CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE)

Draft Measure Information Template – Design-Phase Commissioning

2013 California Building Energy Efficiency Standards

California Utilities Statewide Codes and Standards Team March 2011

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Measure Information Template: Commissioning Design Review

2013 California Building Energy Efficiency Standards

California Commissioning Collaborative, March 31, 2011

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While this measure was originally intended to look at Design Phase Commissioning, it was modified to better coordinate with the new Title 24 Part 11 (CALGreen) commissioning requirements. As such the measure focuses specifically on Commissioning Design Review. The proposed Commissioning Design Review consists of two parts. The first part is a Design Review Kickoff between owner, design team and design reviewer that occurs early in the design process to discuss project scope, schedule, design reviewer involvement and presentation of Design Review Checklists. The second part occurs just prior to the permit submittal and consists of completing the Design Review Checklist while reviewing a complete set of construction documents.

The potential savings attributed to completing a Commissioning Design Review (or more simply called Design Review) was determined through energy modeling of five prototype buildings in five climate zones. Two models were created for each prototype – the first was a code-compliant model and the second a model that included several non-code compliant measures. The estimated savings was calculated to be the difference in energy use of the two models times a savings adjustment factor. This adjustment factor accounted for the following:

- Code compliance measures chosen do not represent all possible non-compliant items;
- Only a fraction of the non-compliance issues will be present in any given building design;
- All non-compliant issues are unlikely to be identified during Design Review; and
- Design Review may result in additional best practices being identified and incorporated into design documents.

The estimated percent savings across climate zones for completing Commissioning Design Review ranges from 1.0% natural gas savings for the restaurant prototype to 9.3% natural gas savings for the large office and 1.7% electric savings for the restaurant to 5% electric savings for the small office. Full savings results are included in Section 4.1: Energy and Cost Savings. Statewide Time Dependent Valuation (TDV) energy savings are estimated to be 770,000,000 kBtu electric and 158,000,000 kBtu natural gas.

A cost of completing Design Review was estimated for each level of design review (a small building with simple mechanical systems to a large building with complex systems), with the cost ranging from $2,400 to $26,000. Applying these costs on a per square foot basis to each of the five prototype models, the life cycle cost was calculated for each prototype building, with the results ranging from -$5,000 for the retail prototype to -$257,000 for the large office. Alternatively, the benefit to cost ratio ranges from 2.6 for the retail to 7.6 for the large office.

1. Purpose

This document evaluates a proposed change to the 2008 California Building Energy Efficiency Standards. The proposed CASE measure is titled Design Phase Commissioning Code Requirements in California Title 24. The objective of this initiative is to determine recommendations for code requirements related to early design decision-making processes that will impact energy efficiency in non-residential buildings. In order to coordinate and integrate with the CALGreen (Title 24 Part 11) commissioning requirements, this measure is looking specifically at Design Phase Commissioning Design Review. As such the working title of this measure is Commissioning Design Review or more simply called Design Review.

1.1 What are current design phase commissioning requirements?

As defined by ASHRAE Guideline 0, “the Commissioning Process is a quality-oriented process for achieving, verifying, and documenting that the performance of facilities, systems and assemblies meets defined objectives and criteria.” Design phase commissioning occurs during the design stage of a project and typically involves the following:

- Owner's Project Requirements – document detailing functional requirements of project and expectations of how it will be used and operated;
- Basis of Design – document that records the concepts, calculations, decisions, and product selections used to meet the Owner’s Project Requirements;
- Commissioning Plan – document outlining organization, schedule, allocation of resources, and documentation requirements of the commissioning process;
- Construction Checklists – documents that include equipment verification, pre-installation checks, installations checks, and any negative responses;
- Design Review – review of design documents occurring at strategic times during the design process that includes a general quality review, coordination between disciplines, review for achieving the Owner’s Project Requirements, and applicability and consistency of specifications.

With the adoption of CALGreen 2010, design phase commissioning will be required on all non-residential buildings that are greater than 10,000 ft^2. However, one aspect of design phase commissioning not included in CALGreen is Design Review. Thus, this document evaluates the recommendation to add Commissioning Design Review as a 2013 Title 24 code requirement.

1.2 What is Design Review?

In this proposal, Design Review is defined as a secondary review of the construction documents (drawings and specifications) that seeks to improve compliance with existing Title 24 regulations, encourage adoption of best practices in design, and encourage designs that are constructable and maintainable. It is an opportunity for an experienced design engineer to look at a project with a fresh perspective in an effort to catch missing or unclear design information and to suggest design enhancements.

1.3 What are the benefits of Design Review?

Potential benefits of including a requirement for Design Review include the following:

- greater Title 24 compliance thus increased energy efficiency;
- greater definition of intended design and more complete design documentation;
- fewer construction problems and corrective actions needed; and
- fewer building operational problems after owner assumes occupancy.

2. Overview

a. Measure Title	Commissioning Design Review Code Requirements in California Title 24
b. Description	The proposed measure, applicable to all non-residential buildings, adds to the code requirements a Design Review process that is completed in two parts: an initial Design Review Kickoff and completion of a construction document Design Review checklist. ◆ Design Review Kickoff: meeting between owner, design team and design reviewer to discuss project scope, schedule, design reviewer involvement and presentation of Design Review Checklists ◆ Construction Document Design Review Checklist • checklist containing both compliance-related and best practice items is completed by the design reviewer; • completed checklist is submitted to the owner and design team for review; • checklist is submitted by the project team for permit application with construction documents; and • code official is responsible for ensuring checklist has been submitted. The design reviewer is required to be a licensed professional engineer. For buildings less than 10,000 ft^2, the Design Review will be completed by the engineer of record. For buildings between 10,000 and 50,000 ft^2, the Design Review will be completed by an in-house licensed engineer that is not part of the project design team. Buildings greater than 50,000 ft^2 will require Design Review by a third party licensed engineer.

c. Type of Change	This new measure would be a new mandatory requirement but would not require new language in *Building Energy Efficiency Standards for Residential and Nonresidential Buildings* - Section 10-103(a), as the existing language generally applies to all mandatory requirements. In addition, no changes would be required for existing compliance options nor would changes be required in the way trade-off calculations are made. The following documents would require modification for implementation of the proposed change: ◆ ***Nonresidential Compliance Manual***: §2.2.1 and 2.2.2: Add directions on completing Design Review checklists. Update Table 2-1 to include forms DESC-1C and DESC-2C. §9.4 Enforcement and Compliance: Add Design Review checklists to each approach and add descriptions of the two new forms (DESC-1C: Design Review Kickoff and DESC-2C: Construction Document Design Review) ◆ ***Appendix A Compliance* Forms** Modify Appendix A: Compliance Forms and Worksheets Certificate of Compliance table to include Design Review Kickoff and Design Review checklists Add a new section for Design Review and include the DESC-1C and DESC-2C forms

d. Energy Benefits	Benefits for the proposed Design Review measure will impact all building types and all climate zones. In order to estimate the overall savings for this measure, five building prototypes were modeled in five climates zones. Each prototype was developed as a 2008 Title 24 code-compliant model. A non-code-compliant model was then created that removed a series of code measures that were chosen based on experience of team members and other published reports indicating that these measures are either commonly excluded from the building design or are not detailed enough to be fully implemented during construction and building operation. Potential energy savings are calculated as follows: *Savings = (Non-Code Compliant Value – Code Compliant Value) x Savings Adjustment Factor* where the savings adjustment factor reduces the savings to account only for those savings that may be attributed directly to design review. See Section 3.3.5 Additional Adjustment Factors for an explanation of these adjustment factors. Details on the method used to choose the prototypes and climate zones are outlined in Sections 3.3.2 and 3.3.4. The first table below illustrates the weighted average of all climate zones for all five modeled buildings plus the college building whose results are extrapolated from the large office building. The weighting is based on projected new construction by climate zone for the year 2014 (as presented by HMG in the file "NonRes Construction Forecast by BCZ v7.xls").

Weighted* Average of All Climate Zones					
Prototype	**Electricity Savings (kWh/yr)**	**Demand Savings (kW)**	**Natural Gas Savings (Therms/yr)**	**TDV Electricty Savings (kBtu/yr)**	**TDV Gas Savings (kBtu/yr)**
Office-Large	87,889	95.3	4,702	2,191,663	800,014
Per SF	0.50	0.0005	0.03	12.52	4.57
Office-Small	12,320	3.5	40	313,472	7,303
Per SF	0.68	0.0002	0.00	17.42	0.41
Retail	2,439	1.1	97	65,990	17,513
Per SF	0.30	0.0001	0.01	8	2
Restaurant	4,139	1.1	184	97,084	32,824
Per SF	0.69	0.0002	0.03	16.18	5.47
School	11,951	7.0	1,196	343,306	216,067
Per SF	0.16	0.0001	0.02	4.58	2.88
College**	50,046	54.2	4,639	1,247,981	789,383
Per SF	0.29	0.0003	0.03	7.13	4.51

*Savings in each CZ are w eighted by the fraction of total SF in that CZ and then summed over all CZ's.
**College results estimated from Office-Large model.

Results for the five prototype buildings and the five modeled climate zones are presented in the following five tables.

Climate Zone 3					
Prototype	**Electricity Savings (kWh/yr)**	**Demand Savings (kW)**	**Natural Gas Savings (Therms/yr)**	**TDV Electricty Savings (kBtu/yr)**	**TDV Gas Savings (kBtu/yr)**
Office-Large	100,613	22	5,244	2,459,726	870,124
Per SF	0.5749	0.0001	0.0300	14.0556	4.9721
Office-Small	10,293	4	25	267,695	4,635
Per SF	0.5718	0.0002	0.0014	14.8719	0.2575
Retail	2,168	1	55	60,798	9,926
Per SF	0.2710	0.0001	0.0068	7.5997	1.2408
Restaurant	3,896	1	147	95,825	25,815
Per SF	0.6494	0.0002	0.0245	15.9709	4.3026
School	9,314	7	951	257,949	168,068
Per SF	0.1242	0.0001	0.0127	3.4393	2.2409

Climate Zone 6					
Prototype	**Electricity Savings (kWh/yr)**	**Demand Savings (kW)**	**Natural Gas Savings (Therms/yr)**	**TDV Electricty Savings (kBtu/yr)**	**TDV Gas Savings (kBtu/yr)**
Office-Large	107,772	107	4,325	2,582,056	723,420
Per SF	0.6158	0.0006	0.0247	14.7546	4.1338
Office-Small	11,149	4	10	289,368	1,978
Per SF	0.6194	0.0002	0.0006	16.0760	0.1099
Retail	2,668	1	17	71,155	3,083
Per SF	0.3335	0.0001	0.0021	8.8944	0.3854
Restaurant	5,214	1	81	116,195	14,350
Per SF	0.8691	0.0002	0.0134	19.3659	2.3917
School	11,835	9	472	340,337	85,425
Per SF	0.1578	0.0001	0.0063	4.5378	1.1390

Climate Zone 10					
Prototype	**Electricity Savings (kWh/yr)**	**Demand Savings (kW)**	**Natural Gas Savings (Therms/yr)**	**TDV Electricty Savings (kBtu/yr)**	**TDV Gas Savings (kBtu/yr)**
Office-Large	109,260	119	4,538	2,647,186	760,966
Per SF	0.6243	0.0007	0.0259	15.1268	4.3484
Office-Small	13,041	4	14	341,388	2,713
Per SF	0.7245	0.0002	0.0008	18.9660	0.1507
Retail	2,959	1	25	83,713	4,694
Per SF	0.3699	0.0002	0.0032	10.4641	0.5867
Restaurant	5,166	1	98	123,563	17,528
Per SF	0.8610	0.0002	0.0163	20.5938	2.9213
School	16,368	12	570	532,227	103,080
Per SF	0.2182	0.0002	0.0076	7.0964	1.3744

Climate Zone 12					
Prototype	**Electricity Savings (kWh/yr)**	**Demand Savings (kW)**	**Natural Gas Savings (Therms/yr)**	**TDV Electricty Savings (kBtu/yr)**	**TDV Gas Savings (kBtu/yr)**
Office-Large	97,494	107	5,113	2,448,565	860,426
Per SF	0.5571	0.0006	0.0292	13.9918	4.9167
Office-Small	12,899	4	29	342,888	5,359
Per SF	0.7166	0.0002	0.0016	19.0493	0.2977
Retail	2,654	1	65	77,949	12,057
Per SF	0.3318	0.0002	0.0081	9.7437	1.5071
Restaurant	4,431	1	157	110,245	28,348
Per SF	0.7386	0.0002	0.0262	18.3742	4.7247
School	14,710	10	1,016	487,136	185,350
Per SF	0.1961	0.0001	0.0135	6.4951	2.4713

Climate Zone 16					
Prototype	**Electricity Savings (kWh/yr)**	**Demand Savings (kW)**	**Natural Gas Savings (Therms/yr)**	**TDV Electricty Savings (kBtu/yr)**	**TDV Gas Savings (kBtu/yr)**
Office-Large	76,991	105	4,849	1,942,280	836,698
Per SF	0.4399	0.0006	0.0277	11.0987	4.7811
Office-Small	12,450	3	55	311,226	10,035
Per SF	0.6917	0.0002	0.0030	17.2904	0.5575
Retail	2,319	1	139	60,919	25,182
Per SF	0.2898	0.0001	0.0174	7.6149	3.1478
Restaurant	3,787	1	247	88,068	43,948
Per SF	0.6312	0.0002	0.0411	14.6781	7.3246
School	10,961	5	1,557	292,727	281,331
Per SF	0.1462	0.0001	0.0208	3.9030	3.7511

e. Non-Energy Benefits	Design Review may lead to non-energy benefits, including improved occupant comfort and indoor air quality. For example, sizing equipment closer to the true cooling load in the space will lead to improved comfort through reduced compressor cycling which will result in better control of the space humidity. Indoor air quality can be improved by ensuring that all information required for proper installation and operation of demand control ventilation is included in the plans and specifications. Variable speed motors will increase fan and motor bearing life, due to low start-up torque and operation at low speeds. Additional non-energy benefits include reduced cost of construction as a result of fewer change orders and increased construction time that results from design documents that are incomplete or unclear that causes incorrect construction which needs to be disassembled and redone.
f. Environmental Impact	This measure should have no adverse impacts on the environment. The proposed measure will reduce natural gas and electric consumption. Air quality benefits would be achieved through reduced natural gas and electric consumption.
g. Technology Measures	This measure does not require or encourage a particular technology.
h. Performance Verification of the Proposed Measure	No new types of performance verification or commissioning are required in order to assure optimum performance of the measure, as the measure is seeking to improve compliance with existing measures.

i. Cost Effectiveness

First costs will be associated with incorporating Design Review into the code requirements. The costs are shown in the table below, along with the present value of the cost savings associated with design phase Design Review. Additional detail on these costs is included in Section 3.4 - Figure 10 and Figure 11 and in Appendix 7.2. As this is not a technology-related measure, it is not expected that there will be a reduction or addition in the post-adoption cost or present value of maintenance.

a	b	c		d		e		f	g	
Measure: Design Review (for all bldg types)	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$)		PV[4] of Energy Cost Savings** – Per Proto Building (PV$)	LCC Per Prototype Building ($)	
									(c+e)-f	(d+e)-f
		Per Unit (SF)	Per Proto Building	Per Unit (SF)	Per Proto Building	Per Unit (SF)	Per Proto Building		Based on Current Costs	Based on Post-Adoption Costs
Office-Large (175000 sf)	15	$ 0.22	$38,763	$ 0.22	$38,763	0	0	$295,865	-$257,102	-$257,102
Office-Small (18000 sf)	15	$ 0.34	$6,053	$ 0.34	$6,053	0	0	$28,752	-$22,700	-$22,700
Retail (8000 sf)	15	$ 0.35	$2,810	$ 0.35	$2,810	0	0	$7,409	-$4,599	-$4,599
Restaurant (6000 sf)	15	$ 0.46	$2,768	$ 0.46	$2,768	0	0	$11,997	-$9,230	-$9,230
School (75000 sf)	15	$ 0.25	$18,699	$ 0.25	$18,699	0	0	$50,742	-$32,043	-$32,043
College (150000 sf)	15	$ 0.24	$35,291	$ 0.24	$35,291	0	0	$197,508	-$162,217	-$162,217

1 - Currently available on the market.
2 - Assume full market penetration of measure with possible reduction in unit cost over time.
3 - Initial cost of both basecase and proposed measure must include the PV of maintenance costs (savings).
4 - PV of the energy savings calculated using the 2013 LCCC Methodology report.
* Measure costs are one-time costs at the beginning of the project and include costs of designer and reviewer.
** Savings are the average TDV $ savings across all climate zones, weighted by the fraction of new construction SF in that CZ.

The results described above are the weighted average savings for all sixteen climate zones. The savings from each climate zone is weighted by the fraction of new construction floor area expected in each climate zone. Additional information on how the different climate zones were analyzed is found in Section 3: Methodology. Full results by climate zone are included in Section 4.2.

j. Analysis Tools	This measure is proposed as a mandatory requirement for all non-residential projects governed by Title 24 Part 6. As a result, this section is not relevant.
k. Relationship to Other Measures	Design Review will impact overall compliance with Title 24 energy efficiency requirements. Design Review checklists may require updates as new energy measures are added to Title 24 Part 6, 2013 code and beyond. Design phase Design Review can have an impact on compliance with the acceptance requirements of Title 24 Part 6. The Design Review can include checking that those elements required for acceptance testing (such as temperature or pressure sensors, air flow stations and control points) are included in the construction documents. The Design Review can also ensure that the acceptance requirement forms are also included in the construction documents. By including these in the drawings at the permit/bid stage, compliance with these requirements may be increased. Design review will also confirm that the CALGreen commissioning requirements of Title 24 Part 11 are clear and complete in the construction documents.

3. Methodology

As previously stated, the objective of this initiative is to determine recommendations for code requirements related to early design decision-making processes that will impact energy efficiency and optimized building operations and encourage commissioning best practices in non-residential buildings. As of January 1, 2011, the Title 24 Part 11 Green Building Standards Code (also known as CALGreen) will go into effect. In this code, non-residential buildings 10,000 ft^2 or more in size must be commissioned during the design and construction phases of the project to verify that the building systems meet the owner's project requirements. While the CALGreen requirements include typical design phase commissioning components of documenting owner's project requirements, documenting the designer's basis of design and requiring that commissioning measures be included in construction documents, there is no requirement for the typical commissioning task of completing a Design Review.

Ideally, commissioning begins in the early stages of design. Figure 1 below shows how early involvement in the design phase of a building project can generate the most influence at the least cost. It is easier and less costly to confirm that energy efficiency measures are included in the design documents prior to the bidding process rather than during construction. For example, sizing equipment and ductwork to meet space loads calculated using realistic plug load and occupancy assumptions is accomplished more easily and at less cost during early design than during permit review. Similarly, including design details to ensure that the installed pressure drop of ductwork or piping meets the design pressure drop can prevent costly equipment changes during construction or occupancy. By incorporating Design Review into Title 24 Part 6 requirements and integrating the Design Review process with the CALGreen commissioning requirements, increased compliance with existing energy efficiency requirements and incorporation of commissioning early in project design will be achieved.

