, Section 6.1)

Figure 8: Summary Description of Simulated Prototype Buildings

3.3.3 Simulation Parameters and Analysis Setup

Simulation Approach

The greatest impact of the proposed revisions would be reducing fenestration U-factor and SHGC requirements for Standards' prescriptive Package D. To evaluate various U-factor and SHGC requirements and their energy impact by climate zone, the following approach was taken using the updated CALRES / MP2013 compliance software modeling tool.

1. Simulate the single-family prototype home in each climate zone for the following cases:
    a. Meeting 2008 Package D in each of the16 climate zones
    b. Incorporating various potential 2013 U-factor and SHGC performance cases (see Figure 9, below) in place of 2008 Package D requirements for all ACM prototype building vertical fenestration.

Case	Description	Performance
PKGD	2008 Package D	U=0.40 / Package D
CLEAR	Dual Glazed Clear	U=0.49 / SHGC=0.65
HSLE	High Solar Low-E	U=0.32 / SHGC=0.50
MSLE	Mid Solar Low-E	U=0.32 / SHGC=0.35
LSLE	Low Solar Low-E	U=0.32 / SHGC=0.30
ELSLE	Extra Low Solar Low-E	U=0.32 / SHGC=0.25
TAX	Tax Credit	U=0.30 / SHGC=0.25
TRIPLE	Triple MSLE	U=0.25 / SHGC=0.28

Figure 9: Summary of Evaluated Window Performance Packages

2. Analyze simulation results across all climate zones and the range of potential fenestration performance value cases using the following metrics per prototype home:
    a. TDV energy savings
    b. Life cycle cost (LCC) / net present value (NPV)
3. Filter the quantitative simulation results through the qualitative parameters/goals as described above in order to establish recommended U-factor and SHGC prescriptive requirements.

    In addition to evaluating the performance package cases shown in Figure 9, potential statewide proposal combinations varying window performance packages by climate zone were also evaluated.
4. Simulate the multi-family prototype using the proposed prescriptive requirements developed in the previous step. Quantify savings statewide and by climate zone, confirming cost-effectiveness of the proposed fenestration requirements for this building type.

5. Present TDV savings and corresponding peak demand (kW) and annual energy (kWh, therm) and savings for each prototype building resulting from the proposed requirements.

   The CALRES 2013 software calculates peak demand internally. Simulated demand for the prototype building during the 250 most demand-constrained hours (statewide) of the year, determined by the 2013 TDV development process and aligned with the 2013 revised weather data, are multiplied by TDV-weighted factors over those 250 hours. The result is the peak demand for that simulated case which, as for annual kwh and therm totals, is then compared to baseline ('standard') case results in order to calculate estimated savings.

Analysis Setup

Initially the range of window specifications defined in Figure 9 was modeled individually across all California climate zones. Based on the results of these runs, a number of "straw proposals" were developed and analyzed for their statewide impact on the prototype single-family home. Three such straw proposals are presented in Figure 10, below, developed by the CASE team per parameters described in Section 3.3.1.

In addition to optimizing savings and NPV, effort was made to minimize the number of distinct U-factor/SHGC packages. The number of such packages varies between two and three per statewide straw proposal (including ELSLE, LSLE, and HSLE as defined previously in Figure 9).

<table>
<tr><th rowspan="2">Climate Zone</th><th colspan="4">Window Performance Package</th><th rowspan="2">Climate Zone</th></tr>
<tr><th>Straw 1</th><th>Straw 2</th><th>Straw 2A</th><th>Straw 3</th></tr>
<tr><td>01</td><td>HSLE</td><td>HSLE</td><td>HSLE</td><td>HSLE</td><td>01</td></tr>
<tr><td>02</td><td>ELSLE</td><td>ELSLE</td><td>ELSLE</td><td>LSLE</td><td>02</td></tr>
<tr><td>03</td><td>HSLE</td><td>HSLE</td><td>HSLE</td><td>HSLE</td><td>03</td></tr>
<tr><td>04</td><td rowspan="12">ELSLE</td><td>ELSLE</td><td>ELSLE</td><td>LSLE</td><td>04</td></tr>
<tr><td>05</td><td>HSLE</td><td>HSLE</td><td>HSLE</td><td>05</td></tr>
<tr><td>06</td><td rowspan="11">ELSLE</td><td rowspan="10">ELSLE</td><td rowspan="3">LSLE</td><td>06</td></tr>
<tr><td>07</td><td>07</td></tr>
<tr><td>08</td><td>08</td></tr>
<tr><td>09</td><td rowspan="7">ELSLE</td><td>09</td></tr>
<tr><td>10</td><td>10</td></tr>
<tr><td>11</td><td>11</td></tr>
<tr><td>12</td><td>12</td></tr>
<tr><td>13</td><td>13</td></tr>
<tr><td>14</td><td>14</td></tr>
<tr><td>15</td><td>15</td></tr>
<tr><td>16</td><td>HSLE</td><td>HSLE</td><td>LSLE</td><td>16</td></tr>
</table>

Figure 10: Primary "Straw Proposals" Evaluated

3.4 Statewide Savings Estimates

Statewide energy savings associated with this CASE proposal are estimated by multiplying the calculated per-building prototype savings by the 2014 new construction forecast for the corresponding residential building type. This is performed for each of the 16 climates zones, and the resulting savings for each climate zone are then summed to determine total savings statewide.

Details and the methodology behind development of the statewide construction forecast are provided in the Appendix, Section 7.4.

4. Analysis and Results

4.1 Existing Requirements and Relevant National Standards

4.1.1 2008 Title 24 Requirement

The 2008 Package D prescriptive performance requirements for fenestration served as the baseline for calculating energy savings, and the requirements include the following:

- Maximum U-factor, all climate zones: 0.40
- Maximum Solar Heat Gain Coefficient (SHGC): 0.40, with the following exceptions:
    - 0.35 in climate zone 15
    - No Requirement (NR) in climate zones 1, 3, and 16
- Prescriptive performance exceptions only for tubular skylights

Per requirements outlined in the 2008 Residential ACM Manual, software approved for use in performance compliance establishes a Standard Design as the reference for calculating the energy budget for a proposed building. In climate zones where maximum U-factor and SHGC prescriptive requirements are defined, the Standard Design uses them directly. In those with no maximum SHGC requirement, compliance software uses a pre-set SHGC value in the Standard Design.