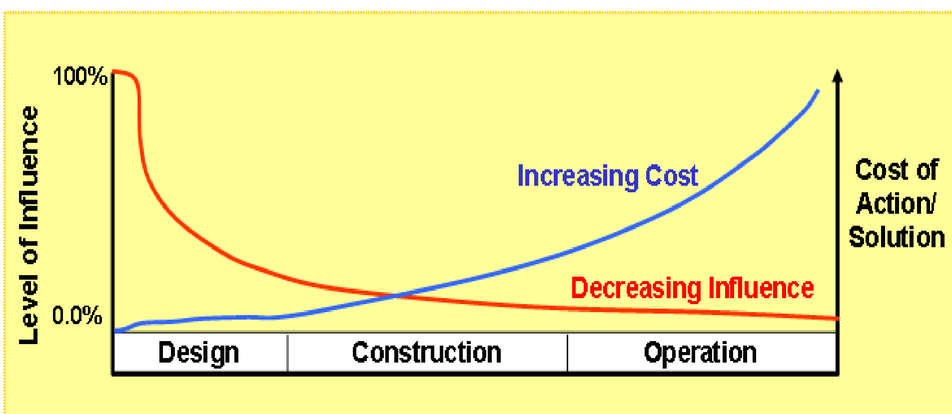

Figure 1: Level of Influence versus Design and Construction Schedule

In order to align Title 24 code requirements with industry accepted design phase commissioning practices, this measure proposes the requirement of a two-step Design Review process for all non-residential buildings. The following approach was used to develop the recommendation to include Design Review under Title 24 Part 6:

1. Perform background research;
2. Develop proposed concept for Design Review;
3. Evaluate savings potential of improved compliance through energy modeling; and
4. Evaluate cost effectiveness of Design Review using life-cycle cost analysis.

3.1 Background Research

Background research on design phase Design Review included conducting a stakeholder survey, reviewing published commissioning protocols and reviewing current Title 24 requirements (Part 6 and Part 11).

3.1.1 Stakeholder Surveys

Stakeholder surveys were completed for four groups: mechanical/electrical/plumbing (MEP) designers, commissioning providers, building owners, and code officials. Full results of the surveys can be found in Section 6.1. To summarize:

- MEP designers were generally supportive of the Design Review concept, although there was concern with adding complexity to the existing compliance process. Another commonly voiced concern was that Design Review would lead to meaningless or low-impact comments. It was also noted that in many firms there is already some form of internal review of design documents that takes place.
- As might be expected commissioning providers across the board consider Design Review to be part of a successful commissioning project. One primary concern for commissioning providers is the qualifications of the design reviewer.
- The owners interviewed had mixed experience with commissioning and found that the value of commissioning varied based on qualifications of the commissioning authority. Owners' main concern was adding time and cost to an already costly building process.
- Code officials were concerned that no additional review or compliance checks would be required, and that the design reviewer would be responsible for sign-off.

3.1.2 Published Commissioning Protocols

Several published commissioning protocols were reviewed for their inclusion of design phase components within the overall commissioning process. Resources included:

- ASHRAE Guideline 0-2005: The Commissioning Process;
- ASHRAE 189.1-2009: Standard for the Design of High-Performance Green Buildings Except Low-Rise Residential Buildings;
- 2010 California Green Building Standards Code Title 24, Part 11 (CALGreen 2010);
- International Green Construction Code (Public Version 2.0, November 2010);
- LEED 2009 (EAp1 Fundamental Commissioning of Building Energy Systems and EAc3 Enhanced Commissioning);
- Building Commissioning Guidelines: A Source Book on Building Systems Performance (Energy Design Resources);
- GSA: The Building Commissioning Guide (April 2005); and

- California Commissioning Guide: New Buildings (California Commissioning Collaborative, 2006).

Information gathered from these sources incorporated steps or components included in design phase commissioning, frequency, timing and content of Design Reviews, qualifications for design reviewers, and compliance and enforcement. Matrices summarizing these finding are found in Section 6.2. Of the resources reviewed, ASHRAE Guideline 0, ASHRAE Standard 189.1, LEED 2009 Enhanced Commissioning, and the GSA building commissioning guide all recommend Design Review as a distinct step in the commissioning process.

3.1.3 Current Title 24 Requirements

The final background piece was to examine in detail the compliance and acceptance requirements currently contained in Title 24 Part 6 and determine what synergies might exist between those requirements and design phase commissioning as defined in Title 24 Part 11 (CALGreen). The following synergies were identified:

- The commissioning authority can include acceptance testing requirements in their more comprehensive commissioning process, thus ensuring that acceptance requirements are completed and that the required forms are submitted to the enforcement agency.
- With the code required commissioning process in place deficiencies identified during acceptance tests are more likely to be properly addressed prior to occupancy.
- Design phase commissioning that includes Design Review will help to verify that system components (such as sensors, air flow stations, two-stage thermostats, etc.) required for acceptance testing are included in the project specifications.
- Design phase commissioning that includes Design Review can include reviewing CALGreen commissioning requirements and Title 24 Part 6 acceptance testing requirements for appropriateness, completeness and clarity, resulting in increased implementation and improved quality of testing.
- Design Review can include reviewing plans for compliance with significant energy code elements and confirming that assumptions used in Performance Path compliance models are reflected in the drawings and specifications.
- Design Review can include suggestions for better practice that exceeds minimum code requirements. Commissioning experience has shown that these suggestions are often accepted by designers.

3.2 Proposed Design Review

Based on the background research and engineering judgment of team members, a single Design Review that is administered in a two-step process was selected. The review would be required for all new non-residential projects that are required to obtain a permit under Title 24 Part 6.

3.2.1 Initial Schematic Review

The review consists of two steps: an initial Design Review Kickoff and a construction document phase design review. The initial review meeting would include the owner, design team and design reviewer. This meeting would include discussion of the project scope, definition of the design reviewer involvement, an outline of the approach, scheduling factors and review of the Design Review Kickoff form. The Design Review Kickoff form would be a standard form included in the *Nonresidential Compliance Manual*. Based on the reviewer's brief review of the previously obtained schematic design documents, including design assumptions and HVAC system selection, energy efficiency recommendations are listed on the form which is then signed by the design reviewer, the design engineer and the owner or owner's representative. Coming out of this first meeting, the design team will have suggestions from the Design Review Kickoff and the appropriate checklists from the *Nonresidential Compliance Manual* to consider during the design process.

3.2.2 Construction Document Review

The second part of the design review occurs during late construction documents phase. The design team provides a set of plans and specifications and a select partial set of the energy model inputs for projects following the performance path to the reviewer. Many of the needed energy model inputs will be included in the compliance report generated by approved compliance software. Those that are not will be identified in a checklist that will be included in the *Nonresidential Compliance Manual* (ideally these will be added to the compliance software report at a later date). The reviewer conducts a review of the design documents against the elements of the code included in the Design Review checklist and in the energy model input checklist.

The Design Review checklist will not contain the entire code, but will include the more important energy elements of the code, particularly those that have been known to be more frequently overlooked, like control-related components. The checklists would also confirm that the acceptance requirements of Part 6 and the CALGreen commissioning requirements of Part 11 are in the plans or specifications and will include specific suggestions for going beyond code minimums. A portion of the checklist is shown below in Figure 2**.**

Code Section	Measure	Complies	Does Not Comply	Consider Better Practice	Notes
HVAC EQUIPMENT SELECTION					
112(a)	Equipment shall meet the applicable requirements in Table 112-A through Table 112-M.				
144 (g)	Electric resistance heating systems shall not be used for space heating.				
144 (i)	No more than 100 tons air-cooled chiller capacity for chilled water plants with more than 300 tons total capacity.				
Best Practice	*In drier climates and when large outdoor air fractions are required, evaporative pre-cooling packages were evaluated to pre-cool outside air and cool the air flowing over the DX condensing unit. Pre-cooled air is then dehumidified across the unitary cooling coil.*				

Figure 2: Sample Checklist Format

The reviewer submits the completed Design Review checklist to the design firm and owner for consideration. Questions and concerns are discussed and a final version of the review is signed and submitted to the designer and owner for incorporation into the design.

The designer makes required changes to the design documents and notes each on the final Design Review checklist. This checklist is then signed by the designer and the entire checklist submitted to the jurisdiction as part of the plan submission compliance documentation. The code official is only responsible for ensuring that the form was completed and signed by a licensed engineer. No back check is required by the reviewer, though if the project is attempting to become LEED-certified or is complying with other guidelines, a back check may be required. Figure 3 below illustrates the proposed timeline and sequence of events.

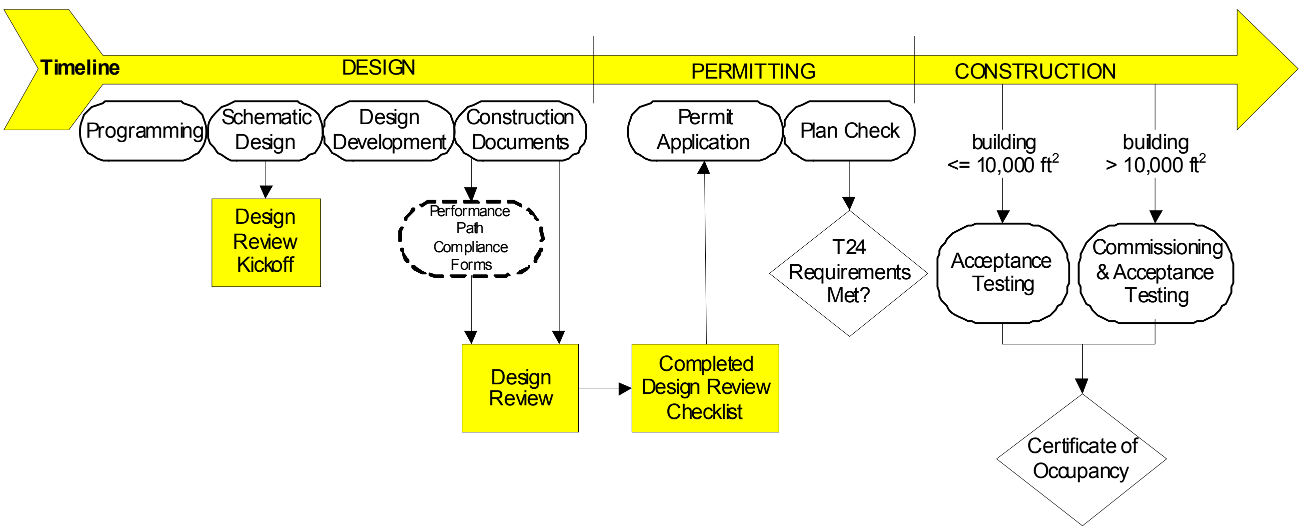

Figure 3: Proposed Timeline for Two-Part Design Review

Qualifications of the person serving as the design reviewer would also vary by size of building and complexity of system type; however, in all cases the design reviewer must be a licensed professional engineer. For small buildings (less than 10,000 ft^2) with simple systems, the design reviewer could be completed by the engineer of record (i.e. self-review) or in cases where no engineer is required, by the contractor. For larger buildings (less than 50,000 ft^2), the design reviewer should be a qualified in-house engineer with no other project involvement or a third party. For all buildings greater than 50,000 ft^2 or complex buildings less than 50,000 ft^2, the design review would need to be completed by a third party engineer. As a significant element of synergy, it is likely that a qualified commissioning lead directing the CALGreen Commissioning requirements would be well suited for the task as a third party reviewer.

Building Size	Type of Review
<10,000 ft^2	Self-review
<50,000 ft^2	In-House
>50,000 ft^2 or complex HVAC systems	Third Party

Figure 4: Type of Review

It is not intended that the Design Review would investigate the accuracy of the entire T24 code compliance submission. However, the review would include confirming that elements that have significant affects on total building energy use are in compliance with mandatory and prescriptive requirements. In addition, for projects using the performance path, the review will include confirming that selected energy model inputs are reflected in the construction documents. Design Review is potentially an additional resource to help local jurisdictions verify that advanced code requirements (such as control sequences for VAV supply air reset, etc.) are documented correctly.

Section 6.3 includes a more detailed matrix of elements evaluated in the Design Review proposal process, as well as an in-depth review of these elements.

3.3 Energy Savings Calculation Methodology

3.3.1 Energy Models

Energy models were created in eQUEST based on modified DEER 2008 and standard eQUEST wizard template models for five building types: large office, small office, retail, school and restaurant. Buildings that were included as part of this study represent 61% of the total estimated new construction in California in 2014 based on the Non-Residential Construction Forecast by Climate Zone prepared by HMG. See Appendix 7.6 for more information on buildings not modeled in eQUEST.

The five models used in the study vary in their square footage and HVAC system types (see Figure 5 below) to more accurately represent an average building of each type. The square footage variance is important for the proposed Design Review measure, as the size of building and type of system will significantly affect the potential energy savings, as well as the cost to complete the Design Review. Additional details on the model input parameters can be found in Appendix 7.1.

	Occupancy Type (Residential, Retail, Office, etc)	Area (ft^2)	Number of Stories	Other Notes
Prototype 1	Large Office	174,960	10	HVAC: Chiller, Gas Boiler, AHUs
Prototype 2	Small Office	18,000	2	HVAC: DX Rooftop Gas Pack, Variable Air Volume, Single Zone
Prototype 3	Retail	8,000	1	HVAC: DX Rooftop Gas Pack, Constant Volume, Single Zone
Prototype 4	School	75,000	1	HVAC: DX Rooftop Gas Pack, VVT, One System per Zone, Six Zones
Prototype 5	Restaurant	6,000	1	HVAC: DX Rooftop Gas Pack, Constant Volume, Single Zone
Prototype 6	College	150,000	N/A	Savings extrapolated from Large Office

Figure 5: Prototype Models

Two models of each prototype were created. The first represents the Title 24 compliant (or near compliant) energy model, also called the "base case" model. A second model, the "interactive case," removes a series of code measures that are likely to be overlooked or not included in the design documents but that could be identified in the Design Review process. The code measures are based on their potential energy savings, how commonly they occur in building design and how likely they are to not be addressed in the construction documents. The list of code measures included in the interactive models may be found in Appendix 7.2: Measures Modeled in Interactive Models.

The code measures assigned to each building type vary based on typical energy systems found in that specific building. For example, a large high rise office building has different T24 code measures than a small retail building, i.e. large built up mechanical system vs. packaged roof top units. Hence, the energy savings attributed to Design Review may vary significantly based on building type. The individual measures of the interactive case were modeled separately to allow evaluation of the significance of each measure. See Appendix 7.3: Measure Savings Charts – By Prototype for Climate Zone 3 for charts showing the energy savings by measure. All measures were modeled together in the "interactive" model for use in calculating the potential energy savings.

The code measures were determined by past design and commissioning experience of the project team and through a review of literature on Design Review (see Appendix 7.7), code compliance and retro-commissioning measures. A key resource referenced for beyond-code measures is the Design Review checklist developed by PECI and Summit Engineering (Energy Design Resources Cx Assistant Design Review Tool Module Master Reference Guide, March 2007).

3.3.2 Climate Zones Modeled

The base case and interactive models for each of the five prototypes were simulated using weather data for five climate zones. To determine how best to group the remaining eleven climate zones, two of the five prototypes (large office and retail) were modeled for all 16 climate zones. The results of total electric building electric, total electric for cooling and total gas use were compared, as shown in Figure 6 and Figure 7.

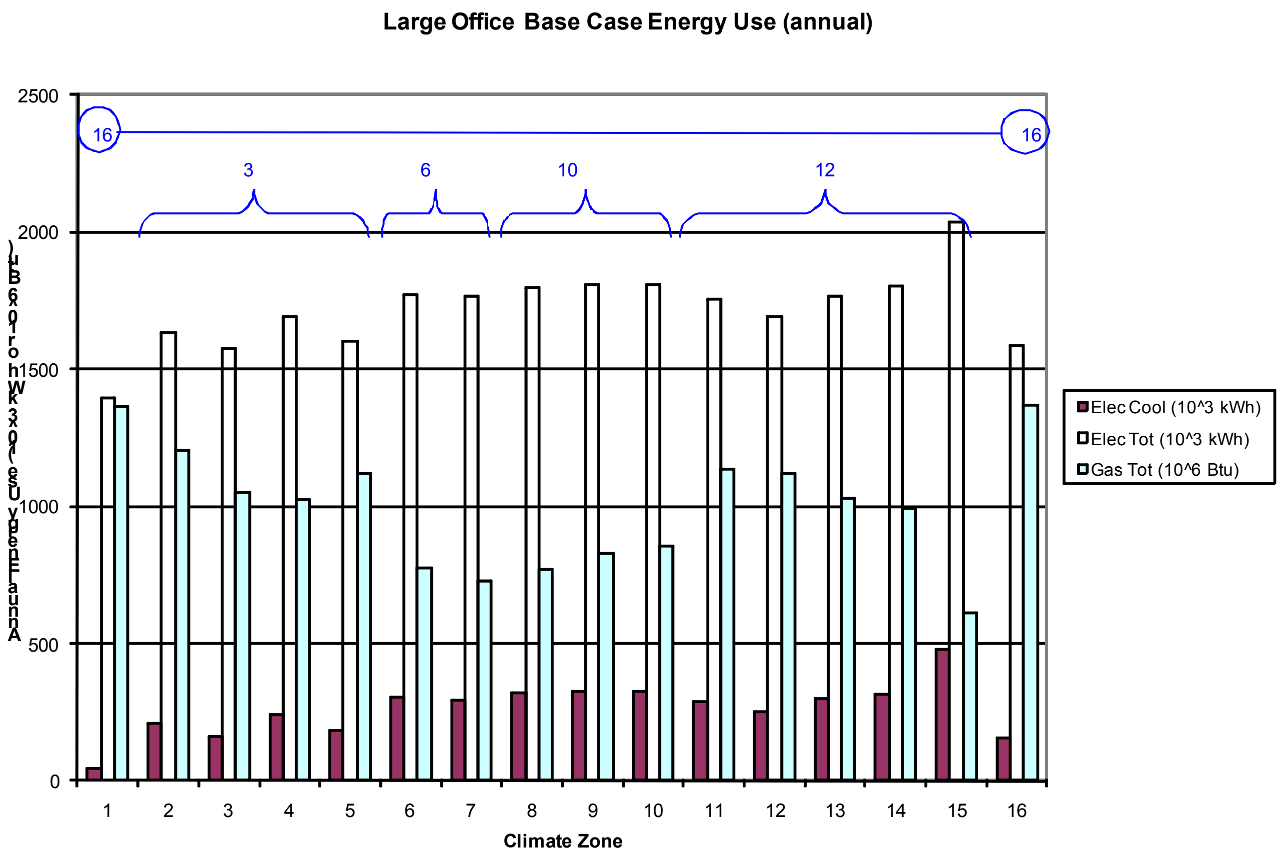

Figure 6: Climate Zone Groupings – Large Office

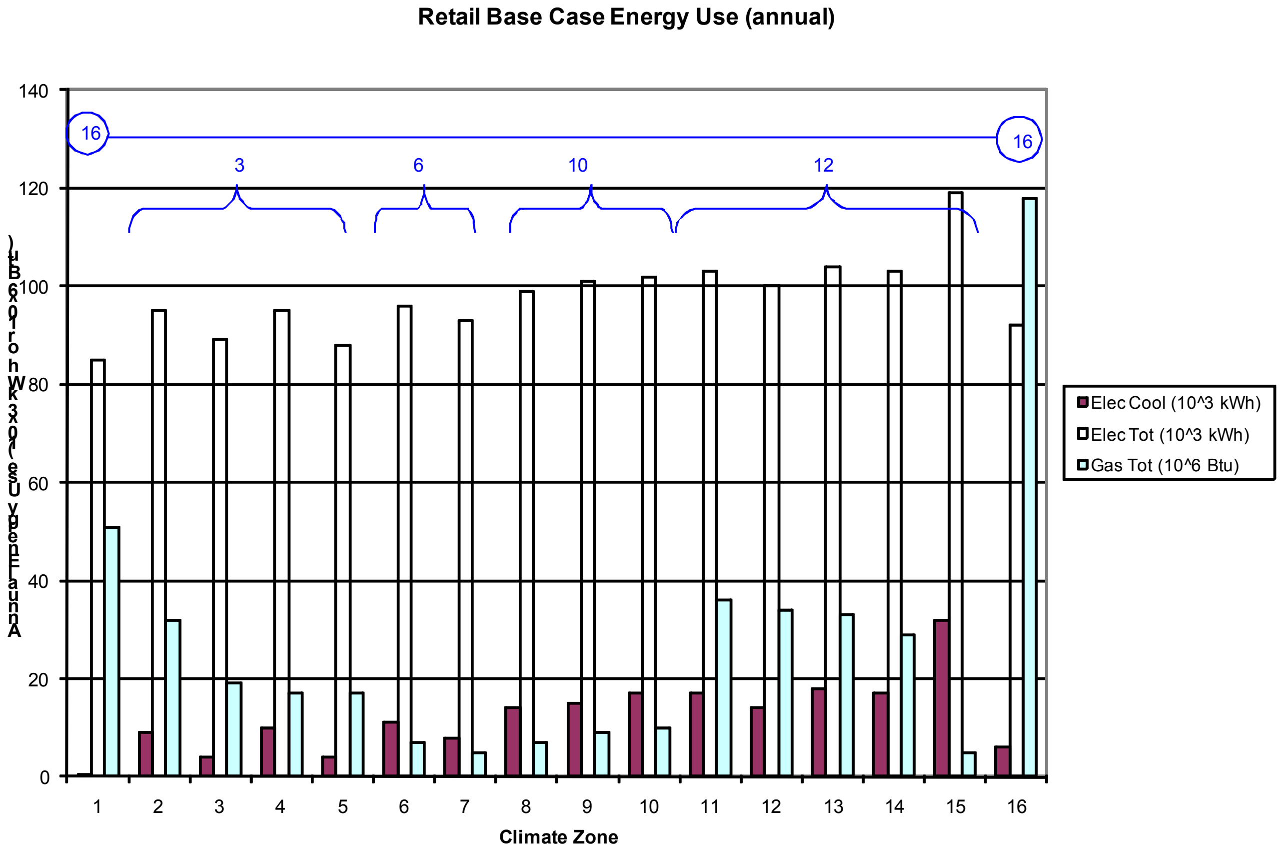

Figure 7: Climate Zone Groupings - Retail

From this comparison, it was possible to group the climate zones with the five modeled climate zones most representative of the total energy use, as shown by the brackets and modeled climate zone number at the top of each graph and in Figure 8.

Modeled Climate Zone	Grouped Climate Zones
3	2, 3, 4, 5
6	6, 7
10	8, 9, 10
12	11, 12, 13, 14, 15
16	1, 16

Figure 8: Climate Zone Groupings

3.3.3 Initial Savings Potential of Modeled Climate Zones

The savings potential of the modeled measures was calculated as the difference in energy use between the code compliant base case model and the non-compliant interactive model, based on hourly modeling output results for each of the five climate zones. The Time Dependent Valuation (TDV) energy factor for each climate zone was then applied separately to the hourly gas and electric savings results from tables of TDV factors (TDV kBTU per kWh and per therm), as provided by the CEC in the file "2011 TDV v3 110112.xls." This resulted in TDV kBtu savings for each hour of the year. As this measure assumes a 15 year life, the cost effectiveness of the proposed measure is evaluated by multiplying the annual TDV kBtu energy savings from the energy modeling by the statewide TDV net present value of $0.089/TDV kBtu.

3.3.4 Climate Zones Savings Adjustment

To estimate the savings potential of the modeled measures for the remaining eleven climate zones, these steps were followed:

1. Use the results of the large office and retail total energy use for each climate zone (see Figure 6 and Figure 7).
2. Find ratio of total electric use and total gas use of each climate zone to the representative climate zone in each group (i.e. ratio of use for climate zone 2 to climate zone 3) using data from step one and the climate zone groupings in Figure 6 and Figure 7.
3. Multiply the ratio from step two by the savings potential of the representative climate zone to find the savings potential for the climate zone in question.

Initial savings figures were then calculated for six prototype buildings over all 16 climate zones. These initial results, however, were not the final savings that could be attributed to Design Review.

3.3.5 Additional Adjustment Factors

In order to attribute potential energy savings to the proposed Design Review measure, an additional adjustment factor must be applied to the modeled measure savings. The adjustment factor assumes the following:

- the code compliance measures chosen do not represent all possible non-compliant items;
- only a fraction of the non-compliance issues will be present in any given building design;
- all non-compliant issues are unlikely to be identified during Design Review;
- Design Review may result in additional best practices being identified and incorporated into design documents; and
- natural gas measures may not be addressed as rigorously during design review as electric measures, as energy engineers and reviewers may focus more on electric measures which typically have higher cost savings.

Using engineering judgment and past commissioning and new construction review experience, the adjustment factors were determined for each of the individual prototypes. Figure 9 shows the assumptions and final adjustment factors applied to the modeled energy savings.

	Office-Large	Office-Small	Restaurant	Retail	School
Fraction of all possible measures that were modeled. [B]	0.80	0.85	0.80	0.75	0.80
Fraction of possible measures that will on average be an issue (be non-compliant at Design Review). [C]	0.15	0.15	0.15	0.20	0.20
Fraction of non-compliant measures expected to be identified at Design Review. [D]	0.80	0.90	0.90	0.80	0.90
Expected savings of Design Review causing designers to incorporate energy saving features beyond code (as a fraction of modeled impacts). [E]	0.10	0.10	0.15	0.10	0.10
Total Savings Adjustment for Elec [F] (C x D x (1+E) / B)	**0.165**	**0.175**	**0.194**	**0.235**	**0.248**
Gas measures adjustment as a % of the Elec Adjustment [G]	0.70	0.70	1.0	0.70	0.70
Total Savings Adjustment for Gas [H] (F x G)	**0.116**	**0.122**	**0.194**	**0.164**	**0.173**

Figure 9: Savings Adjustment Factors Applied to Modeled Energy Savings

3.3.6 Penetration Factor

For determining the statewide impact of Design Review, a penetration factor was applied to the new construction data before multiplying by the savings per square foot for each climate zone. The penetration rate is an average estimated over all years to account for not all jurisdictions implementing design review thoroughly. The fixed penetration rate used in this analysis was 0.70 and is assumed as an average. The actual value will be lower in earlier years and higher in later years. Annual energy savings for each climate zone and each prototype building are included in Section 4.

3.3.7 Example of Methodology for Determining Savings for Large Office

In order to illustrate the methodology used, the large office building modeled in climate zone 3 will be followed through, step by step. The first step was to take the hourly energy consumption from the eQUEST runs for the base case (code-compliant model) and the interactive case (non-code compliant model. The initial energy savings estimate is the sum over all 8,760 hours of the hourly difference in energy consumption. The initial TDV savings multiplies the previous difference by the hourly TDV values for the climate zone and energy type. So, for the electric savings the following equations apply:

$$Initial\ kWh\ savings = \sum_{hour=1}^{8760}\left(kWh_{\mathrm{int}\,eractive} - kWh_{code\,base}\right)$$

$$Initial\ TDV_E = \sum_{hour=1}^{8760}\left(kWh_{\mathrm{int}\,eractive} - kWh_{code\,base}\right)\times TDV_{E,Hour}$$

So for the first hour (January 1) the interactive model kWh use was 67.67, while the base case used only 58.31 kWh. This difference was then multiplied by the hour 1 electric TDV of 16.08 kBtu/kWh (from the file "2011 TDV v3 110112.xls" for electric, non-residential measures with a life of 15 years, as provided by the CEC):

$$Initial\ kWh\ savings_{hour1} = (67.67 - 58.31) = 9.36\, kWh$$

$$Initial\ TDV_{E,hour1} = 9.36\, kWh \times 16.08\ kBtu/kWh = 150.5\ kBtu$$

These hourly values would then be summed over all 8,760 hours per year to find the total initial savings value. However, not all of these savings can be attributed to Design Review, for the reasons discussed previously. To find the final savings figures, the hourly savings values must be multiplied by a savings adjustment factor. For the large office, this adjustment was found to be 0.165.

$$Final\ kWh\ savings = \sum_{hour=1}^{8760} \left(kWh_{interactive} - kWh_{codebase}\right) \times Savings\ Adjustment\ Factor$$

$$Final\ TDV_E = \sum_{hour=1}^{8760} \left(kWh_{interactive} - kWh_{codebase}\right) \times TDV_{E,Hour} \times Savings\ Adjustment\ Factor$$

Using the previous equations for the electric savings, the large office final electric kWh and TDV savings values are found as follows:

$$Final\ kWh\ savings = (2{,}183{,}782 - 1{,}574{,}009) \times 0.165 = 100{,}613\ kWh/yr$$

$$Final\ TDV_E = 14{,}907{,}430 \times 0.165 = 2{,}459{,}726\ kBtu/yr$$

A similar process was used to determine the demand savings and natural gas savings. The TDV present value of savings was found by multiplying the electric and gas TDV kBtu values by $0.089/kBtu.

The results of the climate zone 3 model were used to determine the savings values for climates 2, 4 and 5 as well. Using the data from Figure 6: Climate Zone Groupings – Large Office and applying it to climate zone 2, the savings of climate zone 3 would be multiplied by 1.05 (the ratio of 1636 MWh of electric use in climate zone 2 to 1574 MWh in climate zone 3, from the base case modeling of the large office prototype). Thus the climate zone 2 electric savings are:

$$Final\ kWh\ savings = 100{,}613 \times 1.05 = 105{,}986\ kWh/yr$$

$$Final\ TDV_E = 2{,}459{,}726 \times 1.04 = 2{,}591{,}083\ kBtu/yr$$

This same procedure was used to find the final savings numbers for all remaining climate zones, see Section 2.d for full results of TDV electricity savings by prototype and climate zone.

Statewide savings figures were calculated using the savings per square foot for each prototype building, and multiplying this figure by the projected new construction for the year 2014 for each climate zone. See Figure 14 for the statewide savings summary by prototype.

3.4 Determining Cost Effectiveness

Cost effectiveness of adding a Design Review requirement will be determined as described in *Life-Cycle Cost Methodology: 2013 California Building Energy Efficiency Standards*. The savings estimates from Section 2.d and the estimated cost of implementing Design Review will be used to determine the overall cost effectiveness of Design Review.

The cost premium for adding Design Review to the Title 24 Part 6 requirements is the added cost of having a design reviewer conduct a two-step design review. In addition, there will be a small additional cost for including the project designer and building owner in the schematic Design Review meeting and in discussing the results of the construction document review. Estimates are provided for three scenarios:

- a small building (<10,000 ft^2) with simple mechanical systems in which the Design Review is completed by the project design engineer,
- a medium sized building (between 10,000 and 50,000 ft^2) with the review completed by an in-house engineer, and
- a building larger than 50,000 ft^2 with the Design Review completed by a third party engineer.

The estimated time and associated cost of completing the Design Review for the three scenarios is presented in Figure 10.

	Project and Review Type	Total Cost*	Avg. Cost/sf***
1	Small and Simple Projects (<10k sf) (self review)	$2400	$ 0.48
2	Moderate Project (10-50k sf) (in-house review by design firm)	$6050 - $9650	$ 0.27
3	Large or Complex (>50k sf) (independent 3rd party review)**	$19450 - $26050	$ 0.22

**On large / complex projects, the total cost shown is split about even between the designer and the independent reviewer.
***Average cost is the average cost/sf over the range of sf (Large is 50-300k sf). Refer to Table A-6 in Appendix for a details.
Based on a loaded labor rate of $150/hr.
Costs are one-time review costs at the beginning of the project.

Figure 10: Design Review Cost Summary

Figure 11 shows the costs by square footage that would be associated with each of the five prototype buildings, based on estimates of the fraction of buildings within each category of Design Review from a 2000 California Commissioning Market Characterization Study by PECI. These figures are used in the cost effectiveness analysis included in section 4.2. Additional details on the estimated costs for completing the Design Review, including a listing of tasks assumed to be part of the project review, can be found in Appendix 7.3, Figure 33 through Figure 36.

	Fraction in Size / Type*				
	Building Type	**Small/ Simple**	**Moderate**	**Large/ Complex**	**Weighted** Avg Cost/sf**
CO	College	3%	12%	85%	$0.24
OL	Office-Large	0%	0%	100%	$0.22
OS	Office-Small	31%	69%	0%	$0.34
RE	Restaurant	91%	9%	0%	$0.46
RL	Retail	44%	32%	24%	$0.35
SC	School***	3%	40%	57%	$0.25

*Estimate of breakdown in SF areas are based on floor area breakdown for new construction in the California Commissioning Market Characterization

**Average cost is weighted by the fraction of this type of building (small, moderate, large) in the mix of the bldg type.

***School estimate from the above source appeared low in the >100k sf sector, so it was modified by actual data from Oregon that is considered more representative. The OR data showed 54%<100k; 46%>100k sf.

Figure 11: Design Review Costs by Prototype

4. Analysis and Results

Energy simulations using eQUEST were run for five prototype buildings in five climate zones for two separate cases – a code-compliant base case and a non-code-compliant interactive model. As expected, the interactive models show a significant increase in energy consumption as a result of code measures not being included in the building design. The analysis then takes these potential savings and determines what fraction could be gained by completing a Commissioning Design Review. These results, together with the estimated costs of implementing a Design Review, are used to determine the cost effectiveness of the Design Review measure.

Final savings estimates and cost effective analysis information is included in section 2 and in the following sections:

- *Energy and Cost Savings.* See section 4.1.
- *Cost-effectiveness.* See section 4.2.
- *Modeling Rules or Algorithms.* No new modeling rules or algorithms will be required for implementation of Design Review.

4.1 Energy and Cost Savings

There is significant savings potential available from implementing a code requirement for Design Review to occur during the design process. A summary of the results by prototype building for each modeled climate zone was presented in the energy savings summary tables in Section 2.d. Figure 12 is a summary of the total savings (after the savings adjustment factors have been applied) of the five prototypes for each modeled climate zone. The weighted average savings (based on 2014 new construction projections) for each prototype building is presented in Figure 13.

	OL	Office Large	OS	Office-Small	RE	Restau-rant	RL	Retail	SC	School
CZ	Elec	Gas	Elec	Gas	Elec	Gas	Elec	Gas	Elec	Gas
3	4.6%	9.4%	4.8%	4.1%	1.6%	1.0%	2.2%	10.5%	2.5%	6.4%
6	4.4%	9.6%	4.6%	3.3%	1.9%	0.6%	2.5%	9.6%	2.8%	5.4%
10	4.4%	9.5%	5.1%	3.8%	1.8%	0.7%	2.6%	10.1%	3.4%	5.6%
12	4.3%	9.2%	5.2%	3.5%	1.6%	1.1%	2.4%	8.9%	3.3%	6.2%
16	3.8%	8.7%	5.4%	2.7%	1.5%	1.5%	2.3%	6.9%	2.8%	5.4%
Ave.	**4.3%**	**9.3%**	**5.0%**	**3.5%**	**1.7%**	**1.0%**	**2.4%**	**9.2%**	**3.0%**	**5.8%**

Figure 12: Percent Savings by Utility

Weighted* Average of All Climate Zones					
Prototype	**Electricity Savings (kWh/yr)**	**Demand Savings (kW)**	**Natural Gas Savings (Therms/yr)**	**TDV Electricty Savings (kBtu/yr)**	**TDV Gas Savings (kBtu/yr)**
Office-Large	87,889	95.3	4,702	2,191,663	800,014
Per SF	0.50	0.00	0.03	12.52	4.57
Office-Small	12,320	3.5	40	313,472	7,303
Per SF	0.68	0.00	0.00	17.42	0.41
Retail	2,439	1.1	97	65,990	17,513
Per SF	0.30	0.00	0.01	8	2
Restaurant	4,139	1.1	184	97,084	32,824
Per SF	0.69	0.00	0.03	16.18	5.47
School	11,951	7.0	1,196	343,306	216,067
Per SF	0.16	0.00	0.02	4.58	2.88
College	50,046	54.2	4,639	1,247,981	789,383
Per SF	0.29	0.00	0.03	7.13	4.51

*Savings in each CZ are weighted by the fraction of total SF in that CZ and then summed over all CZ's.

Figure 13: Weighted Average Savings per Prototype

The total statewide impacts by prototype for projected new construction square footage for 2014 are shown in Figure 14. Figure 15 shows the statewide impact by climate zone and prototype building for the years 2014 through 2020.