During analysis for this report, our team discovered an error in this pre-set SHGC value of 0.65 used in the 2008 performance compliance software. Practically speaking, it is not realistic for a double pane low-e window with a U-factor of 0.40 to have an SHGC higher than 0.55. Therefore, for this CASE analysis we corrected this error and instead used a Standard Design SHGC of 0.55 where applicable (climate zones where max prescriptive SHGC = 'NR') in the baseline case simulations. This adjustment better reflects performance of a market-available high solar gain, low-e window and thus provides more representative estimates of savings resulting from the proposed revisions.

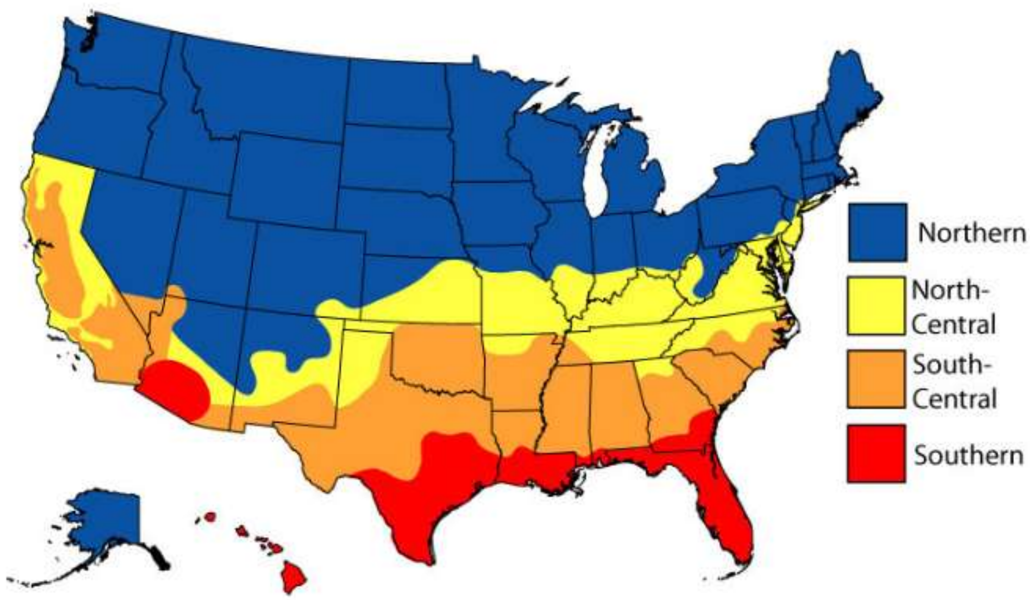
4.1.2 Relevant National Standards

Nationally recognized codes and criteria that establish levels of fenestration energy efficiency were identified and reviewed for comparison to the existing California 2008 Standards. Provisions in the most recently adopted International Energy Conservation Code (IECC 2012), the U.S. Department of Energy (DOE) and Environmental Protection Agency's (EPA) Energy Star program, and the U.S. federal tax credit criteria were especially relevant. Figure 11 below summarizes the range of recent fenestration standards, across these three national codes/programs and the various California climates. These performance standards, their ranges, and the specific California regions to which each applies are described in the following subsections.

	Energy Star	IECC (2012)	Federal Tax Credit	
			2009 - 2010	2011
U-factor (range)	0.32 - 0.40	0.32 - 0.40	0.30	(same as Energy Star)
SHGC (range)	0.30 - 0.40	0.25 - 0.40	0.30	

Figure 11: Summary of Relevant National Fenestration Performance Standards

Energy Star



North Central region: U-factor = 0.32, SHGC = 0.40
South Central region: U-factor = 0.35, SHGC = 0.30

Figure 12: ENERGY STAR Climate Zone Map

Energy Star is a federal rating/certification program, jointly run by the U.S. Department of Energy (DOE) and the Environmental Protection Agency (EPA). Its primary function is to identify energy efficient options for consumers. The Energy Star label is well established and recognized across a range of product categories, including windows.   Due to the national nature of the Energy Star program, in effect it sets a minimum standard for 'high efficiency' windows.

North Central region: U-factor = 0.32, SHGC = 0.40
South Central region: U-factor = 0.35, SHGC = 0.30

Figure 12, above, portrays the Energy Star climates and the performance criteria required by climate zone for a window product to be Energy Star-labeled. Note that the relevant climate regions to California, North and South-Central, require U-factor and SHGC levels lower than those in the 2008 Title 24 Standards.   In other words, nationally the window industry already has a more stringent performance threshold to meet than that required in California.

The International Energy Conservation Code (IECC)

The IECC is a 'model energy code' first released in 1998.   It contains minimum energy efficiency provisions for residential and commercial buildings, offering both prescriptive and performance-based approaches, as well as envelope requirements for thermal performance and air leakage. The IECC was initially developed and continues to evolve through public hearings involving national experts and coordinated by the International Code Council (ICC), as part of its family of codes including the International Building Code (IBC), International Residential Code (IRC), and others. It is readily adoptable by a state or local jurisdictions as its main energy code, or can be used as a base upon which to tailor a code to local priorities.

Recently finalized updates to the IECC's 2012 release established the minimum window performance requirements by IECC climate zone shown in Figure 13, below. U-factors are set at 0.32 in cooler California climates. In hotter regions, including those containing most of California's population, SHGC performance levels are 0.25. Similar to but even more so than with the Energy Star label performance criteria, these IECC fenestration standards are more stringent than those of the 2008 Title 24 Standards. Note that the IECC 2012 grants skylights a performance requirement exception, allowing for a maximum U-factor of 0.55 and SHGC of 0.30.

	IECC Climate Zone				
	2	3	4	5, Marine 4	6
U-factor	0.40	0.35	0.35	0.32	0.32
SHGC	0.25	0.25	0.40	NR	NR

Figure 13: IECC Climate Zone Map and Minimum Window Performance Requirements (2012)

Federal Tax Credits

The American Recovery and Reinvestment Act of 2009 (ARRA) provided for energy incentives in the form of tax credits up to $1,500 for both individuals and businesses. Among these was a potential credit for new windows meeting or exceeding the following minimum performance criteria: U-factor = 0.30; SHGC = 0.30. The Tax Relief, Unemployment Insurance Reauthorization, and Job Creation Act of 2010 continued federal tax credits for windows into 2011, but at lower financial incentive levels and with qualifying performance criteria equivalent to that of the Energy Star program (see Section 4.1.1, above).