	Electric Savings (kWh/yr)	Demand Savings (kW/mo)	Natural Gas Savings (therms/yr)	TDV-Elec (kBtu)	TDV-Gas (kBtu)	TDV - $
Office - Large	11,491,163	9,765	519	281,546,485	86,779,745	$32,781,035
Office - Small	4,313,360	1,421	7	113,033,510	1,299,069	$10,175,599
Retail	7,682,409	3,383	108	216,351,556	19,871,454	$21,023,848
Restaurant	2,891,855	696	63	68,518,591	11,294,184	$7,103,337
School	1,283,749	915	70	40,408,549	12,682,672	$4,725,119
College	2,045,495	1,873	155	50,033,396	25,981,363	$6,765,314
TOTAL	29,708,032	18,054	922	769,892,088	157,908,487	$82,574,251

Figure 14: Statewide Savings Summary by Prototype

CZ	New SF (10^6)	College			Office-Large			Office-Small			Retail			Restaurant			School		
		MWh	kW	Therm (10^3)	MWh	kW	Therm (10^3)	MWh	kW	Therm (10^3)	MWh	kW	Therm (10^3)	MWh	kW	Therm (10^3)	MWh	kW	Therm (10^3)
1	0.021	3.9	5.29	0.3	8.8	12.00	0.4	19.0	4.89	0.1	8.1	3.47	0.4	3.6	0.99	0.2	4.7	2.31	0.5
2	0.176	50	11	6.0	367	80	25.6	99	41	0.3	112	52	3.8	25	6	1.3	24	18	3.3
3	0.696	186	41	16.8	1590	346	82.9	319	131	0.8	421	195	10.6	104	24	3.9	79	60	8.1
4	0.431	123	27	9.7	974	212	44.2	236	97	0.5	295	137	6.5	57	13	1.9	55	42	4.9
5	0.084	22	5	2.0	177	39	9.0	43	18	0.1	54	25	1.3	10	2	0.4	10	8	1.0
6	0.616	177	176	12.3	906	903	36.4	327	126	0.3	602	257	3.7	326	71	5.0	86	68	3.4
7	0.382	108	107	6.3	581	579	19.6	378	145	0.3	835	357	4.4	386	84	5.0	129	102	4.3
8	0.764	218	238	12.8	1266	1384	42.8	459	142	0.4	752	316	5.2	326	76	5.0	141	100	4.0
9	1.677	484	530	32.8	2418	2644	94.4	864	267	0.9	1565	658	12.6	649	151	11.6	272	193	8.9
10	0.254	74	81	5.3	299	327	12.4	240	74	0.3	514	216	4.4	199	46	3.8	125	89	4.3
11	0.168	45	50	4.1	232	256	12.2	135	38	0.3	212	101	5.2	37	11	1.3	70	47	4.9
12	0.990	256	282	23.3	2185	2407	114.6	625	177	1.4	980	465	24.1	303	88	10.8	237	160	16.4
13	0.529	143	157	11.8	564	621	26.9	328	93	0.7	524	249	11.7	144	42	4.6	143	96	8.9
14	0.105	29	32	2.2	124	136	5.4	63	18	0.1	96	45	1.9	33	10	1.0	24	16	1.4
15	0.039	12	13	0.3	93	103	1.4	25	7	0.0	48	23	0.3	15	4	0.2	9	6	0.2
16	0.140	29	39	3.1	130	177	8.2	76	19	0.3	97	42	5.8	34	9	2.2	20	10	2.9
Total	**7.074**	**1959**	**1793**	**149**	**11916**	**10226**	**536**	**4237**	**1398**	**7**	**7117**	**3142**	**102**	**2652**	**639**	**58**	**1429**	**1019**	**77**

Values in this table combine the new construction floor area from Table A-7 with the Table B-7 series Annual Savings tables and averaged in Tables A-8 - A-10.
The New SF is the projection of total new stock. The total savings come from a fraction of the total new stock, as a 70% penetration rate for design reviews was assumed.

Figure 15: Statewide Savings Summary by Prototype and Climate Zone

Full savings results (kWh, kW, therms, TDV-electric, TDV-gas, and TDV-$) for the years 2014 through 2020 are included in Appendix 7.8: Statewide Savings Analysis for Years 2014 through 2020.

4.2 Cost Effectiveness

Based on the "Life-Cycle Cost Methodology: 2013 California Building Energy Efficiency Standards" analysis, a cost effective measure is one which reduces the overall life-cycle cost from the current base case. Using this criterion, Commissioning Design Review is cost effective for all six building types examined. Life-cycle costs range from -$5,000 for the retail prototype to -$257,000 for the large office building. See Figure 16 below for full results.

CZ	College 150000 sf				Office-Large 175000 sf				Office-Small 18000 sf				Retail 8000 sf				Restaurant 6000 sf				School 75000 sf			
	Cost $/sf & $/bldg (10^3):		$ 0.24	$ 35.3			$ 0.22	$ 38.8			$ 0.34	$ 6.1			$ 0.35	$ 2.8			$ 0.46	$ 2.8			$ 0.25	$ 18.7
	Value		LCC		Value		LCC		Value		LCC		Value		LCC		Value		LCC		Value		LCC	
	TDV $/sf	TDV $/Bldg (10^3)	$/sf	$/Bldg (10^3)	TDV $/sf	TDV $/Bldg (10^3)	$/sf	$/Bldg (10^3)	TDV $/sf	TDV $/Bldg (10^3)	$/sf	$/Bldg (10^3)	TDV $/sf	TDV $/Bldg (10^3)	$/sf	$/Bldg (10^3)	TDV $/sf	TDV $/Bldg (10^3)	$/sf	$/Bldg (10^3)	TDV $/sf	TDV $/Bldg (10^3)	$/sf	$/Bldg (10^3)
1	$0.94	$141	-$0.71	-$106	$1.20	$209	-$0.97	-$170	$1.42	$26	-$1.09	-$20	$0.81	$6	-$0.46	-$4	$1.64	$10	-$1.18	-$7	$0.55	$41	-$0.30	-$23
2	$1.60	$239	-$1.36	-$204	$1.94	$340	-$1.72	-$301	$1.43	$26	-$1.09	-$20	$0.87	$7	-$0.52	-$4	$2.04	$12	-$1.58	-$9	$0.60	$45	-$0.35	-$27
3	$1.34	$201	-$1.11	-$166	$1.69	$296	-$1.47	-$258	$1.35	$24	-$1.01	-$18	$0.79	$6	-$0.44	-$3	$1.80	$11	-$1.34	-$8	$0.51	$38	-$0.26	-$19
4	$1.37	$205	-$1.13	-$169	$1.75	$307	-$1.53	-$268	$1.44	$26	-$1.10	-$20	$0.83	$7	-$0.48	-$4	$1.88	$11	-$1.42	-$9	$0.51	$39	-$0.26	-$20
5	$1.33	$200	-$1.10	-$165	$1.69	$295	-$1.47	-$257	$1.35	$24	-$1.01	-$18	$0.79	$6	-$0.44	-$3	$1.80	$11	-$1.34	-$8	$0.50	$38	-$0.25	-$19
6	$1.30	$194	-$1.06	-$159	$1.68	$294	-$1.46	-$255	$1.44	$26	-$1.10	-$20	$0.83	$7	-$0.47	-$4	$1.94	$12	-$1.48	-$9	$0.51	$38	-$0.26	-$19
7	$1.21	$181	-$0.97	-$146	$1.59	$279	-$1.37	-$240	$1.41	$25	-$1.08	-$19	$0.81	$6	-$0.45	-$4	$1.87	$11	-$1.41	-$8	$0.48	$36	-$0.23	-$17
8	$1.23	$185	-$1.00	-$150	$1.63	$286	-$1.41	-$247	$1.67	$30	-$1.33	-$24	$0.96	$8	-$0.61	-$5	$2.01	$12	-$1.55	-$9	$0.72	$54	-$0.47	-$35
9	$1.31	$196	-$1.07	-$161	$1.70	$298	-$1.48	-$259	$1.69	$30	-$1.36	-$24	$0.98	$8	-$0.62	-$5	$2.07	$12	-$1.61	-$10	$0.74	$56	-$0.49	-$37
10	$1.34	$201	-$1.10	-$166	$1.73	$303	-$1.51	-$265	$1.70	$31	-$1.37	-$25	$0.98	$8	-$0.63	-$5	$2.09	$13	-$1.63	-$10	$0.75	$57	-$0.50	-$38
11	$1.38	$206	-$1.14	-$171	$1.74	$304	-$1.52	-$266	$1.78	$32	-$1.44	-$26	$1.03	$8	-$0.68	-$5	$2.13	$13	-$1.66	-$10	$0.83	$62	-$0.58	-$43
12	$1.33	$200	-$1.10	-$164	$1.68	$295	-$1.46	-$256	$1.72	$31	-$1.39	-$25	$1.00	$8	-$0.65	-$5	$2.06	$12	-$1.59	-$10	$0.80	$60	-$0.55	-$41
13	$1.34	$201	-$1.10	-$165	$1.71	$299	-$1.49	-$261	$1.79	$32	-$1.46	-$26	$1.03	$8	-$0.68	-$5	$2.10	$13	-$1.64	-$10	$0.81	$61	-$0.56	-$42
14	$1.31	$196	-$1.07	-$161	$1.69	$295	-$1.46	-$256	$1.80	$32	-$1.46	-$26	$1.03	$8	-$0.67	-$5	$2.08	$12	-$1.62	-$10	$0.80	$60	-$0.55	-$41
15	$1.16	$175	-$0.93	-$139	$1.64	$287	-$1.42	-$248	$2.04	$37	-$1.70	-$31	$1.08	$9	-$0.73	-$6	$2.10	$13	-$1.64	-$10	$0.77	$58	-$0.52	-$39
16	$1.15	$172	-$0.91	-$137	$1.41	$247	-$1.19	-$209	$1.59	$29	-$1.25	-$23	$0.96	$8	-$0.61	-$5	$1.96	$12	-$1.50	-$9	$0.68	$51	-$0.43	-$32
Avg:	**$1.31**	**$197**	**-$1.08**	**-$161**	**$1.69**	**$296**	**-$1.47**	**-$257**	**$1.60**	**$29**	**-$1.26**	**-$23**	**$0.93**	**$7**	**-$0.57**	**-$5**	**$2.00**	**$12**	**-$1.54**	**-$9**	**$0.68**	**$51**	**-$0.43**	**-$32**

Notes:

-Values in this table originate with the B-7 series tables for each building type.
-Design review measure has an assumed 15 yr measure life.
-Costs are one-time review costs at the beginning of the project.
-TDV value is the present value of 15 yrs of impacts of energy savings expected from the average design review.
-The LCC is the life cycle cost of the design review (cost and savings impacts) and equals Cost - TDV Value.
-Per building costs and value are for the prototype buildings.
-Avg is the average over all climate zones of the cost or value per sf or per building weighted by the fraction of total new construction floor area in each climate zone.

Figure 16: Cost Effectiveness by Prototype and Climate Zone

Another way to look at the cost effectiveness of the Design Review measure is to look at the cost benefit ratio – examining whether the benefits exceed the costs. The benefit to cost ratio is higher for the larger, more complex building types – 7.6 for the large office compared with 2.6 for retail.

CZ	College		Office-Large		Office-Small		Retail		Restaurant		School	
	Cost ($/sf):	$ 0.24		$ 0.22		$ 0.34		$ 0.35		$ 0.46		$ 0.25
	Value (TDV $/sf)	Value /Cost Ratio	Value (TDV $/sf)	Value /Cost Ratio	Value (TDV $/sf)	Value /Cost Ratio	Value (TDV $/sf)	Value /Cost Ratio	Value (TDV $/sf)	Value /Cost Ratio	Value (TDV $/sf)	Value /Cost Ratio
1	$ 0.94	4.0	$ 1.20	5.4	$ 1.42	4.2	$ 0.81	2.3	$ 1.64	3.6	$ 0.55	2.2
2	$ 1.60	6.8	$ 1.94	8.8	$ 1.43	4.2	$ 0.87	2.5	$ 2.04	4.4	$ 0.60	2.4
3	$ 1.34	5.7	$ 1.69	7.6	$ 1.35	4.0	$ 0.79	2.2	$ 1.80	3.9	$ 0.51	2.0
4	$ 1.37	5.8	$ 1.75	7.9	$ 1.44	4.3	$ 0.83	2.4	$ 1.88	4.1	$ 0.51	2.1
5	$ 1.33	5.7	$ 1.69	7.6	$ 1.35	4.0	$ 0.79	2.2	$ 1.80	3.9	$ 0.50	2.0
6	$ 1.30	5.5	$ 1.68	7.6	$ 1.44	4.3	$ 0.83	2.4	$ 1.94	4.2	$ 0.51	2.0
7	$ 1.21	5.1	$ 1.59	7.2	$ 1.41	4.2	$ 0.81	2.3	$ 1.87	4.1	$ 0.48	1.9
8	$ 1.23	5.2	$ 1.63	7.4	$ 1.67	5.0	$ 0.96	2.7	$ 2.01	4.4	$ 0.72	2.9
9	$ 1.31	5.6	$ 1.70	7.7	$ 1.69	5.0	$ 0.98	2.8	$ 2.07	4.5	$ 0.74	3.0
10	$ 1.34	5.7	$ 1.73	7.8	$ 1.70	5.1	$ 0.98	2.8	$ 2.09	4.5	$ 0.75	3.0
11	$ 1.38	5.9	$ 1.74	7.9	$ 1.78	5.3	$ 1.03	2.9	$ 2.13	4.6	$ 0.83	3.3
12	$ 1.33	5.7	$ 1.68	7.6	$ 1.72	5.1	$ 1.00	2.9	$ 2.06	4.5	$ 0.80	3.2
13	$ 1.34	5.7	$ 1.71	7.7	$ 1.79	5.3	$ 1.03	2.9	$ 2.10	4.6	$ 0.81	3.3
14	$ 1.31	5.5	$ 1.69	7.6	$ 1.80	5.4	$ 1.03	2.9	$ 2.08	4.5	$ 0.80	3.2
15	$ 1.16	4.9	$ 1.64	7.4	$ 2.04	6.1	$ 1.08	3.1	$ 2.10	4.6	$ 0.77	3.1
16	$ 1.15	4.9	$ 1.41	6.4	$ 1.59	4.7	$ 0.96	2.7	$ 1.96	4.2	$ 0.68	2.7
Wt'd Avg		**5.6**		**7.6**		**4.8**		**2.6**		**4.3**		**2.7**
-Values in this table originate with the B-7 series tables for each building type. -Costs are one time review costs at the beginning of the project.								**Simple Avg All Bldg Types:**				**4.6**

Figure 17: Cost Benefit Ratio by Climate Zone and Building Type

For all prototype buildings, the average benefit to cost ratio is 4.6 – for every $1 invested, $4.6 are returned. This is a strong recommendation for requiring Commissioning Design Review for all new construction projects required to comply with Title 24 Part 6. But improved compliance with current regulations and subsequent energy savings is only one of the benefits to be had from Commissioning Design Review. Design review can result in improved communication of energy efficient design details. While the design engineer is intimately familiar with the project, an outside reviewer can identify those areas that may not be completely clear. This can help to keep construction on schedule with fewer requests for information and reduce times the contractor may incorrectly interpret the drawings. Another benefit with similar results is ensuring consistency between the various disciplines. For instance, last minute changes to the mechanical equipment selections may not get carried over into the electrical drawings. These inconsistencies can delay construction and lead to increased construction costs. Finally, having an outside design review can help to review design assumptions that may lead to equipment oversizing. Right-sized equipment results in reduced energy costs but also decreased first costs. No set of drawings is perfect; having an outside design review, particularly for large, complex buildings, simply aids in the process of catching these errors and omissions which may result in increased energy use as well as increased construction costs and reduced comfort from systems not operating as intended.

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

Provide complete language change recommendations for the Standards, ACM Manuals, and Reference Appendices. This section should have specific recommended language and contain enough detail to develop the draft standard in the next phase of work. Use the language from the relevant 2008 document(s), and use underlining to indicate new language and strikethroughs to show deleted language.

5.1 Building Energy Efficiency Standards for Residential and Nonresidential Buildings

§10-103(a)1 Certificate of Compliance: The Design Review Checklist will take the form of a Certificate of Compliance. This section describes in general terms responsibilities for signing the compliance forms. No new language is thus required.

5.2 Nonresidential Compliance Manual

§2.2.1 Design Phase – Certificate of Compliance

Modify the first paragraph as follows:

During the design phase, the plans and specifications are developed that define the building or system that will be constructed or installed. The design must incorporate features that are in compliance with applicable codes and standards. The building or system overall design must be detailed in the construction documents and specifications. **For buildings larger than 50,000 ft^2 or for buildings with complex mechanical systems, an independent, third party review of these documents is required to ensure required design features are included by completing a design review checklist. Buildings between 10,000 and 50,000 ft^2 require completion of the design review checklist by an in-house engineer not associated with the project in question. For buildings less than 10,000 ft^2, this review may be completed by the design engineer.** ~~, and t~~These documents must be submitted to the enforcement agency for approval.

§2.2.2 Permit Application – Certificate of Compliance

Add the following text to paragraph 2:

A Certificate of Compliance is required to be submitted along with the construction documents, and these documents must be approved by the enforcement agency. **All buildings, whether following the prescriptive or performance method, must submit the design phase Design Review compliance forms.** If the prescriptive method. . .

Add to Table 2-1 - Certificate of Compliance Forms:

Design Review	Envelope	Mechanical	Lighting	Outdoor Lighting	Sign Lighting
DESC-1C **Certificate of Compliance Schematic Design Review** **DESC-2C** **Certificate of Compliance Construction Document Review**	No change	No change	No change	No change	No change Refrigerated Warehouse No change

§9.4 Enforcement and Compliance (for Performance Compliance)

1. §9.4.1 Approaches

Envelope Only
DESC-1C: Design Review Kickoff
DESC-2C: Construction Document Design Review
PERF-1: Performance Certificate of Compliance
ENV-1C: Envelope Certificate of Compliance (2 parts)

Envelope and Mechanical
DESC-1C: Design Review Kickoff
DESC-2C: Construction Document Design Review
PERF-1: Performance Certificate of Compliance
ENV-1C: Envelope Certificate of Compliance (2 parts)
MECH-1C: Mechanical Certificate of Compliance (2 parts)
MECH-2C: Air System, Water System, Service Hot Water & Pool Requirements (3 parts)
MECH-3C: Mechanical Ventilation (1 part)

Mechanical Only
DESC-1C: Design Review Kickoff
DESC-2C: Construction Document Design Review
PERF-1: Performance Certificate of Compliance
MECH-1C: Mechanical Certificate of Compliance (2 parts)
MECH-2C: Air System, Water System, Service Hot Water & Pool Requirements (3 parts)
MECH-3C: Mechanical Ventilation (1 part)
Possibly existing ENV and/or existing LTG forms: (for partial compliance alteration)

Mechanical and Lighting
DESC-1C: Design Review Kickoff
DESC-2C: Construction Document Design Review
PERF-1: Performance Certificate of Compliance
MECH-1C: Mechanical Certificate of Compliance (2 parts)

MECH-2C: Air System, Water System, Service Hot Water & Pool Requirements (3 parts)
MECH-3C: Mechanical Ventilation (1 part)
LTG-1C: Lighting Certificate of Compliance (3 parts)
LTG-4C: Lighting Controls Credit Worksheet (if control credits used)
LTG-6C: Tailored Method Summary and Worksheet (if tailored lighting used) (3 parts)
Existing ENV forms: (for partial compliance alteration)

2. §9.4.2 Compliance Forms:

Add two new forms:

DES-1C: Design Review Kickoff Checklist

The schematic design review has one part that is completed during the schematic design phase of the project. This form documents that the owner or owner's representative, design team and design reviewer have met to discuss the project scope, schedule and how the design reviewer will coordinate with the project team.