4.2 Market Study

4.2.1 Surveys and Interviews

Window Industry

Manufacturer representatives were more receptive than those from dealers to providing input relevant to this proposal. Reps from five distinct manufacturers participated in the survey, collectively representing a significant portion of the California residential window market. Only one dealer representative, of the many contacted, responded to our invitation to contribute input via the dealer survey.

Survey feedback included confirmation that no significant technical challenges exist to producing high efficiency products at the levels considered in this proposal (the retail site visit component of our research supported this as well—see Section 4.2.2). Manufacturers already make and sell window products of similar performance. A significant percentage of California sales volume for our respondents at the time of our communication could be driven by the 2009-2010 federal tax credits, as shown in **Figure 14** below and also, again, supported by data collected through our retail site visits.

Window Performance Level	**% of CA sales volume** (estimated)	
	Manufacturers	Dealer
Meeting ENERGY STAR criteria	50 - 95%	90%
Meeting (2009-2010) Federal Tax Credit criteria	35 - 60%	80%
EXCEEDING (2009-2010) Federal Tax Credit criteria	1 - 30%	50%

Figure 14: Survey Respondents' Reported California Sales Volumes by Performance Level

The surveyed representatives also sell products in California *exceeding* federal tax credit criteria to various degrees and including both dual and triple-pane windows with U-factors from 0.20 – 0.29 and SHGC values from 0.13 – 0.25. For the same performance level, the dealer respondent reported U-factors of 0.28 – 0.30 and SHGC values from 0.19 to 0.24, both with dual-pane low-e glass.

Three out of five manufacturer respondents and the dealer provided some level of cost data, but were overall hesitant or unable to share absolute incremental costs for high performance windows. Instead, costs were typically given as a percentage increase over the baseline window named in our survey—one meeting the 2008 Title 24 Standards requirements. Note that this baseline window performance level differs from the one ultimately arrived at through the research as a whole, summarized in the following Section 4.2.4. Thus incremental costs reported through the industry surveys are relative to a baseline nonexistent in the market, making respondent's information on this topic less relevant to our research than as well as not directly comparable to incremental cost data collected through retail site visits. That said, manufacturer respondents reported a wide range of additional incremental cost above baseline (10- 30%) between meeting and exceeding the federal tax credit performance criteria. The dealer respondent, however, reported zero additional incremental cost between windows at these two performance levels.

Finally, survey respondents consistently reported a residential market sales volume skew towards retrofit / renovation over new construction, and towards single-family over multi-family. These findings are shown in Figure 15.

Low-rise Residential Market Sector	**% of CA sales volume** (estimated)	
	Manufacturers	Dealer
New Construction	20 – 50%	30%
Retrofit + Renovation	50 – 80%	70%
Single-Family	60 – 80%	65%
Multi-Family	20 – 40%	35%

Figure 15: Survey Respondents' Reported California Sales Volumes by Residential Market Sector

Energy Consultant

The CASE team interviewed industry contacts to get data on window specifications they have reviewed or proposed in recent projects. These interviews confirmed findings from other research channels that the baseline windows installed in California are better performing than required by current (2008) Title 24 Standards. Low-e glass is the norm, and U-factors / SHGC of 0.35 / 0.35 are basically default values. While not universal, SHGC values in the low to mid-0.20's are common and, for some builders the interviewees work with, already standard practice.

Building Departments

Relative to this topic, California building department staff were asked regarding the frequency of residential compliance via the prescriptive path. The thirty-four responses are tabulated in Figure 16, below.

Approximately, how many residential permits were filed over the past 4 years used the prescriptive method?		
Answer Options	**Response Percent**	**Response Count**
None (0%)	9%	3
Very few (1-10%)	41%	14
Few (11-40%)	24%	8
Many (41-80%)	15%	5
Most (81-100%)	12%	4

Figure 16: Building Department Survey, Frequency of Prescriptive Compliance

The main take-away from Figure 16 is that 74% of respondents estimate few to none of the residential building permits processed at their jurisdiction complied with Title 24 Standards using the prescriptive approach. Looked at another way, this data confirms our hypothesis that the performance method is the predominant compliance path for permitted residential construction. This confirmation supports updating the fenestration prescriptive standards at least to the actual market performance baseline in order to remove the 'built-in' window compliance credit. Such credit, which can be traded off against other efficiency measures, results from a market baseline but better-than-code windows being installed as the default and, when compared to the 2008 Package D requirements reflected in the performance approach Standard Design, indicating efficiency 'savings' above a non-existent typical window product.

4.2.2 Retail Site Visits

As described in Section 3.2.2, data collection research included visits to several retail locations to documented in-stock and display windows. All observed windows were dual-pane, and most were low-e glass. The distribution of their U-factor and SHGC performance values are provided in the following figures, Figure 17 and Figure 18, respectively.

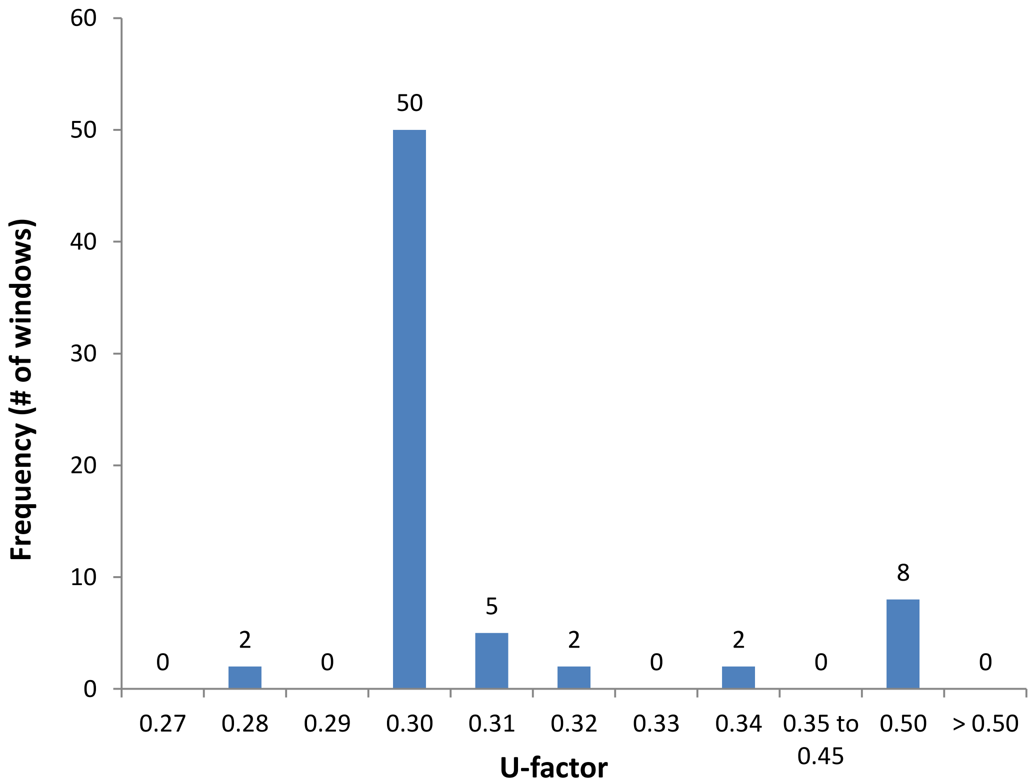


Figure 17: Retail Site Visits, Product Histogram: U-factor

As Figure 17 conveys, most windows (75%) had U-factors at or below 0.32. The eight products with U-factors between 0.45 and 0.50 were clear glass varieties.

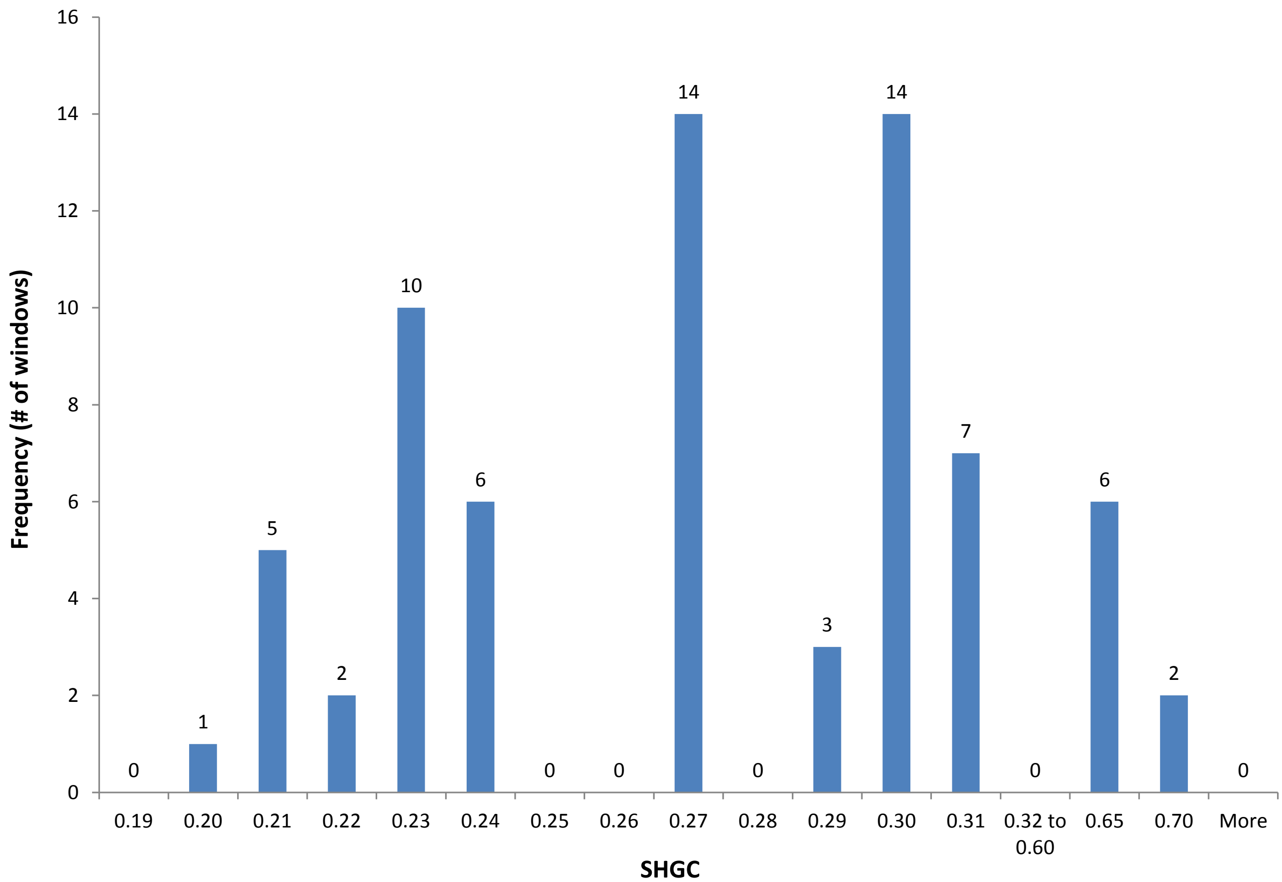


Figure 18: Retail Site Visits, Product Histogram: SHGC

The distribution of SHGC values across observed in-stock retail windows is shown in Figure 18, above. 34% of SHGC performance values were at 0.24 or lower, and 79% were at or below 0.30, similar to the percentage of window U-factors below 0.30. U-factor = 0.30/SHGC = 0.30 are together the minimum qualification levels for the 2010 federal tax credits, which had just ended at the time of our data collection. It is apparent that manufacturers and the retail outlets responded to the tax credit criteria in their production and inventory decisions. Most windows also carried the Energy Star label.

Costs per square foot of window for low-e glass products varied only slightly across the range of U-factors and SHGC values shown in the figures above. In some cases the higher performance window actually cost the same or less than a lower performance window. Overall, collected data shows that incremental costs of production and to end-use consumers due to varying performance levels of low-e windows are small to none. Incremental costs used in our cost-effectiveness analysis are based primarily on these retail site visits and are included in Figure 6 and Figure 7 of this report.

4.2.3 CEC Staff Pre-Rulemaking Workshop

Previous Standards have treated residential windows and skylights the same in regards to required prescriptive performance. However, the nature of residential skylight construction and installation does differ relative to that for windows. Stakeholders including both skylight and building industry representatives concurred that, unlike for windows as documented in this report, the level of proposed prescriptive fenestration performance is no longer equally reasonable for skylights. Potential for compliance difficulty was particularly noted in the case of small addition and/or alternation projects that include installing skylights and use the prescriptive compliance method.

The CEC workshop follow-up included additional discussions with industry stakeholders and CEC staff, review of manufacturer and third-party (NFRC) performance data for existing skylight products, and consideration of skylight requirements in other codes and standards, namely the IECC 2012 (see Section 0.0.0, above). The authors' experience as well as industry input indicate that skylights are infrequently implemented in production-level residential new construction. The market for residential skylight products exists primarily in custom home new construction and the addition/alteration of existing homes.