DES-2C: Construction Document Design Review Checklist

This form contains a listing of the items that should be checked by the design reviewer during the construction document review. Code items as well as best practice suggestions for envelope, mechanical system and lighting systems have been incorporated into the form. The completed form is returned to the owner and design team for review and sign-off.

5.3 Appendix A Compliance & Acceptance Forms

Two new compliance forms will be needed at the beginning of the Compliance Forms section. The first is the initial Design Review Kickoff form. The second is the Design Review checklist to be completed on the substantially complete construction documents, prior to permit application. The checklists DESC-1C and DESC-2C are included in Appendix 7.5. Only one sheet with signatures will be required to be submitted with the construction documents for permit review. This sheet will confirm that the Design Review Kickoff was held and the Construction Document Design Review checklist was completed and presented to the design engineer and owner/owner's representative.

Modify the Appendix A: Compliance Forms and Worksheets Certificate of Compliance table:

Certificate of Compliance						
Design Review **DESC-1C** **Certificate of Compliance** **Design Review Kickoff** **DESC-2C** **Certificate of Compliance Construction Document Review**	Envelope No change	Mechanical No change	Lighting No change	Outdoor Lighting No change	Sign Lighting No change	Refrigerated Warehouse No change

Add new section Appendix A and include the two new forms:

2013 Compliance Forms
Design Review Forms

- Form DES-1C
- Form DES-2C

6. Bibliography and Other Research

List and describe each of the research studies, reports, and personal communications that provide background for this research. Identify all resources that have been pursued to further this measure. Identify all "experts" that were involved in further developing the change, all research and analysis reports and documents that were reviewed, and all industry standards that were consulted (e.g., ASTM, UL, ASHRAE test procedures, etc.). Include research that is underway that addresses the measure/change. Indicate if data or information will be produced in time to be used in this update of the Standards.

6.1 Design Phase Commissioning Stakeholder Surveys

Stakeholders were identified and determined to fall into one of three groups: Mechanical, Electrical, and Plumbing Designers, Commissioning Agents or Building Owners These individuals were interviewed in an effort to:

- Assess knowledge of Code Commissioning Requirements
- Assess perceived benefits resulting from Commissioning
- Document current Commissioning practices
- Gather opinions on important Commissioning and documentation requirements
- Gather opinions of who is the responsible party.

Questions posed to Stakeholder Group Number 1: MEP Designers

1. Approximately how many projects do you work on annually that comply with Title 24 requirements?
2. Do you regularly provide commissioning services?
3. If your firm is working on a project that you know is going to be commissioned, what guideline do you follow, if any, to guide you through the process? (ASHRAE Guideline 0, LEED, ACG, BCA, CCC, other). Is design review part of your standard commissioning practice? This could be performed by someone in-house or a third party reviewer.
4. Are you familiar with the pending Title 24 code requirements for commissioning? Have you heard of CALGreen? (Consider OPR BOD, Commissioning Plan, F(n) Testing, Documentation & Systems Manual, Systems Training, Commissioning Report)
5. What is your general internal design review process (formal or informal – follow checklist etc) and would you consider this to be consistent with requirements for commissioning design review?
6. In your opinion or from experience is completing a design review critical to a successful commissioning project?
7. Has your firm ever been responsible for performing 3rd party design review commissioning? If so, what benchmark do you use to weigh the design against? What documentation do you use to assist with the review, i.e. OPR, BOD, Code, good practice, checklists, etc.?
8. In a commissioned project, how effective do you think the process will be if the following perform the reviews (independent third party, non project specific staff within firm)?

9. What criteria are useful to judge or determine if commissioning design review should be required? Building size, simple vs. complex systems, other criteria?
10. Given a 100,000 sq.ft. office building with commissioning, how much time is required to perform a design review you consider appropriate?
11. What benefits have you found with commissioning design review and do they justify the cost?
12. How should code required design review be enforced? Any thoughts on documentation needed to show compliance?

The following key points were taken from the interviews with Mechanical, Electrical, and Plumbing Designers:

- Seven design firms were interviewed in an effort to gauge knowledge and involvement in the commissioning process. Six out of the seven firms offer commissioning services and all indicated that commissioning was very common. The concept of design review was supported in general; however there was hesitation with respect to the added value of such a review and issue with the cost and complexity such a step would add to Title 24 compliance. Interview details can be found in the attached matrix.

- Qualifications of MEP design firm: All firms interviewed had multiple offices around the state and worked on about 75 projects a year. All but one regularly provides commissioning services and was familiar with the process.

- General Design Phase Commissioning Practice: ASHRAE GL 0 was the most common commissioning guideline used. LEED was the most common driver for requiring commissioning on a project. One firm used ACG as a guide and has several certified members of their staff certified by this group. If a project isn't commissioned, design review was common, with common design practice as a guideline.

- 4 of the 7 designers interviewed had heard of CALGreen but for the most part were not very familiar with it. None were familiar with the pending Title 24 commissioning requirements.

- All of the firms interviewed they had some form of internal design review process that is typically done by a senior staff member. All that responded to this question said the review was performed by someone other than the designer. One firm indicated their design review occurred at about 50% CD phase. He suggested a two stage design review is more effective, one during the DD phase and one during the CD phase. The feeling was design review was valuable and usually found issues that needed correction. The skill of the designer typically influenced what issues came up during design review. Most firms indicated a fraction of their designs get subjected to design review, around 2/3 to ¾ of the projects. Checklists were typically used. One firm felt checklists were very effective. Equipment sizing, equipment selection, and Title 24 energy compliance were indicated by one firm to be reviewed early on in the design and with respect to energy compliance by a junior level engineer.

- Whether or not design review was critical to a successful project depended on the complexity of the project and the competency of the engineer doing the design. Overall designers felt this depended on who did the design and their thoroughness, but one designer said a design review is definitely critical to a successful project.

- Six of the seven firms interviewed have been responsible for 3rd party design review. If available the OPR and/or BOD are used. Sometimes these documents aren't available. One interviewee said the OPR typically never comes from the owner and is generated by the design firm or Cx agent.

- The feeling was 3rd party design review and in house design review were both effective. The advantage of 3rd party design review was it allowed a "different set of eyes" to review the design. Also review from a different perspective was beneficial. One firm felt in house review was more effective than 3rd party review. Two of the interviewees suggested 3rd party review lacked value and said the review comments were sometimes not useful. This can sometimes create conflict between the reviewing party and the design team. One interviewee said if a 3rd party is going to be used, communication between them and the design team is critical. Several interviewees felt the 3rd party review was more thorough than in house review.

- Based on the responses there didn't seem to be much of a conflict of interest between design team and reviewer. In one case in house design review avoided conflict by having separate department review design. Since in house review was typically done by someone outside of the design team it seemed conflict was avoided. As far as 3rd party review goes, the conflict of interest that was mentioned was reviewer comments having little value, or if a deficiency is noted in the design - finger pointing results.

- Generally it was suggested that design review should be based on both size of project and complexity of design. A small data center may warrant a design review whereas a large office TI may not. It would be hard to quantify. One interviewee said all designs should be reviewed except for the most basic. One week was indicated as the most amount of time that is reasonable for a complete design review.

- The designers interviewed generally felt the benefits of design review justified the cost. It was suggested that it's important who does the review. It needs to be by a senior staff member. One designer specifically mentioned a project that closed out much quicker with design review than another project without design review. This same interviewee also suggested there is some variability in design review completeness. You get what you pay for. A "design review" doesn't guarantee quality.

- When asked how code required design review should be enforced everyone suggested minimal paperwork should be required. Perhaps a sign-off by the commissioning agent and designer that issues have been addressed. One interviewee suggested enforcing existing Title 24 requirements more effectively before adding additional requirements. Current forms require 40-60 hours to complete so any additional forms should be minimal. A checklist could be a useful tool. The general feedback on this subject was there should be an acknowledgement between the reviewer and designer that issues from the design review are resolved.

Questions posed to Stakeholder Group Number 2: Commissioning Agents

1. Can you define the commissioning protocol that you consider to be the current baseline practice? (Closest to ASHRAE Guideline Zero, LEED Prerequisite, LEED Enhanced, others).
2. Are there additional steps or rigor that you would like to see become part of current baseline practice?
3. Are you familiar with the new CALGreen commissioning requirements that will be in effect starting in January 2011?
4. How often are you asked by building owners to perform acceptance testing currently required by Title 24?
5. What are the key factors that prevent owners from adopting commissioning in all buildings?
6. Is Design Review part of your standard commissioning work? If so, do you consider it critical to completing a successful project?
7. What do you include as part of your Design Review (i.e. general quality review, coordination between disciplines, design achieves the owner's project requirements, specifications applicable to the OPR and BOD)?
8. How much time is required for completing a comprehensive Design Review?
9. Who should be responsible for the Design Review portion of the commissioning requirement: independent 3rd party outside of the design firm or non-project specific staff within firm?
10. How should code-required commissioning be enforced? Do you have any thoughts on documentation needed to show compliance?

The following key points were taken from interviews with Commissioning Providers:

- Six commissioning providers were interviewed to determine what current practices are and whether owners currently require commissioning of new construction projects. The commissioning providers were selected from a list of companies that are registered on the California Commissioning Collaborative website. An attempt was made to interview companies that work in various parts of the state and that cover a wide range of years of commissioning experience and number of commissioning projects completed each year. Some companies provide both commissioning and engineering design services. Full interview results are found in the attached matrix.

- When asked to define the commissioning protocol considered to be the current baseline practice, results four of the six responded with ASHRAE Guideline 0. Three respondents also mentioned LEED – that LEED is one of the major reasons why projects are requesting commissioning services. Despite this, the majority of providers also believe that additional rigor needs to be part of the baseline practice, because the guidelines are not being followed. Nearly all respondents identified cost and lack of knowledge about commissioning were the main factors that prevent owners from adopting commissioning. When asked about meeting the current Title 24 acceptance testing requirements, only one firm (the smallest with only six employees) responded that they are asked to perform the acceptance requirements.

- Regarding knowledge of the new CALGreen 2010 commissioning requirements, five of the six providers were aware of the code; however, only two had significant knowledge. One had actually read through the code, and showed concern over the lack of rigor included. His concerns covered the lack of requirements on who can provide the commissioning, lack of detail on what is involved in the commissioning and the lack of enforcement. The other provider is actually on the CALGreen commissioning task force.

- The next set of questions put to the providers concerned design phase commissioning and design review in particular. All provided agreed that design review is a standard part of their standard commissioning work and a critical part of a successful commissioning project. Only one provider qualified their answer that they prefer to have design review as part of their process but will do whatever the owner contracts for. One provider added that they will even do a design review if brought into a project late. Responses regarding what are included in the design review varied, but typically involved reviewing the OPR and BOD, reviewing drawings for constructability, maintainability of designs, and integration of controls. Only two mentioned energy efficiency/sustainability. Responses regarding time spent were fairly similar, with all stating that it depends on complexity of the project with times ranging from one day to a week or more. Three of four respondents agreed that a third party independent should be responsible for the design review.

- Most of the providers responded that sign-off by a commissioning authority is a good way to enforce the code. Two providers felt that inspectors needed additional training for enforcement to occur. One provider felt that enforcement of other aspects of the energy code was required before trying to enforce the commissioning code.

- Two providers had additional comments at the conclusion of the interview. The first stated that the design review should be standardized because of the impact on the bidding process. He also believed that design review should be completed by someone with a professional engineering license. Another provider (the only one to have studied the new CALGreen requirements) stated his belief that the code is too vague and has the potential to hurt the commissioning industry. If the process is left vague, contractors will only do what is required, thereby causing commissioning to become a commodity only.

Questions posed to Stakeholder Group Number 3: Building Owners

1. What (if any) past experience do you have with building commissioning?
2. Do you require all of your buildings to be commissioned prior to occupancy?
3. Are you familiar with the pending Title 24 (CALGreen) code requirements for commissioning?
4. Who typically is your commissioning agent (third party, designer, contractor, owners staff, etc)
5. Do you require a specific process / protocol to be used and can you define your typical commissioning protocol that you require your Cx providers to follow. (ASHRAE Guideline Zero, LEED, other).
6. Does your preferred protocol include Design Review Commissioning?
7. As an owner, what (if any) impact was there on project budget and schedule?

8. What value do you place on the commissioning process or why is it important?
9. Have you seen any direct construction cost benefits that you could attribute to Design Review Commissioning, i.e. project cost savings associated with less change orders, fewer problems during start up which may have delayed occupancy / move in date.
10. Have you seen any operational benefits energy savings that can be directly attributed to commissioning improved comfort and less trouble / compliant calls to maintenance staff?

The following key points were taken from interviews with Building Owners:

- Five building owners/engineers and one Sustainability Director were interviewed in an effort to gauge knowledge of the commissioning process. The five interviewees were selected from a list of building owners that have participated in the PECI Retro-Commissioning Program, located in the following utility territories: Pacific Gas and Electric (PG & E), Southern California Edison, San Diego Gas and Electric (SDGE), and Sacramento Municipal Utility District (SMUD). The intent of these interviews was to discuss commissioning and the process with building owners located throughout the state to gauge how involvement and knowledge may vary.

- Each of the interviewees was aware of the pending CALGreen commissioning requirements, but for five of the six were not concerned with the details because they do not manage new buildings.

- The economy was a common theme throughout several discussions given that commissioning and new building acquisitions affect long term budgets and planning efforts. The Sustainability Director indicated that longer term plans include having all new construction projects be LEED certified and the points for commissioning will be sought; however, given the economy this real estate company is not sure of the implementation dates on this long term plan. She is also aware of design phase commissioning, but because of the long term plans and goals of her employer, does not anticipate implementing for a long time.

- Several other participants indicated a concern with the impact that the CALGreen requirements will have on the already high cost of construction in California. Local governments are already cash strapped and short strapped; additional code requirements will put more strain on limited resources. A common thread was that the State should enforce what is already codified before implementing additional requirements.

- All participants indicated that there was benefit to the commissioning process, both prior to and during occupancy. It is difficult to quantify the energy savings that results from pre-occupancy commissioning. The value in this commissioning is that there are less start up issues, saving money and time. Interviewees that have gone through retro-commissioning indicated that there were less occupant complaints, increased occupant comfort, and substantial energy savings as a result of the process.

6.2 Matrices of Commissioning Components

	ASHRAE Guideline 0	CALGreen 2010	Title 24 Part 6 Acceptance Testing	ASHRAE 189.1	IGCC	LEED 2009 Enhanced Cx	GSA: the building commissioning guide
Pre-Design Phase Cx							
Owner's Project Requirements	√	√		√		√	√
Cx Plan	√	√		√	√	√	√
Design Phase Cx							
Basis of Design	√	√		√		√	√
Cx in Construction Documents	√	√		√		√	√
Construction Checklists	√		√				√
Design Review	√			√		√	√
Construction Phase Cx							
Functional Performance Testing	√	√	√	√	√	√	√
Documentation and Training	√	√		√	√		√
Final Cx Report	√	√		√	√	√	√
Post Occupancy Cx	√				√	√	√

Figure 18: Components of the Commissioning Protocols

	ASHRAE 189.1	ASHRAE Guideline 0	GSA: the building commissioning guide	LEED 2009 Enhanced Cx
Design Review Timing Not Specified		√		
End of Design Concepts			√	
50% Design Development	√		√	
100% Design Development				
50% Construction Documents				√
95% Construction Documents	√		√	
Back Check				√

Figure 19: Design Review Timing within the Commissioning Protocols

Several of the protocols also describe what should occur during the Design Review. This is summarized below.

- **ASHRAE Standard 189.1**: The purpose of the reviews is to "verify that the documents achieve the construction phase OPR, and the BOD document fully supports the OPR, with sufficient details."
- **ASHRAE Guideline 0:** A targeted Design Review is composed of four tasks:
  - General quality review of the documents, including legibility, consistency and level of completeness,
  - Coordination between disciplines,
  - Discipline-specific review for achieving the OPR, and
  - Specification applicability and consistency with OPR and BOD.

  Significant information is provided in section 6.2.8 and in Appendix N on how these reviews can be implemented.
- **LEED Enhanced Commissioning EAc3:** The Design Review is intended to give the owner and design team an independent assessment of the design. Typically this involves the following:
  - Ensuring clarity, completeness, and adequacy of the OPR,
  - Verifying that all issues discussed in the OPR are addressed adequately in the BOD, and
  - Reviewing design documents for achieving the OPR and BOD and coordination of commissioned systems.
- **GSA: the building commissioning process:** The Design Review should identify areas for improvement such as energy efficiency, indoor environmental quality, operations and

maintenance, etc. Its intent is to review the design from a commissioning perspective and not for design concepts or compliance with codes.

- Facilitate certification goals,
- Facilitate effective commissioning,
- Review control systems and sequences of operations for adequacy and efficiency,
- Review building and system design for energy efficiency and for thermal and water integrity,
- Verify that contract documents will meet OPR, and
- Verify adequate operator training requirements.

6.3 Review of Existing Commissioning Protocols

	ASHRAE Guideline 0	ASHRAE 189.1	LEED 2009 Fundamental Cx <50,000 ft^2	LEED 2009 Fundamental Cx >50,000 ft^2	GSA: the building commissioning guide	Energy Design Resources: Bldg Cx Guidelines	CCC California Commissioning Guide – New Buildings	Telephone Survey of Stakeholders
Delivery: In-house vs Third Party	3rd Party	No guidance	Self-review	In-house	N/A	3rd party	In-house or 3rd Party	In-house and 3rd party
Frequency	Not clearly specified	2 reviews	1 review	1 review	3 reviews	Not clearly specified	3 reviews	N/A
Timing	Not clearly specified	1. 50% design 2. 100%	Prior to mid-construction documents		1. end of design concepts 2. 50% DD 3. end of CD	Not clearly specified	1. schematics 2. 50% design 3. near end of design	N/A
Delivery Method	No specific information on delivery method. See section below for information on topics that may be included in the Design Review.							
Qualifications	Past Cx experience, communication skills, bachelor's degree and certification or professional license	No specific qualifications	Experience with two other projects of similar managerial and technical complexity		Technical background and in-depth experience with the commissioning process	Experience in design, specification or installation of commercial building mechanical and controls systems; cx experience with at least two projects	Good technical knowledge of the systems being commissioned; complete understanding of the Cx process	Technical knowledge including hands-on field experience; relevant experience with similar system types
Sign Off & Compliance & Enforcement	CxA responsible for the Design Review comments, with review/ approval by the owner	Final Cx report to owner	CxA reports directly to owner		CxA leads the Design Review process and is responsible for issuing a final commissioning report	CxA submits cx report to owner for review	CxA responsible for planning, organizing and facilitating Cx on behalf of the owner	Owner's responsibility to evaluate and approve recommend-ations from the Design Review

Figure 20: Design Phase Commissioning Design Review - Evaluation Elements

The table of Evaluation Elements shown in Figure 6 was developed to determine how best to incorporate Design Review into the Title 24 process. Each of those elements is discussed in greater detail.