This proposal reflects the above-described stakeholder concerns and follow-up discussions and research regarding prescriptive requirements specific to skylights.

4.2.4 Overall Findings

Collectively, the research described here documented current typical practice, including defining the baseline window in terms of the energy performance of products being typically sold/installed, confirming the availability of high performance window products, and quantifying an estimated incremental cost (relative to the existing baseline) to meet the proposed prescriptive requirements. The over-arching findings across research channels are summarized below. These findings informed the energy and cost-effectiveness analysis described in the next section as well as the requirements proposed in this report.

- Window products matching the prescriptive efficiency requirements of the 2008 Standards, Table 151-C (Package D), are difficult to find if not non-existent in the market. Even the lesser performance low-e windows installed and available for purchase typically exceed the efficiencies required by 2008 Package D.
- The 'market baseline' residential window, and that on which incremental costs outlined in Section 2(i) and described in Section 4 of this report are based, can be described as follows:
    - Installed type/characteristics: vinyl frame, double-pane air or argon-filled, low-e glass
    - Available/installed performance levels – U-factor: 0.30 – 0.35, SHGC: 0.23 – 0.35
    - Incremental costs: minimal across above typical performance levels
- The 'market baseline' residential skylight generally does not achieve equivalent performance as that of the 'market baseline' window, particularly in regards to U-factor.

4.3 Energy Simulation Analysis

Statewide TDV savings averages and the corresponding LCC for the single family prototype, weighted by percentage of construction starts by climate zone, were compared across straw proposals. Among the evaluation criteria were high statewide TDV savings, low 30-year LCC, and positive heating TDV impacts in mild climates, as discussed in Section 3.3 in greater detail. Attention was paid to achieving these goals in each climate zone as well as on a statewide basis.

Figure 19 summarizes analysis results from straw proposals 1, 2, 2A, and 3. All show significant statewide TDV savings and NPV savings, therefore all are cost-effective. Straw 2 demonstrates the strongest results in these categories, especially compared to Straw 3, as well as achieving positive NPV in all climate zones (as opposed to Straw 1). Straw 2A, different only in the window performance package for climate zone 16, falls just short of Straw 2 in both estimated savings and NPV.

Evaluated Proposal	Total TDV savings		PV Savings	Cost	NPV
	TDV kBtu/ft2	%	$	$	$
Straw 1	12.0	13.6%	$5,633	$383	$5,249
Straw 2	12.4	14.1%	$5,799	$383	$5,416
Straw 2A	12.1	13.8%	$5,675	$383	$5,292
Straw 3	12.1	13.5%	$5,652	$297	$5,355

Figure 19: Summary Comparison of Straw Proposal Simulation Statewide Results

4.4 Cost Effectiveness Results and Conclusions– New Construction

Straw 2's window performance package / climate zone combinations described in Figure 20 are recommended as 2013 Package D fenestration performance requirements. This package of requirements most successfully meets the multiple goals for the CASE as described in Section 3.3.1.

	Description
Standard	U-factor 0.40 SHGC per Package D* (no overhang)
Proposed (Straw 2)	ELSLE in CZ 2, 4, 6-16: U-factor <u>0.32</u>, SHGC <u>0.25</u> HSLE in CZ 1, 3, 5: U-factor <u>0.32</u>, SHGC <u>0.50</u>

Figure 20: Standard and Proposed Fenestration Cases

The 2008 Standards Package D served as the modeled standard design for calculating potential energy savings. SHGC was adjusted to 0.55 for the 'Standard' case in climate zones where no maximum SHGC is currently required, as described previously in Section 3.1.1.
Negative life cycle costs (LCC) resulted from the proposed requirements in all climate zones. Thus the proposed revisions are demonstrated to be cost-effective. Simulated energy saving and cost-effectiveness results for the proposed requirements for single and multi-family new construction prototype buildings across California's sixteen climate zones are further discussed in the following subsections, and summarized in Overview Section 2(i). Corresponding proposed code language is presented in Section 5 below.

4.4.1 Savings and Cost-effectiveness: Single-Family

Comparison of the single-family prototype simulation results for the 'standard' and 'proposed' cases described in Figure 20 (above), including TDV savings and cost-effectiveness, are summarized in Figure 21, below. In this figure positive $ numbers indicate savings.

	Proposed Design	Difference (Proposed - Standard)			Percent Difference (Proposed - Standard / Standard)			Net Present Value		
Climate Zone	Window Spec	Heating kTDV/ft2	Cooling kTDV/ft2	Total kTDV/ft2	Heating	Cooling	Total	Savings $	Cost $	NPV $
01	HSLE	-2.6	0.0	-2.6	-8%		-5%	$1,216	$383	$832
02	ELSLE	1.4	-5.9	-4.5	5%	-47%	-8%	$2,090	$383	$1,707
03	HSLE	-1.4	-0.7	-2.1	-8%	-16%	-5%	$982	$383	$599
04	ELSLE	1.6	-9.4	-7.8	8%	-46%	-13%	$3,624	$383	$3,241
05	HSLE	-5.8	0.4	-5.4	-28%		-14%	$2,525	$383	$2,142
06	ELSLE	1.5	-8.3	-6.8	19%	-45%	-16%	$3,184	$383	$2,801
07	ELSLE	1.0	-6.3	-5.3	46%	-42%	-16%	$2,488	$383	$2,104
08	ELSLE	1.1	-10.0	-8.9	19%	-32%	-17%	$4,162	$383	$3,778
09	ELSLE	1.2	-12.9	-11.8	13%	-25%	-15%	$5,494	$383	$5,111
10	ELSLE	1.3	-13.9	-12.7	13%	-25%	-15%	$5,920	$383	$5,537
11	ELSLE	1.0	-18.9	-17.9	5%	-22%	-14%	$8,380	$383	$7,996
12	ELSLE	0.8	-13.4	-12.6	4%	-28%	-14%	$5,887	$383	$5,504
13	ELSLE	0.5	-19.1	-18.6	3%	-22%	-15%	$8,698	$383	$8,314
14	ELSLE	1.9	-15.3	-13.5	9%	-20%	-12%	$6,294	$383	$5,911
15	ELSLE	0.0	-14.1	-14.1	-2%	-10%	-9%	$6,607	$383	$6,224
16	ELSLE	6.7	-20.5	-13.9	15%	-65%	-15%	$6,486	$383	$6,102
Statewide		1.0	-13.4	-12.4	9%	n/a	-14.1%	$5,799	$383	$5,416
Average		0.6	-10.5	-9.9	7%	-32%	-13%	$4,627	$383	$4,244
Min		-5.8	-20.5	-18.6	-28%	-65%	-17%	$982	$383	$599
Max		6.7	0.4	-2.1	46%	-10%	-5%	$8,698	$383	$8,314

Figure 21: Comparison of Proposed and Standard Simulation Results, Single Family Prototype D

The prototype home incorporating the proposed revisions (Figure 21 'Proposed' case) results in simulated TDV savings ranging from 2.1 to 18.6 TDV kBtu/sf (5 - 17%) relative to the same home built per 2008 Package D (Figure 21 'Standard' case). Factoring in weighted new construction starts by climate zone, this translates to 12.4 TDV kBtu/sf or 14.1% statewide TDV savings per prototype single-family home.

Based on incremental costs per square foot of window area summarized in Section 2(i), estimated incremental costs per prototype home was $383. The 30-year NPV of the LCC savings calculated per designated CEC methodology ranged from $599 to $8,314 across California's sixteen climate zones (see Figure 21, above). Cost-effectiveness of the proposed prescriptive requirement revisions by climate zone is summarized in Section 2(i) of this report.

Statewide Savings

Applying 2014 construction forecasts for this building type to the per-prototype savings results, estimated 2014 statewide savings equal 27.6 GWh, -0.68 million therms, and 1,587,226 TDV MBtu. Statewide savings estimates are summarized in Section 2(d) of this report. Details and the methodology for the development of the statewide construction forecast used in this CASE study are provided in the Appendix, Section 7.4.

4.4.2 Savings and Cost-effectiveness: Multi-Family

Comparison of the low-rise multi-family prototype simulation results for the 'standard' and 'proposed' cases described in Figure 20, including TDV savings and cost-effectiveness, are summarized in Figure 22, below. In this figure positive $ numbers indicate savings, not costs.

Climate Zone	Proposed Design Window Spec	Difference (Proposed - Standard)			Percent Difference (Proposed - Standard / Standard)			Net Present Value		
		Heating kTDV/ft2	Cooling kTDV/ft2	Total kTDV/ft2	Heating	Cooling	Total	Savings $	Cost $	NPV $
01	HSLE	-1.8	0.0	-1.8	-11%		-3%	$2,170	$741	$1,428
02	ELSLE	0.6	-5.9	-5.4	4%	-34%	-8%	$6,461	$741	$5,720
03	HSLE	-1.0	-0.6	-1.6	-13%	-9%	-3%	$1,880	$741	$1,139
04	ELSLE	0.6	-7.9	-7.3	7%	-28%	-10%	$8,751	$741	$8,010
05	HSLE	-3.0	1.7	-1.3	-37%	271%	-3%	$1,507	$741	$765
06	ELSLE	0.3	-6.9	-6.6	20%	-25%	-11%	$7,980	$741	$7,238
07	ELSLE	0.0	-5.9	-5.8	100%	-26%	-10%	$7,039	$741	$6,298
08	ELSLE	0.2	-7.4	-7.3	16%	-19%	-10%	$8,739	$741	$7,998
09	ELSLE	0.3	-9.4	-9.1	14%	-15%	-9%	$10,921	$741	$10,180
10	ELSLE	0.4	-9.6	-9.2	14%	-16%	-9%	$11,065	$741	$10,324
11	ELSLE	0.2	-11.5	-11.3	2%	-13%	-9%	$13,609	$741	$12,868
12	ELSLE	0.1	-9.7	-9.6	1%	-18%	-10%	$11,608	$741	$10,867
13	ELSLE	0.0	-11.1	-11.1	0%	-13%	-9%	$13,428	$741	$12,687
14	ELSLE	0.9	-10.8	-9.9	9%	-14%	-8%	$11,982	$741	$11,240
15	ELSLE	0.0	-9.7	-9.7		-7%	-5%	$11,644	$741	$10,903
16	ELSLE	3.7	-16.7	-13.0	13%	-48%	-13%	$15,622	$741	$14,881
Statewide		**0.2**	**-8.5**	**-8.3**	**n/a**	**n/a**	**-9.1%**	**$9,977**	**$741**	**$9,236**
Average		0.1	-7.6	-7.5	9%	-1%	-8%	$9,025	$741	$8,284
Min		-3.0	-16.7	-13.0	-37%	-48%	-13%	$1,507	$741	$765
Max		3.7	1.7	-1.3	100%	271%	-3%	$15,622	$741	$14,881

Figure 22: Comparison of Proposed and Standard Simulation Results, Multi-Family Prototype E

The prototype multi-family building incorporating the proposed revisions (Figure 22 'Proposed' case) results in simulated TDV savings ranging from 1.3 – 13.0 TDV kBtu/sf (3 - 13%) relative to the same home built per 2008 Package D (Figure 22 'Standard' case). Factoring in weighted new construction starts by climate zone, this translates to 8.3 TDV kBtu/sf or 9.1% statewide TDV savings per prototype multi-family building.

Based on incremental costs per square foot of window area summarized in Section 2(i), incremental cost per prototype building was $741. The 30-year NPV of the LCC savings calculated per designated CEC methodology ranged from $765 to $14,881 across California's sixteen climate zones (see Figure 22, above). Cost-effectiveness of the proposed prescriptive requirement revisions by climate zone is summarized in Section 2(i) of this report.

Statewide Savings

Applying 2014 construction forecasts for this building type to the per-prototype savings results, estimated 2014 statewide savings equal 2.65 gWh, -0.02 million therms, and 135,010 TDV MBtu.

Statewide savings estimates are summarized in Section 2(d) of this report. Details and the methodology behind development of the statewide construction forecast used in this CASE study are provided in the Appendix, Section 7.4.

4.5 Cost Effectiveness Results and Conclusions– Existing Buildings

This report does not quantify estimated potential savings from the retrofit / renovation window market, which per our collected research (see Figure 15, Section 4.2.1) currently makes up a majority of California residential window sales volume. Collected data presented here regarding window performance and availability would also be applicable to window retrofits in existing buildings. However, due to the varying vintages of existing buildings and the varying nature of their window types, identifying a 'typical' single and multi-family building for analysis is more difficult and less appropriate. Thus quantifying expected savings for fenestration retrofits of existing single or multi-family buildings is less conducive to the simulation-based approach described here.