6.3.1 Design Review Approach – Who should perform the Design Review

The first question considered was the delivery method – should the Design Review be completed by an independent, third party reviewer, should the Design Review be completed by another staff member from within the design firm, or should the Design Review be completed by the project designer? Issues that were considered include:

- availability of third party design reviewers,
- potential cost of hiring an outside firm,
- effectiveness of completing self reviews,
- time delays that might result from additional coordination and schedule availability of an outside design reviewer, and
- irrelevant or insignificant comments by a third party review that could delay the project and result in additional design team costs while adding no real benefit to the project.

Supporting Documentation:

- ASHRAE Guideline 0-2005: The Commissioning Authority should "review the in-depth design documentation developed by the design professional." The Commissioning Authority should also have the following qualifications (From ASHRAE Guideline 0-2005 Information Annex E, the Commissioning Authority will be an independent contractor and not an employee or subcontractor of the General Contractor or any other subcontractor on this project, including the design professionals. This implies what we would classify as Third Party Review.
- ASHRAE Standard 189.1-2009: The commissioning authority is to complete two focused OPR reviews of the construction documents; however, no requirements on commissioning authority qualifications are included. The commissioning authority should be identified by the owner.
- LEED 2009 for New Construction: Projects require the commissioning authority for fundamental commissioning to be, at a minimum, a disinterested employee or subcontractor of the project architect, engineer or general contractor. If the project is less than 50,000 gross square feet, they may be an employee with project design or construction responsibilities. This implies what we would classify as Self Review for under 50,000 ft^2 and In-House Review above 50,000 ft^2.
- For enhanced commissioning, the commissioning authority cannot be a disinterested employee of the architect or engineer (i.e. an employee or subcontractor who has no project responsibilities other than commissioning). This implies what we would classify as Third Party Review.
- GSA: building commissioning process: Typical GSA practice is to have the Construction Manager hire the CxA. There is not sufficient information in the document to make a determination of self-review, in-house or third party.
- Energy Design Resources: Building Commissioning Guidelines: This guidance document identifies that many owners who commission their buildings recommend that the CxA be an independent third party. This implies what we would classify as Third Party Review. It also states that if the commissioning provider is not an independent party under contract with the owner, a formal plan for addressing potential conflict of interest must be developed. The

Guideline suggests that the higher costs associated with an independent CxA are outweighed by future energy savings, particularly for larger and/or more complex buildings.

- California Commissioning Collaborative California Commissioning Guide - New Buildings: This document identifies the following as the most common qualifications required: technical knowledge, relevant experience, communication and organizational skills, references and sample work products, and objectivity. Several different parties can fill this role, including building staff, design engineer/architect, contractor, or independent third party. To prevent any conflict of interest, the CxA should report directly to the owner. In the case where the CxA is the design engineer/architect, it is suggested that the Design Review should be performed by an independent third party consultant. This implies what we would classify as In-House or Third Party Reviews.
- Associated Air Balance Council (AABC) Commissioning Group Commissioning Guideline: Per the AABC Commissioning Guideline, the CxA should be hired directly by the owner and should be independent of the designers, contractors, vendors and suppliers on the project, as a third party professional brings objectivity and a level of assurance that the owner's best interests will be served. This implies what we would classify as 3rd Party Review.
- Telephone Survey of Commissioning Providers and MEP Design Firms: Design firms in general described both third party and in-house Design Reviews as being effective, although some firms believed in-house was more effective while others felt that third party review was more thorough. Design firms suggested that Design Review should be based on both size of project and complexity of design. In general, commissioning providers felt that an independent third party reviewer should be responsible for the Design Review.

Design Review Approach Recommendation

There are sufficient resources supporting the idea that the Design Review should be completed by an independent third party. However, it is assumed that there will be cost implications to bringing in another contractor to the project, from the costs associated with the design reviewer's time to possible costs caused by time delays in coordinating the Design Review, particularly with regard to smaller buildings or buildings with simple systems (as defined by code). The proposal is thus to allow a mix of qualified professionals to perform the commissioning Design Review based on building size and complexity of mechanical systems. If the building size is less than the 10,000 ft^2 used in Title 24 Part 11 for requiring full commissioning, no Design Review will be required. The code required acceptance requirements will, however, still be required. For buildings larger than 10,000 ft^2, the Design Review professional will be as shown in the proposed commissioning Design Review matrix, included below:

Qualifications	Minimum Requirements		
	Size (ft^2)	System	General Building Classification
Self Review	≥10,000 and <50,000	Simple	Any
In-House	≥50,000 and <100,000	Simple and Complex	Retail, Office, Education, Warehouse
Third Party	≥100,000	Complex	Hospitals, Labs

Figure 21: Qualifications of Design Reviewer

6.3.2 Frequency and Timing of Design Review

The second question considered is when in the design process the Design Review should be performed. One optimum point in the design process for completing a commissioning Design Review does not exist. Rather there are benefits to be achieved at various stages in the design process. Early Design Reviews may provide a high level overview of the project early in the design process. This review can provide input on system selection both from an energy efficiency perspective and from the perspective of meeting the owner's project requirements before significant design time and energy (and hence cost) has been spent by the design firm. Another benefit of an early Design Review would be to help define if Title 24 compliance is to be achieved through the prescriptive or the performance path.

Reviews that occur later in the design process – once the systems have been selected and the overall design is set – allows the reviewer to check for design details and compliance with Title 24 Part 6 requirements. Items include equipment and pipe/duct sizing, inclusion of control sequences, coordination among disciplines, system selection and layout effects on operations and maintenance, and inclusion of test ports, sensors and other in-situ measurement devices required for meeting acceptance requirements. A final check is useful for providing a last look at the design documents for any inadvertent errors and omissions that could lead to delays in the construction process and potential issues with the efficient operation of systems during occupancy.

Supporting Documentation:

- ASHRAE Guideline 0-2005: This guideline does not specifically address when in the design process the Design Review should occur, but merely states that targeted Design Reviews should be completed at strategic times during the design phase.
  - Not clearly specified.
- ASHRAE Standard 189.1-2009: The CxA conducts two Design Reviews – one at around 50% design completion and the second at completion of the design documents prior to delivery to the contractor.
  - Two reviews
- LEED 2009 for New Construction: Design Review is included only in the enhanced commissioning credit. This requires that the CxA conduct at least one commissioning Design Review prior to the mid-construction documents phase. The review comments should be back-checked in the subsequent design submission.
  - Enhanced commissioning only - one review

- GSA: building commissioning process: The GSA document recommends three focused Design Reviews at the end of the design concepts, at 50% of design development and finally toward the end of construction document phase.
  - Three reviews.
- Energy Design Resources: Building Commissioning Guidelines: In a discussion of design phase commissioning, the guideline recommends that the commissioning provider formally reviews and comments on the design at various stages of development, however, these stages are not defined.
  - Not clearly specified.
- California Commissioning Collaborative California Commissioning Guide: New Buildings: This guide suggests Design Reviews at three times during the design phase of the project: during schematics, midway through the design process and near the end of design.
  - Three reviews.
- Associated Air Balance Council (AABC) Commissioning Group Commissioning Guideline: This guideline only suggests that a project may benefit from independent Design Reviews. Timing of any reviews is not provided.
  - Not clearly specified.

Frequency and Timing of Design Review Recommendation
Based on this information, a two-part Design Review is recommended. The first is to be completed once the design process is approximately 20% complete (during schematic design) and the second at approximately 90% of design completion (Construction Documents nearly complete, prior to submittal for plans review. The early Design Review will provide an opportunity for the design reviewer to meet with the owner and project team to provide an explanation of their role in the project. The checklists will be delivered to the project designers at this time. The design reviewer should also identify the importance of including adequate information on the sequence of operations, as this will be a key area included in the Design Review. Finally this should be an opportunity to discuss key design criteria such as assumed building loads, operating schedules and system selection. The second portion of the Design Review will be a more in-depth review of the nearly completed design documents. There are several key outcomes of this Design Review: increased compliance with the Title 24 Part 6 requirements, identification of fatal flaws in the design that might result in construction delays or systems that do not operated as intended, and a reduction in change-orders resulting from errors and omissions and unclear information on the design drawings.

6.3.3 Design Review Delivery Method – Checklist Process

The third evaluation element concerns the delivery method of the Design Review. In other words, what tool or process will be used to verify the Design Review has been completed and meets the intent of the proposed code. There are several concerns that must be addressed prior to defining code requirements on how the Design Review will be conducted. These include the following:

- Irrelevant or insignificant comments returned to the design team, as indicated from telephone surveys;
- Variation in time, cost and quality of Design Review between design reviewers;
- Burden on code officials for another review item; and
- Integration of design elements with most impact on building energy efficiency.

One way to address these concerns is to be very specific about what is required in the Design Review. In this case, it is recommended that a checklist format be used. The checklist items can be focused on the areas that are determined to have the most impact on meeting the energy efficiency code requirements and that are important to successfully completing the acceptance requirements. By specifically identifying the issues to be reviewed, irrelevant and/or insignificant comments as well as variation in the time to complete the review should be minimized. Items to be included in the checklists include but are not limited to the following:

- Mandatory and prescriptive compliance requirements,
- Best practices related to mandatory and prescriptive compliance measures,
- Sufficient clearances for maintenance access, and
- Sequences of operation for all systems.

In order to incorporate two Design Reviews, as recommended in the previous discussion, the checklist will be made up of two parts – one to be completed early in the design process and a second at 90% completion and prior to submission of the construction documents for plan review.

None of the commissioning resources used in this study address the issue of delivery method. However, several of the documents do address in basic terms the areas that should be addressed, such as verifying that the Owner's Project Requirements have been met, ensuring that the design documents are of good quality, and identifying areas to improve energy efficiency. A brief summary follows.

Supporting Documentation:

- ASHRAE Guideline 0-2005: No specific information on the Design Review delivery method. The Design Review is made up of four tasks: general quality review of the documents; coordination between disciplines; discipline-specific review for achieving the Owner's Project Requirements; and specification applicable and consistency with Owner's Project Requirements and Basis of Design documents.
- ASHRAE Standard 189.1-2009: No specific information on the Design Review delivery method. The Design Review should verify that the construction documents achieve the Owner's Project Requirements and the Basis of Design supports the Owner's Project Requirements.
- LEED 2009 for New Construction: No specific information on the Design Review delivery method. The following elements are identified as being typical for a Design Review: ensuring clarity, completeness and adequacy of the owner's project requirements; verify that the Basis of Design addresses the owner's project requirements; and design documents achieve the Basis of Design and coordinate commissioned systems.
- GSA: building commissioning process: No specific information on the Design Review delivery method. Over three reviews, the design should be compared against the Owner's Project Requirements. The review should identify any areas for improved energy efficiency. The Design Review does not check for compliance with Codes.
- Energy Design Resources: Building Commissioning Guidelines: No specific information on the Design Review delivery method. The Design Review should note potential system performance problems and energy efficiency improvements and makes recommendations to facilitate commissioning and improve building performance. The design reviewer should work with the designer (Engineer of Record) to incorporate commissioning requirements in such a way as to minimize liability issues for the designer.
- California Commissioning Collaborative California Commissioning Guide: New Buildings: No specific information on the Design Review delivery method. An early Design Review should provide a general review for quality of documents and for system choices that meet the

Owner's Project Requirements. A second review mid-way through the design process should examine system interaction. The final review is a detailed check for errors. The following decisions should be reviewed: sizing and selection of systems and equipment, accessibility for operations and maintenance, energy impact of design decisions, details of controls and ability of controls to facilitate functional testing, and identification of access of test ports, sensors, and in-situ measurement devices for use in meeting acceptance requirements/functional testing and re-commissioning.

- Associated Air Balance Council (AABC) Commissioning Group Commissioning Guideline: No specific information on the Design Review delivery method. The Design Review should draw upon extensive field experience to look for potential issues such as access for Test and Balance, maintenance access, flow and schematic diagrams, particularly for complex systems, and control sequence descriptions.

Delivery Method for Design Review Recommendation

A checklist format is recommended to achieve consistent Design Reviews. These checklists will ensure that areas having the greatest impact on achieving energy reductions required under Title 24 Part 6 are reviewed, that the requirements are not overly burdensome and that concerns over insignificant or irrelevant review items are reduced.

6.3.4 Who Hires

There are several different options for a given project on who should be responsible for hiring the design reviewer. Responsibility could fall on the owner, the construction manager or project manager, the architect, or the contractor. This is a potentially important decision as who hires the design reviewer can influence how independent and unbiased that person is. However, it would be difficult to codify a requirement such as this, and the diversity of project types makes it difficult to have one path to compliance. Thus no recommendation will be made regarding the evaluation element. Instead, the proposed Design Review process, including submittal requirements, will be structured such that influence from the hiring process will be minimal or non-existent.

Supporting Documentation:

Not applicable.

Hiring of Design Reviewer Recommendation

This evaluation element was removed from consideration.

6.3.5 Qualifications of Design Reviewer

The fifth evaluation element considered was qualifications of the design reviewer. In most of the references used for this study, the commissioning authority is assumed to be the party responsible for carrying out the Design Review. The two primary qualifications that appear in most of the references include technical knowledge and experience on similar type projects. These qualifications are quite broad as they are typically used within a larger request for qualifications procedure used for the entire commissioning project.

In discussions on this evaluation element, potential parties who could be assigned to carrying out the Design Review included a senior person with design experience, licensed architect or engineer, commissioning agent with certification such as the Building Commissioning Association Certified

Commissioning Professional, field experience, system's designers, Certified Energy Managers, or energy auditors. Because the Design Review is a very specific task within the overall commissioning process, it was felt that some minimum criteria should be established to ensure that the reviewer is technically qualified.

Supporting Documentation:

- ASHRAE Guideline 0-2005: In Informative Annex F: Roles and Responsibilities, the Commissioning Authority is tasked with reviewing and commenting on the ability of the design documents to achieve the Owner's Project Requirements for the commissioned systems. The Design Professional is tasked with reviewing and incorporating the Commissioning Authority's comments from submittal reviews. Desired qualifications for the Commissioning Authority include:
  - Communication skills,
  - Knowledgeable in building operation and maintenance,
  - Experience as principal CxA for at least three projects during past year,
  - Bachelor's degree and certification or professional license is desired, and
  - An independent contractor.
- ASHRAE Standard 189.1-2009: The commissioning authority conducts the Design Reviews. No specific qualifications are identified for the commissioning authority.
- LEED 2009 for New Construction: Commissioning authority conducts Design Review. The commissioning authority must have experience with two other projects of similar managerial and technical complexity. The owner may specify additional qualifications.
- GSA: building commissioning process: The Commissioning Agent should have a technical background and in-depth experience with the commissioning process. The Commissioning Agent should also be familiar with fire codes, LEED, energy efficiency imperatives, among other qualifications. From the sample scope document, desired qualifications include, among others:
  - Significant in-building commissioning experience and
  - Bachelor's degree in engineering and a P.E. license.
  - Membership with BCxA, USGBC, and LEED Accredited Professional
- Energy Design Resources: Building Commissioning Guidelines: Recommended minimum qualifications for the commissioning provider include: experience in design, specification or installation of commercial building mechanical and controls systems; history of responsiveness; experience working with project teams, project management and conducting scoping meetings; good communication skills; and, experience commissioning at least two projects of similar size and equipment to the current project, including writing of functional tests. The recommended minimum qualifications for the CxA are stated as being the following:
  - Experience in design, specification or installation of commercial building mechanical and control systems and other systems being commissioned,
  - History of responsiveness and proper references,
  - Meet owner's liability requirements,
  - Experience working with project teams, project management and conducting scoping meetings; good communication skills, and
  - Experience commissioning at least two projects of similar size and of similar equipment to the current project; experience to including writing functional tests.

- California Commissioning Collaborative California Commissioning Guide: New Buildings: The Design Review is completed by the commissioning lead. Potential qualifications for the commissioning lead include the following: technical knowledge including hands-on field experience; relevant experience with similar system types; communication and organizational skills, and objectivity.
- Associated Air Balance Council (AABC) Commissioning Group Commissioning Guideline: This guideline recommends that the commissioning authority be responsible for carrying out the Design Review. A short section on potential qualifications for the Commissioning Authority is included. Qualifications include the following:
  - Knowledge of systems being commissioned, including HVAC systems and controls,
  - complete understanding of the commissioning process
  - Practical field construction background,
  - Organizational and communication skills, and
  - Experience working with multi-disciplinary teams.

Qualifications of Design Reviewer Recommendation

It is recommended that the design reviewer be a licensed professional engineer. Through the use of this well-established technical certification, minimum criteria for experience, competence and professional ethics are established. There should also be no shortage of design professionals with an engineering license that would be qualified to provide the necessary review. Using this licensure, there should also be few barriers to using either an independent third party or someone within the project design firm to complete the required review.

6.3.6 Sign off Requirements

In order to show that the Design Review has occurred, an entity must sign off on the checklist form. Possible roles that could perform this function include the owner, the designer or the dedicated design reviewer. Commissioning guidance documents do not include specifics on the delivery method for the Design Review. They do generally indicate that the commissioning authority is responsible for the final commissioning plan that is submitted to the building owner. Because the Design Review is separate from the other commissioning activities that will be required under CALGreen Part 11, the checklist should be signed off by the person completing the Design Review. This does assume that the design reviewer is a licensed professional engineer, due to the fact that this position carries accepted credentials.

Supporting Documentation:

- ASHRAE Guideline 0-2005: Commissioning authority is responsible for leading, planning, scheduling and coordinating the commissioning team to implement the commissioning process. Informative Annex D documentation matrix shows commissioning authority responsible for the Design Review comments, with review/approval by the owner.
- ASHRAE Standard 189.1-2009: Commissioning authority is responsible for leading, reviewing and overseeing the commissioning activities and for completing the final commissioning report. A copy of the report shall go to the owner.
- LEED 2009 for New Construction: Commissioning authority is responsible for leading, reviewing and overseeing the commissioning activities. They report directly to the owner.

- GSA: building commissioning process: Commissioning authority leads the Design Review process and is responsible for issuing a final commissioning report.
- Energy Design Resources: Building Commissioning Guidelines: The commissioning provider is responsible for providing input on design features and reviewing and commenting on technical considerations from design through installation. Project manager is responsible for evaluating and discussing findings with design team. The commissioning authority issues final commissioning report to owner for review.
- California Commissioning Collaborative California Commissioning Guide: New Buildings: Commissioning authority is responsible for leading, reviewing and overseeing the commissioning activities and for completing the final commissioning report. It is the owner's responsibility to evaluate and approve any of the lead's recommendations from the Design Review.
- Associated Air Balance Council (AABC) Commissioning Group Commissioning Guideline: The commissioning authority leads the commissioning team and is responsible for planning, organizing and facilitating commissioning on behalf of the owner.