However, following the reasonable assumption that existing California buildings, including their windows, are less energy efficient than new construction, retrofit / replacement windows would result in a greater potential savings for the same incremental cost. Thus the proposed revisions are deemed cost-effective for the retrofit/replacement market as well.

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

This section outlines code language corresponding to the proposed Standards revisions described in this report. All take place in Standards Subchapter 8, Section 151. Removed portions of the 2008 Standards are in ~~blue, crossed-out text~~. Proposed 2013 revisions are in underlined red.

5.1 2008 Package D (2013 Package A)

As described previously, revisions to prescriptive Package D make up the core of this proposal. Figure 23, below, outlines proposed code language changes to Package D. Note that the CEC staff has recently made a decision to rename the prescriptive packages and Package D as it is known to date will be referred to as Package A in the 2013 standards.

(Package D)	CLIMATE ZONE															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Maximum U-factor	~~0.40~~ 0.32	~~0.40~~ 0.32	~~0.40~~ 0.32	~~0.40~~ 0.32	~~0.40~~ 0.32	~~0.40~~ 0.32	~~0.40~~ 0.32	~~0.40~~ 0.32	~~0.40~~ 0.32	~~0.40~~ 0.32	~~0.40~~ 0.32	~~0.40~~ 0.32	~~0.40~~ 0.32	~~0.40~~ 0.32	~~0.40~~ 0.32	~~0.40~~ 0.32
Maximum SHGC	NR	~~0.40~~ 0.25	NR	~~0.40~~ 0.25	~~0.40~~ NR	~~0.40~~ 0.25	~~0.40~~ 0.25	~~0.40~~ 0.25	~~0.40~~ 0.25	~~0.40~~ 0.25	~~0.40~~ 0.25	~~0.40~~ 0.25	~~0.40~~ 0.25	~~0.40~~ 0.25	~~0.35~~ 0.25	~~NR~~ 0.25

Figure 23: Proposed Revisions to Standards Section 151, Table 151-C

Note that Figure 23 lists 'NR' (no requirement) for SHGC in heating-dominated climate zones 1, 3, and 5, rather than the 0.50 value (HSLE window—see Figure 9 and Figure 20) simulated in our straw proposals, including Straw 2 which informs the proposed revisions. Such an approach to implementing code language is consistent with past fenestration updates and familiar to the industry and market. In addition, with low-e / low-solar windows the predominant product type in the California market, the 'NR' designation also eases prescriptive compliance where a low-e / high-solar window (U-factor = 0.32 / SHGC = 0.50) may not be as available for purchase.

The SHGC = 0.50 value would, however, replace the current Standard Design value of 0.65 used to determine the energy budget for performance compliance in climate zones 1, 3, and 5. Builders in these climate zones complying via the performance approach would therefore be rewarded for using low-e / high-solar windows, and conversely need to increase efficiency in other areas to compensate for the energy penalty of using the low-solar gain windows required in all other climate zones.

5.2 2008 Package C

Package C in the 2008 Title 24 standard allows for prescriptive compliance with electric resistance space and water heating. In return it requires increased envelope efficiency as well as solar water heating to balance the increased TDV that would otherwise result. The intent is that a building built to Package C with electric heating results in equivalent energy impacts in each climate zone as one built per 2013 Package A (with natural gas heating).

The 2013 Package A baseline is not yet established. Thus a Package C resulting in equivalent energy usage as 2013 Package A cannot yet be determined. Proposed revisions to Package C will be developed and corresponding proposed code language revisions incorporated into Figure 24, below, once 2013 Package A is established.

(Package C)	CLIMATE ZONE															
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Maximum U-factor	0.38 (TBD)	0.38 (TBD)	0.38 (TBD)	0.38 (TBD)	0.38 (TBD)	0.38 (TBD)	0.38 (TBD)	0.38 (TBD)	0.38 (TBD)	0.38 (TBD)	0.38 (TBD)	0.38 (TBD)	0.38 (TBD)	0.38 (TBD)	0.38 (TBD)	0.38 (TBD)
Maximum SHGC	NR (TBD)	0.40 (TBD)	0.40 (TBD)	0.40 (TBD)	0.40 (TBD)	0.40 (TBD)	0.40 (TBD)	0.40 (TBD)	0.40 (TBD)	0.40 (TBD)	0.40 (TBD)	0.40 (TBD)	0.40 (TBD)	0.40 (TBD)	0.35 (TBD)	NR (TBD)

Figure 24: Proposed Revisions to Standards Section 151, Table 151-B (TBD)

5.3 2008 Package E

Package E, Standards Section 151, Table 151-D, appeared for the first time in the 2008 Standards. It intends to represent equivalent energy usage as Package D while allowing for higher U-factor windows. Package E balances the lower efficiency of such windows with increases in required efficiency of other prescriptive building components in order to achieve equivalent energy impacts as Package D in each climate zone.

With the significant increase in typical window performance reflected in this report's proposed revisions, not to mention Package D changes being proposed by other authors, achieving equivalent energy use through augmenting other envelope features in Package E may be difficult if not infeasible in many climate zones. The authors of this report recommend eliminating Package E as a prescriptive option in the 2013 Standards. The performance approach could instead be selected for compliance in cases where prescriptive Package E had previously been used.

If eliminating Package E is deemed not feasible, then efforts to update it can be made. As with Package C, because 2013 Package D will be affected by this report's as well as other proposed revisions, the 2013 Package D baseline is not yet established and thus a Package E resulting in equivalent energy impacts cannot yet be developed. Should they be necessary, proposed revisions to Package E and the corresponding code language would be developed once 2013 Package D is established.

5.4 Section 151(f)

Proposed revisions to Section 151(f) of the Standards are outlined below. The added exceptions for skylight performance specifications apply only to use of the prescriptive compliance method. There is no proposed change to the performance compliance methodology and thus no corresponding changes to the Residential ACM Manual. The current exception for tubular skylights would also not be affected.

Section 151(f)

…

3. **Fenestration.**

A. Installed fenestration products shall have an area weighted average U-factor equal to or lower than those shown in TABLE 151-B, TABLE 151-C, or TABLE 151-D. The U-factor of installed fenestration products shall be determined in accordance with Section 116.

EXCEPTION 1 to Section 151(f)3A: For each building, up to 3 square feet of the glazing installed in doors and up to 2 square foot of tubular skylights with dual-pane diffusers.

EXCEPTION 2 to Section 151(f)3A: For each building, up to 8 square feet of skylight with a maximum U-factor of 0.55.

…

4. **Shading.** Where TABLE 151-B, TABLE 151-C, or TABLE 151-D require a solar heat gain coefficient (SHGC), the requirements shall be met by ~~either~~ one of the following:

A. Installing fenestration products, except for skylights, that have an area weighted average SHGC equal to or lower than those shown in TABLE 151-B, TABLE 151-C, or TABLE 151-D. Skylights shall have an SHGC equal to or lower than those shown in TABLE 151-B, TABLE 151-C, or TABLE 151-D. The solar heat gain coefficient of installed fenestration products shall be determined in accordance with Section 116; or

EXCEPTION to Section 151(f)4A: For each building, up to 8 square feet of skylight with a maximum SHGC of 0.30.

B. An exterior operable louver or other exterior shading device that meets the required solar heat gain coefficient~~; or~~

…

6. Bibliography and Other Research

6.1 Documents and Resources

2008 Building Energy Efficiency Standards for California (Title 24, Section 6), and accompanying documents (http://www.energy.ca.gov/title24/2008standards/index.html), including the following:

- 2008 Building Energy Efficiency Standards for Residential and Nonresidential Buildings: http://www.energy.ca.gov/2008publications/CEC-400-2008-001/CEC-400-2008-001-CMF.PDF
- 2008 Residential Compliance Manual: http://www.energy.ca.gov/2008publications/CEC-400-2008-016/CEC-400-2008-016-CMF-REV1.PDF
- 2008 Residential Alternative Compliance Method (ACM) Approval Manual: http://www.energy.ca.gov/2008publications/CEC-400-2008-002/CEC-400-2008-002-CMF.PDF
- 2008 Reference Appendices: http://www.energy.ca.gov/2008publications/CEC-400-2008-004/CEC-400-2008-004-CMF.PDF

Architectural Energy Corporation. *Life-Cycle Cost Methodology: 2013 California Building Energy Efficiency Standards*. California Energy Commission. November 16, 2011. http://energy.ca.gov/title24/2013standards/prerulemaking/documents/general_cec_documents/2011-01-14_LCC_Methodology_2013.pdf

D&R International, Ltd. *Windows Doors, and Skylight: Draft Criteria and Analysis*. U.S. Department of Energy ENERGY STAR Program. August 6, 2008.

Energy Star program, main site: http://www.energystar.gov/

Energy Star program, window qualification criteria: http://www.energystar.gov/ia/partners/prod_development/archives/downloads/windows_doors/WindowsDoorsSkylightsProgRequirements7Apr09.pdf

Federal tax credit window criteria: http://www.energystar.gov/index.cfm?c=tax_credits.tx_index

IECC 2012 window requirements: email correspondence to Ryan Schmidt from Ken Nittler, 4/5/2011

7. Appendices

7.1 Survey Instruments

7.1.1 Manufacturer and Dealer Market Survey:

http://www.surveymonkey.com/s/Y8ZXN3S

7.2 Site Visit and Survey Contacts

7.2.1 Retail Sites

Home Depot – Colma, CA: November 30, 2010
Truitt & White window showroom – Berkeley, CA: January 26, 2011
(http://www.truittandwhite.com/win_door/)
Home Depot – Emeryville, CA: January 26, 2011
Lowe's – San Bruno, CA: January 27, 2011
Home Depot – Colma, CA: January 27, 2011
Home Depot Pro – Colma, CA: January 27, 2011

7.2.2 Survey Contacts

Energy Consultant, Company. Contact Date

Bob Seibel, Consol. March 11, 2011
Rudy Sains, Heritage Energy Group. March 11, 2011
Rick Maurer, Rick Maurer Title-24. March 11, 2011
Mark Gallant, Gallant Energy Consulting. March 11, 2011
Jeremiah Ellis Duct Testers. March 11, 2011
Bill Lilly, California Living. March 11, 2011
Bill Mattinson, SolData. March 11, 2011
Marcos Hernandez, Beutler. March 11, 2011

7.3 Stakeholder Outreach

7.3.1 CASE Residential Envelope Stakeholder meetings

Stakeholder Meeting #1 - San Ramon, CA: April 13, 2010

Agenda: http://www.h-m-g.com/T24/Res_Topics/Res_Envelope_Mtg_1/ResEnvelopeStakeholderMtg1Agenda.pdf

Presentations: http://www.h-m-g.com/T24/Res_Topics/Res_Envelope_Mtg_1/ResEnvelopeStakeholderMtg1Presentations.pdf

Meeting Notes: http://www.h-m-g.com/T24/Res_Topics/Res_Envelope_Mtg_1/Res%20Envelope%20Meeting%201%20Notes.pdf

Stakeholder Meeting #2 - Davis, CA: April 12, 2011

Agenda: http://www.h-m-g.com/T24/Res_Topics/2011.04.12MeetingDocuments/Res_Meeting2_Agenda.pdf

Presentation: http://www.h-m-g.com/T24/Res_Topics/2011.04.12MeetingDocuments/Res_4_2nd_Stakeholder_Mtg_SchmidtNittler_041111.pdf

Meeting Notes: http://www.h-m-g.com/T24/Res_Topics/2011.04.12MeetingDocuments/ResStakeholderMtg2_CondensedNotes_041211.pdf

7.3.2 CEC Staff Workshops

CEC Staff Workshop on Draft Revisions to Residential and Nonresidential 2013 Building Efficiency Standards – Sacramento, CA: May 31, 2011

Notice: http://www.energy.ca.gov/title24/2013standards/prerulemaking/notices/

Agenda:
http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/2011-05-31_workshop/2011-05-31_Agenda.pdf

Presentation:
http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/2011-05-31_workshop/presentations/Res_Windows-053111.pdf

WebEx Recording:
https://energy.webex.com/energy/onstage/playback.php?FileName=http%3A%2F%2Fwww.energy.ca.gov%2Ftitle24%2F2013standards%2Fprerulemaking%2Fdocuments%2F2011-05-31_workshop%2F20110531-2013_Building_Standards_Staff_Workshop_on_Lighting.wrf&isUTF8=1

Documents and Reports for Review:
http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/2011-05-31_workshop/review/

7.3.3 Conference Presentations

2010 AAMA Western Regional Meeting - Oakland, CA: May 5 -6, 2010
California Code Update

7.4 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 CEC's initial 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 the current trend, 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 25: Residential Construction Forecast for 2014 (in total dwelling units)

The CEC's demand generation office publishes its new construction 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.

7.4.1 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)