Sign Off Requirement Recommendation
The recommendation for this evaluation element is based on the results of the first evaluation element – who should carry out the Design Review. Assuming that the design reviewer is a licensed professional engineer, it is recommended that this same reviewer should sign that the items in the checklist have been reviewed with the design team.

6.3.7 Compliance and Enforcement

The final evaluation element considered is compliance and enforcement – identifying what should be submitted to code officials to verify that commissioning Design Review has been performed. Sign off on the checklist form, as discussed in the previous evaluation element signifies that the defined process was followed and Design Review checklists were completed. Including the following items on the checklist form can be used to show that the intent of the Design Review has been complied with.

- Checklist items;
- Line certifying that the Design Review has been completed by a qualified person (licensed professional engineer);
- Line certifying that the form has been delivered to the design team and to the owner; and
- Line certifying that outstanding issues have been defined and results adjudicated.

Supporting Documentation:
See supporting documentation in section 6.

Compliance and Enforcement of Design Review Recommendation
Sign off on all signature lines on the proposed checklist form will be used to show compliance with the code required Design Review. The code official will check this form (included in the project construction drawings) for enforcement purposes – plans should not be approved without the completed checklist form.

7. Appendices

7.1 Model Input Parameters

	Element	Office-Small	Office-Large	Retail	Restaurant	School
1	**EUI of Model (CZ6)** kWh/sf / All fuels kBtu/sf	9.8 / 34.7	10.1 / 39.0	12.0 / 41.9	40.4 / 355	5.1 / 25.5
2	**EUI** 2006 Statewide Existing Bldg Survey (for reference)	13.1 / 55.3	17.7 / 82.3	14.1 / 52.6	40.2 / 347	7.5 / 41.4
3	**Areas**					
4	Gross Building Area	18,000 sf (116' x 77')	174,960 sf (162' x 108')	8,000 sf	6,000 sf	75000 (L-shape)
5	Floors above / below grade	2 / 0	10 / 0	1 / 0	1 / 0	1 / 0
6	**Envelope**					
7	Above Grade Exterior Wall	Metal frame 2x6 @ 24" OC. 3/4" Sheathing R-2, R-19 batt. Stucco. Medium color.	Glass Spandrel 2x6 Metal Studs @ 16" OC. 3/4" R-2 sheathing, R-21 batt. Med color (0.45 abs). U-0.081.	Metal frame 2x6 @ 24" OC. 3/4" Sheathing R-2, R-11 batt. Stucco. Medium color. E & W walls are adiabatic, assuming adjacent bldgs.	Metal frame 2x6 @ 24" OC. 3/4" Sheathing R-2, R-11 batt. Stucco. Medium color.	Block wall with 2x4 stud inside with R-11 batt. Medium color.
8	Roof	Metal frame. 3" R21 poly insul, Light color (0.45 abs).	Built-up, metal frame, 3in R-21 poly. Light Color. 0.45 Absorp.U-Factor = 0.038	Metal frame. 2" R14 poly insul, Light color (0.45 abs).	Wood frame. 2" R14 poly insul, Light color (0.45 abs).	Built-up, metal frame, 2 in R-14 poly. Light Color. 0.45 Absorp.U-Factor =
9	Ground Floor Type	4" conc slab. 2' vert R-5 perim insul. Carpet w/o pad	4" conc slab. 2' vert R-5 perim insul. Carpet w/o pad	6" conc slab. 2' vert R-5 perim insul. Tile.	4" conc slab. 2' vert R-5 perim insul. Carpet w/o pad	6" conc slab. 2' vert R-5 perim insul. Vinyl tile.
10	Vertical Glazing *(North)*	Alum 2-pane, air, Low-E, tinted, w/o TB, fixed. U-assembly 0.57, SHGC 0.61 Tvis 0.58. 40% of wall.	Alum 2-pane, air, Low-E, tinted, w/o TB, fixed. U-assembly 0.57, SHGC 0.61 Tvis 0.58. 40% of wall.	Alum 2-pane, air, Low-E, tinted, w/o TB, fixed. U-assembly 0.57, SHGC 0.61 Tvis 0.58. 40% of wall.	Alum 2-pane, air, Low-E, tinted, w/o TB, fixed. U-assembly 0.57, SHGC 0.61 Tvis 0.58. 40% of wall.	Alum 2-pane, air, Low-E, tinted, w/o TB, fixed. U-assembly 0.57, SHGC 0.61 Tvis 0.58. 40% of wall.
11	Vertical Glazing *(South, East, West)*	Alum 2-pane, air, Low-E, tinted, w/o TB, fixed. U-assembly 0.57, SHGC 0.41 Tvis 0.58. 40% of wall.	Alum 2-pane, air, Low-E, tinted, w/o TB, fixed. U-assembly 0.57, SHGC 0.41 Tvis 0.58. 40% of wall.	S.: Alum 2-pane, air, Low-E, tinted, w/o TB, fixed. U-assembly 0.57, SHGC 0.41 Tvis 0.58. 40% of wall. E&W 0 glass.	S & E: Alum 2-pane, air, Low-E, tinted, w/o TB, fixed. U-assembly 0.57, SHGC 0.41 Tvis 0.58. 40% of wall. W 0 glass.	Alum 2-pane, air, Low-E, tinted, w/o TB, fixed. U-assembly 0.57, SHGC 0.61 Tvis 0.58. 40% of wall.
12	Exterior Window Shading	None	None	4' on South	4' on South	None
13	Skylights	None	None	None	None	None
14	Infiltration (Perim: cfm/sf of wall, Core: cfm/sf of FA)	Perimeter: 0.038 Core: 0.001	Perimeter: 0.038 Core: 0.001	Perimeter: 0.038 Core: 0.001	Perimeter: 0.038 Core: 0.001	Perimeter: 0.07. Core :0.001.
15	Exterior Lighting		None	None	None	None

16	**Lighting, Internal Loads & Occupancy**					
17			Lighting Power / Misc Loads (W/sf)			
18	Office Open	1.0 / 1.5	0.9 / 1.42	1.1 / 0.75	N/A	N/A
19	Office Private	1.0 / 1.5	1.1 / 1.0	N/A	N/A	1.0 / 0
20	Corridor	0.6 / 0.0	0.6 / 0.0	N/A	N/A	0.60 / 0
21	Lobby	1.2 / 0.1	1.3 / 0.2	N/A	N/A	N/A
22	Restrooms	0.6 / 0.1	0.6 / 0.1	0.9 / 0.10	0.9 / 0.10	0.90 / 0
23	Conference / classroom	1.1 / 0.1	1.1 / 0.1	N/A	N/A	1.0 / 0
24	Mechanical	0.7 / 0.3	0.7 / 0.3	1.5 / 0.10	1.5 / 0.10	N/A
25	Copy Center	0.9 / 0.7	0.9 / 1.0	N/A	N/A	N/A
26	Retail Sales	N/A	N/A	1.7 / 0.75	N/A	N/A
27	Exhibit Display	N/A	N/A	2.0 / 0.25	N/A	N/A
28	Storage	N/A	N/A	0.8 / 0	N/A	N/A
29	Dining	N/A	N/A	N/A	2.1 / 0.50	0.90 / 0
30	Kitchen (1440 sf in Restaurant, 3750 sf in School)	N/A	N/A	N/A	1.2 / 1.5 & 1.0 Btuh/sf gas. + Cooking 14W/sf & 245 Btuh/sf gas	1.10 / 2.0 elec; 80 Btuh/sf gas
31	Gymnasium & auditorium	N/A	N/A	N/A	N/A	1.0 / 0
32	Library	N/A	N/A	N/A	N/A	1.0 / 0
33	Daylighting Control	None	Yes	None	None	None
34	Occupancy Density Average (sf/person)	147	137	200	65	89
35	Max occupants	122	1271	40	92	843
36	Occupancy Schedule	WD: 7am-6pm Sat: 10am-2pm Sun: 0. Holidays: 0	WD: 7am-6pm Sat: 8am-5pm Sun: 0 Holidays: 0	WD: 9am-8pm Sat: 9am-8pm Sun: 10am-6pm Holidays: 0.	WD: 6am-10pm Sat: 6am-10pm Sun: 6am-10pm Holidays: 7am-9pm	9 mo's: 7am-9pm. Sat: 8am-7pm. Sun: 10am-3pm. Holidays: off.
37	**HVAC Systems**					
38	General Description	DX rooftop 1 zone VVT	Chiller, boiler, AHU's	DX rooftop CV	DX rooftop CV	DX RTU gaspack, VVT, 1 sys per zone. 6 zones.
39	**Air Side Details**	Packaged rooftop, single zone, VAV (VVT) w/ NG furnace.	Built-up VAV AHU w/ HW reheat & CHW coil, 1 per flr.	Packaged rooftop, single zone, CV w/ NG furnace.	Packaged rooftop, single zone, CV w/ NG furnace.	Packaged rooftop, single zone, VAV (VVT) w/ NG furnace.
40	Fan Type (eQuest efficiency curve)	Variable Speed	Variable Speed Drive (FPLR)	CV	CV	Variable Speed
41	Fan Control (eQuest)	Variable Speed	Fan EIR FPLR	CV	CV	Variable Speed
42	Fan Motor Type	Prem	SF & RF: Prem	High	High	Prem
43	Supply Fan Delivery Efficiency (fan W/cfm)	0.751	0.636	0.749	0.748	0.75
44	Fan Ext Static Pressure (In WG)	3.20	3.50	3.38	3.38	3.38
45	Min Design Flow (cfm/sf)	0.50	0.80	0.50	0.70	0.60
46	Air Distribution	1-zone duct	Air terminals (OH)	1-zone duct	1-zone duct	1-zone duct
47	VAV TU Min Flow	N/A (1 zone)	40%	N/A (CV)	N/A (CV)	N/A (1 zone)
48	Mech. Ventilation (min cfm/sf overall)	0.15	0.121	0.15	0.56	0.20
49	Air-side Economizer (OA cutoff, F)	75 DB	75 DB	75 DB	75 DB	75 DB
50	Demand Controlled Ventilation	None	None	None	None	None
51	DX Cooling System Efficiency	EER 11.2	Chiller IPLV kW/ton: 0.634	11.2	11.20	11.20
52	NG Furnace Efficiency (AFUE)	78%	N/A	78%	78%	78%
53	Hours fan starts before occup / Continuous or cycles during occup / Cycles during unoccupied)	1 hr / cont / cycles	1 hr / cont / cycles	1 hr / cont / cycles	1 hr / cont / cycles	1 hr / cont / cycles
54	SAT reset cooling	55F resets to T-stat	55-60F reset based on OAT	55F fixed	55F fixed	55F resets to T-stat

55	**Water Side**					
56	Chiller Type / Efficiency	N/A	3 centrifugals constant speed, constant flow, IPLV 0.634 kW/ton.	N/A	N/A	N/A
57	Chiller Part Load Effic Curve	N/A	eQuest default: CentH20-EIR-fPLR&dT	N/A	N/A	N/A
58	Chiller Primary Pumps	N/A	CV	N/A	N/A	N/A
59	CHW Secondary Loop Pumps	N/A	VFD	N/A	N/A	N/A
60	CHW Loop Temp Reset	N/A	44-50F reset on zone demand.	N/A	N/A	N/A
61	Cooling Tower Type / Fan	N/A	Open / 2 speed	N/A	N/A	N/A
62	Cooling Tower Range / WB / Approach, F	N/A	10 / 75 / 10	N/A	N/A	N/A
63	Condenser Water Reset	N/A	85F fixed	N/A	N/A	N/A
64	HW Boiler Type / Efficiency	N/A	3 NG, boilers 80% Eff.	N/A	N/A	N/A
65	Boiler Primary Pumps	N/A	CV boiler pumps	N/A	N/A	N/A
66	HW Secondary Loop Pumps	N/A	VFD	N/A	N/A	N/A
67	HW Loop Temp Reset	N/A	140-180F reset on zone demand.	N/A	N/A	N/A
68	**Space Set Points**					
69	Heating Thermostat Set Point, F (Occup / Unoccup / Throttle)	70 / 55 / 2	71 / 55 / 2	70 / 55 / 2	70 / 55 / 2	70 / 55 / 2
70	Cooling Thermostat Set Point, F (Occup / Unoccup / Throttle)	75 / 85 / 2	76 / 85 / 2	75 / 85 / 2	75 / 85 / 2	75 / 85 / 2
71	**Domestic Hot Water**					
72	Fuel Type / Effic / Tank Insulation / Recirc pump	NG / 80% / R-12 / None	NG / 80% / R-15 / Yes	NG / 80% / R-12 / None	NG / 83% / R-12 / None	NG / 83% / R-12 / None
73	Gals of Use Per Person/Day	1.2	1.2	0.5	10	2

Figure 22: Baseline Model Input Summary

7.2 Measures Modeled in Interactive Models

Parametric Run Label (in eQuest)	Measure Summary Description	Sub Measure 1			Sub Measure 2			Sub Measure 3		
		Sub Measure 1 Description	Sub Measure 1 Base Case Value	Sub Measure 1 Measure Value	Sub Meaure 2 Description	Sub Measure 2 Base Case Value	Sub Measure 2 Measure Value	Sub Meaure 3 Description	Sub Measure 3 Base Case Value	Sub Measure 3 Measure Value
1A	All measures modeled together	See above.								
2CT	CT fan size vs. gpm	CT Fan EIR	0.0132	0.0158						
3WI	Fenestration U value & SHGC	[1]	0.57	0.74	SHGC	N-0.61, Others 0.41	N=0.65; Others 0.49			
4TS	T-stat settings and deadband (occupied & unoccup)	Occup htg / clg set point	70 / 75	72 / 75	Unoccup htg / clg set point	55 / 85	63 / 80			
5LT	Lighting switching, auto controls, over-rides, TOD schedules	Simulate all ltg issues by changing W/sf	Code	+ 10%						
6EO	Equipment oversizing (chiller, boiler, airflow, coils).	Chiller over sizing ratio	10%	30%	Boiler over-sizing ratio	10%	30%	AHU over-sizing ratio	10%	30%
7SP	Duct static pressure reset	No reset simulated with less effic fan	Reset is VSD FPLR curve	[2]						
8TU	Air terminal turndown ratio	TU turndown	0.40	0.50						
9RS	Supply air, heating water, chilled water temperature reset	CHWST reset	44-50F	none	HWST reset	140-180	none	SAT reset	55-61	55-57
10CS	Staging not using all available cooling towers.	CT staging	1 Chiller uses 2 towers	1 Chiller for 1 tower						
11V	Variable flow on HW and CHW systems	Variable flow CHW	VSD on 2nd CHW pump	Constant volume on CHWP	Variable flow HW	VSD on 2nd CHW pump	Constant volume on HWP			

Figure 23: Large Office Parametric Inputs

Office-Small		Sub-Measure 1			Sub-Measure 2			Sub-Measure 3		
eQuest Run Label	**Measure Summary Description**	**Description**	**Base Case**	**Measure Value**	**Descrip-tion**	**Base Case**	**Measure Value**	**Descrip-tion**	**Base Case**	**Measure Value**
BaseCase	See Table A-1.									
1A	All measures modeled together	See above.								
2TS	T-stat space settings and deadband (occupied & unoccup)	Occup htg / clg set point	70 / 75	72 / 75	Unoccup htg / clg set point	55 / 85	63 / 80			
3ER	AC unit EER	EER	11.2	10						
4WI	Fenestration U & SHGC	Uoa	0.57	0.86	SHGC	N-0.61, Others 0.41	N=0.65; Others 0.49			
5OA	Mechanical minimum ventilation rate	Mech ventilation rate	0.123 cfm/sf (~20 cfm/ per)	0.157 cfm/sf (~25 cfm/ per)						
6LT	Lighting switching, auto controls, over-rides, TOD schedules	Simulate all ltg issues by changing W/sf	Code	+ 10%					Savings from these 2 thermostat measures were combined.	
7EC	Economizer functions	Econ integrated with mech cooling	Inte-grated	Non-Inte-grated	Econ chang-eover	75F change over	70F change over			
8VV	Single zones have variable volume	Single zone variable volume	VVT with gas	CV with gas						
9TS-HC*	Thermostat controls after hours override.	Thermostat override	No excess operation	Equip doesn't shut off after 4 hrs.						
10AR-HC*	AR testing & CalGreen Cx Reqr clear in specs and tested well.	AR & CG Cx in specs	[3]	[4]						

Referenced Notes:

[1] BaseCase U 0.57 is for assembly. In parametric could only input glass ctr, so it was entered as 0.86 which = 0.74 for assembly.

[2] Note not used.

[3] Testing and Cx requirements clearly shown in specs. Systems tested well.

[4] Testing and Cx requirements not well reflected in specs. Systems well tested. Assume a 10% energy performance degradation.

* HC indicates hand calculated measures. However, HC measures (except for the T-Stat override) were not included in the Base Savings values collective interactive run shown in the tables before savings are adjusted (Potential Annual Impacts from Design Review (non-adjusted). However, the HC measures were accounted for in the adjustment factor B in the Building Savings Adjustments.

Figure 24: Small Office Parametric Inputs

Restaurant		**Sub-Measure 1**			**Sub-Measure 2**			**Sub-Measure 3**		
eQuest Run Label	**Measure Summary Description**	**Description**	**Base Case**	**Measure Value**	**Descrip-tion**	**Base Case**	**Measure Value**	**Descrip-tion**	**Base Case**	**Measure Value**
BaseCase	See Table A-1.									
1A	All measures modeled together	See above.								
2TS	T-stat space settings and deadband (occupied & unoccup)	Occup htg / clg set point	70 / 75	72 / 75	Unoccup htg / clg set point	55 / 85	63 / 80			
3ER	AC unit EER	EER	11.2	10						
4WI	Fenestration U & SHGC	Uoa	0.57	0.86	SHGC	N=0.61, Others 0.41	N=0.65; Others 0.49			
5WH	Water heater efficiency (code is 80%. 94% are available.	Water heater efficiency	0.83	0.78				Savings from these 2 thermostat measures were combined.		
6LT	Lighting switching, auto controls, over-rides, TOD schedules	Simulate all ltg issues by changing W/sf	Code (ASHRAE 90.1)	+ 10%						
7RO	Increase roof insulation R-value	Roof R-value	2" R-14	1 1/2" R-10						
10TS-HC*	Thermostat controls after hours override.	Thermostat override	No excess operation	Equip doesn't shut off after 4 hrs.						
11AR-HC*	AR testing & CalGreen Cx Reqr clear in specs and tested well.	AR & CG Cx in specs	[3]	[4]						

Referenced Notes:

[1] BaseCase U 0.57 is for assembly. In parametric could only input glass ctr, so it was entered as 0.86 which = 0.74 for assembly.

[2] Note not used.

[3] Testing and Cx requirements clearly shown in specs. Systems tested well.

[4] Testing and Cx requirements not well reflected in specs. Systems well tested. Assume a 10% energy performance degradation.

* HC indicates hand calculated measures. However, HC measures (except for the T-Stat override) were not included in the Base Savings values collective interactive run shown in the tables before savings are adjusted (Potential Annual Impacts from Design Review (non-adjusted). However, the HC measures were accounted for in the adjustment factor B in the Building Savings Adjustments.

Figure 25: Restaurant Parametric Inputs

		Sub Measure 1			Sub Measure 2			Sub Measure 3		
Parametric Run Label (in eQuest)	**Measure Summary Description**	**Sub Measure 1 Description**	**Base Case Value**	**Measure Value**	**Sub Meaure 2 Description**	**Base Case Value**	**Measure Value**	**Sub Meaure 3 Description**	**Base Case Value**	**Measure Value**
BaseCase	BaseCase									
1A	All measures modeled together	See above.								
2TS	T-stat space settings and deadband (occupied & unoccup)	Occup htg / clg set point	70 / 75	72 / 75	Unoccup htg / clg set point	55 / 85	63 / 80			
3ER	AC unit EER	EER	11.2	10						
4WI	Fenestration U & SHGC	Uoa	0.57	0.86	SHGC	N=0.61, Others 0.41	N=0.65; Others 0.49			
5OA	Mechanical minimum ventilation rate	Mech ventilation rate	0.20 cfm/sf	0.25 cfm/sf						
6LT	Lighting switching, auto controls, over-rides, TOD schedules	Simulate all ltg issues by changing W/sf	Code (ASHRAE 90.1)	+ 10%				Savings from these 2 thermostat measures were combined.		
7EC	Economizer functions	Econ integrated with mech cooling	Inte-grated	Non-Inte-grated	Econ chang-eover	75F change over	70F change over			
8RO	Increase roof insulation R-value	Roof R-value	2" R-14	1 1/2" R-10						
9TS-HC*	Thermostat controls after hours override.	Thermostat override	No excess operation	Equip doesn't shut off after 4 hrs.						
10AR-HC*	AR testing & CalGreen Cx Reqr clear in specs and tested well.	AR & CG Cx in specs	[3]	[4]						

Figure 26: Retail Parametric Inputs

School		Sub-Measure 1			Sub-Measure 2			Sub-Measure 3		
eQuest Run Label	**Measure Summary Description**	**Description**	**Base Case**	**Measure Value**	**Descrip-tion**	**Base Case**	**Measure Value**	**Descrip-tion**	**Base Case**	**Measure Value**
BaseCase	See Table A-1.									
1A	All measures modeled together	See above.								
2TS	T-stat space settings and deadband (occupied & unoccup)	Occup htg / clg set point	70 / 75	72 / 75	Unoccup htg / clg set point	55 / 85	63 / 80			
3ER	AC unit EER	EER	11.2	10						
4WI	Fenestration U & SHGC	Uoa	0.57	0.86	SHGC	N=0.61, Others 0.41	N=0.65; Others 0.49			
5WH	Water heater efficiency (code is 80%. 94% are available.	Water heater efficiency	0.83	0.78					Savings from these 2 thermostat measures were combined.	
6LT	Lighting switching, auto controls, over-rides, TOD schedules	Simulate all ltg issues by changing W/sf	Code (ASHRAE 90.1)	+ 10%						
7RO	Increase roof insulation R-value	Roof R-value	2" R-14	1 1/2" R-10						
10TS-HC*	Thermostat controls after hours override.	Thermostat override	No excess operation	Equip doesn't shut off after 4 hrs.						
11AR-HC*	AR testing & CalGreen Cx Reqr clear in specs and tested well.	AR & CG Cx in specs	[3]	[4]						

Referenced Notes:
[1] BaseCase U 0.57 is for assembly. In parametric could only input glass ctr, so it was entered as 0.86 which = 0.74 for assembl
[2] Note not used.
[3] Testing and Cx requirements clearly shown in specs. Systems tested well.
[4] Testing and Cx requirements not well reflected in specs. Systems well tested. Assume a 10% energy performance degradatio

* HC indicates hand calculated measures. However, HC measures (except for the T-Stat override) were not included in the Base Savings values collective interactive run shown in the tables before savings are adjusted (Potential Annual Impacts from Design Review (non-adjusted). However, the HC measures were accounted for in the adjustment factor B in the Building Savings Adjustments.

Figure 27: School Parametric Inputs

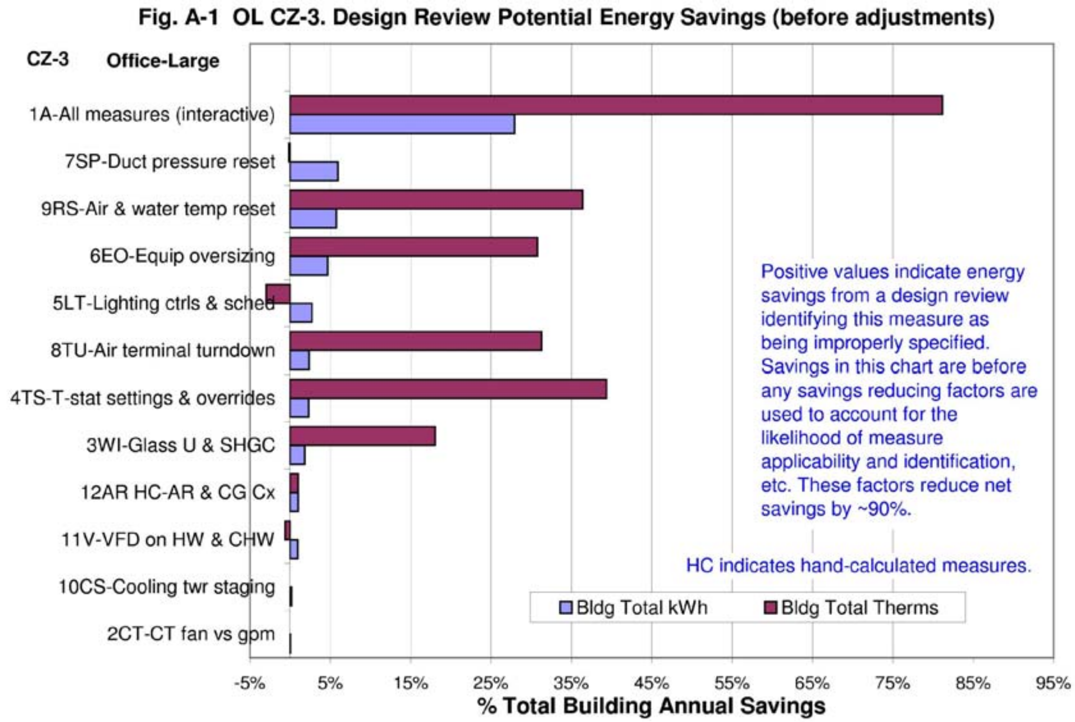

Figure 28: Energy Savings by Measure – Large Office, Climate Zone 3

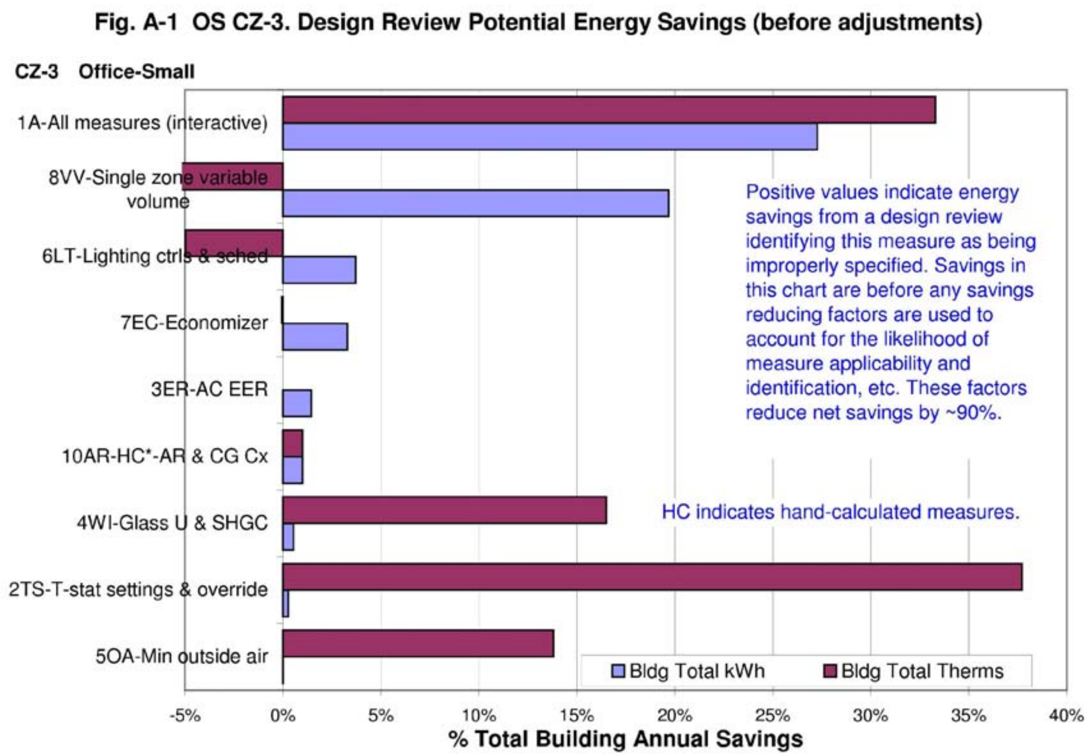

Figure 29: Energy Savings by Measure – Small Office, Climate Zone 3

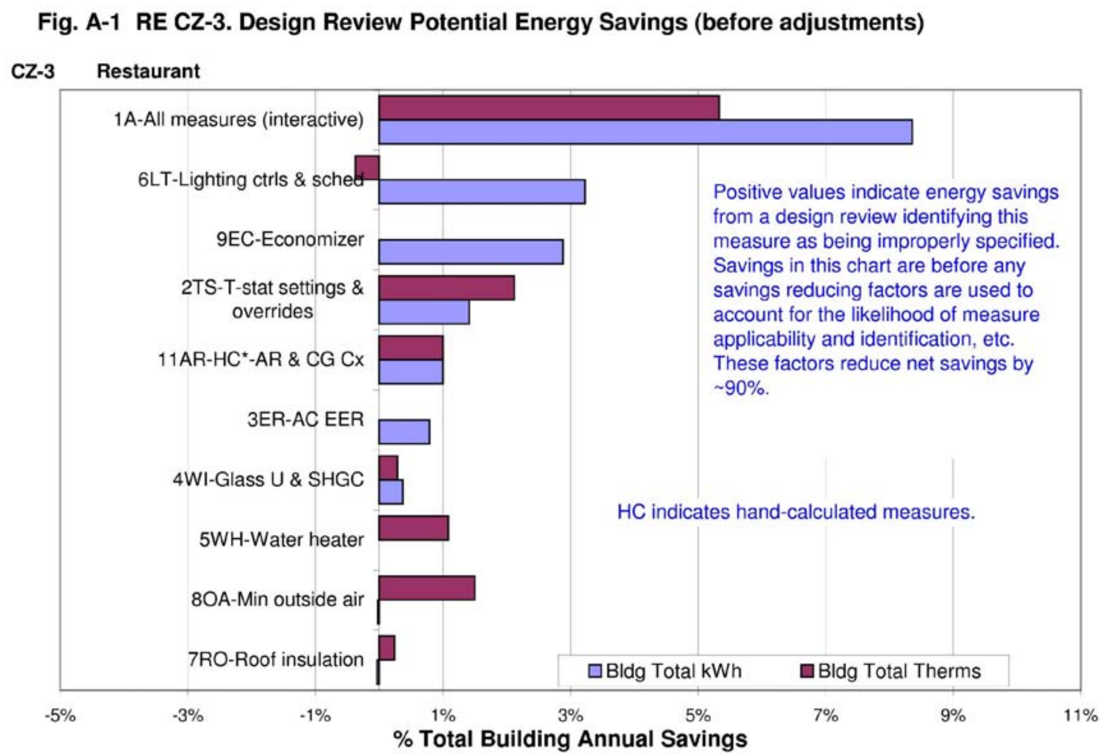

Figure 30: Energy Savings by Measure – Restaurant, Climate Zone 3

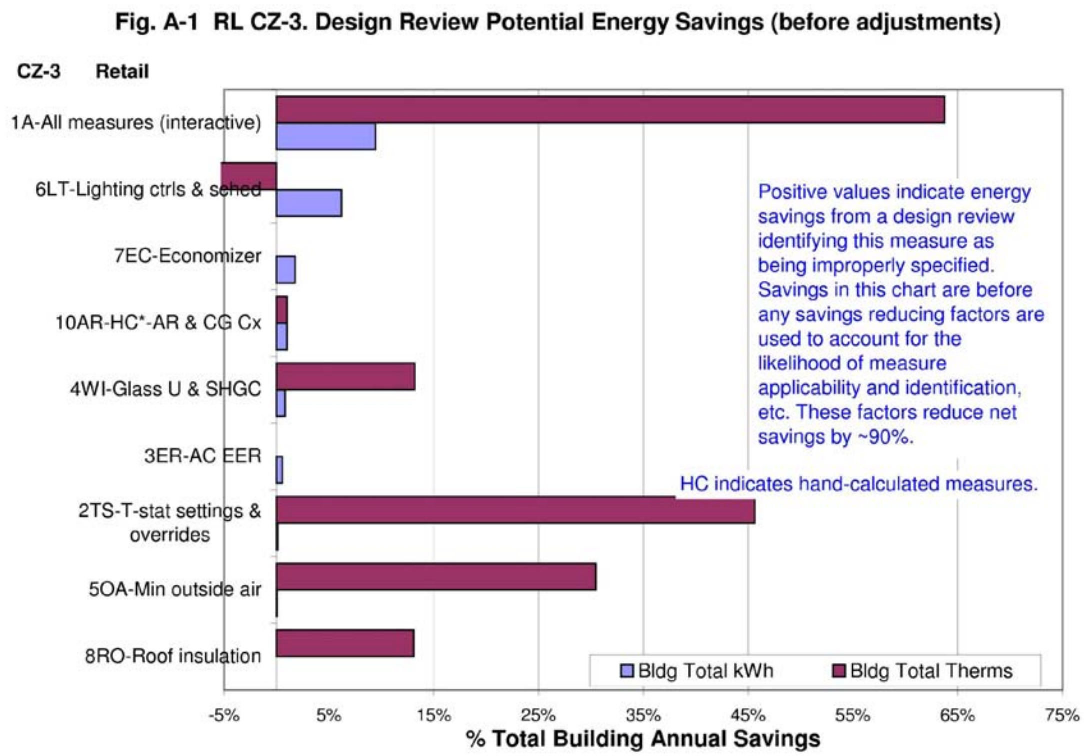

Figure 31: Energy Savings by Measure – Retail, Climate Zone 3

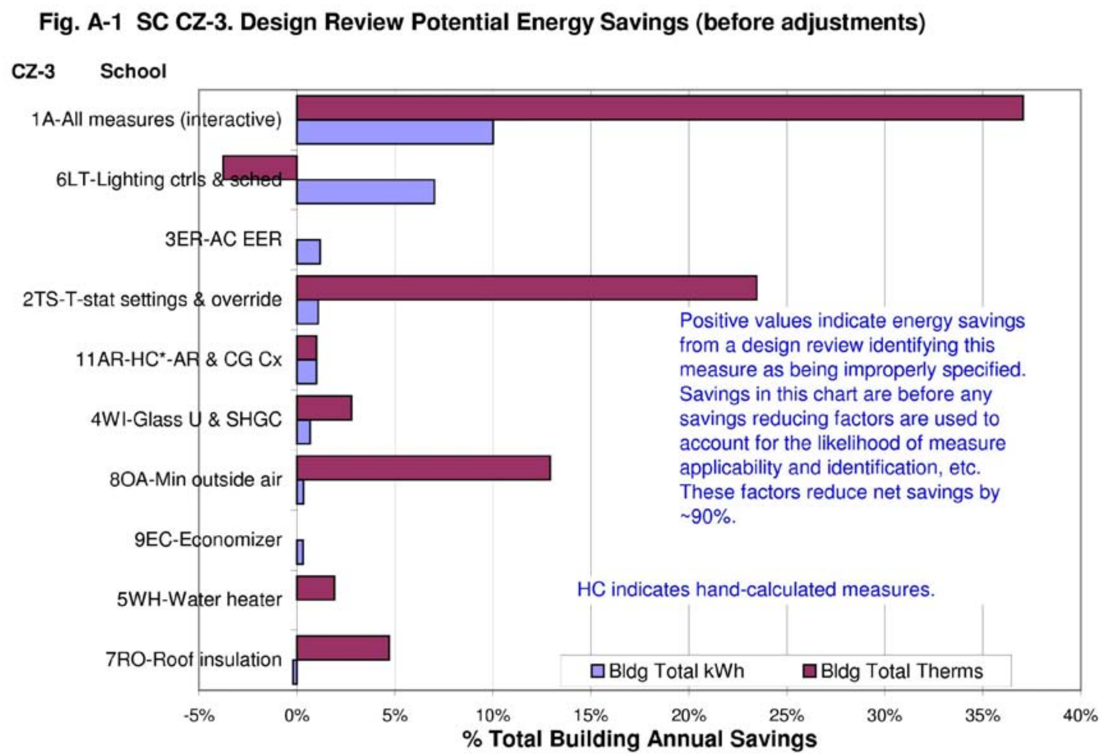

Figure 32: Energy Savings by Measure – School, Climate Zone 3

7.4 Details on Estimated Cost of Performing Design Review

	Small and Simple Projects (<10k sf)	**Reviewer Hrs**	**Designer, Owner or Contractor Hrs**
Review type: Self (designer, owner or contractor)			
1	**Design Review Kickoff**		
a	Obtain checklists for project (CEC website).	0	2
b	Review checklists and consider incorporating elements for this project. Check off each applicable item.	0	4
2	**Mid- and End-CD phase**		
a	Obtain checklists for project (CEC website).	0	2
b	Review checklists and consider incorporating elements for this project. Check off each applicable item.	0	5
c	At end of CD phase, print out all energy model Compliance Reports, including Performance, Envelope, Lighting, Mechanical and Ventilation reports. Confirm that all required signatures and initials are made. Fill in Energy Model Verification Checklist confirming energy model inputs are reflected in the drawings and specifications.	0	2
3	**Permit confirmation form**		
a	Sign and submit confirmation form	0	1
4	Not used.	0	0
	Total Hours	**0**	**16**
5	Cost	$ -	$ 2,400
6	**Total Cost (all parties)**	**$ 2,400**	

Figure 33: Design Review Cost Breakdown – Small Projects

	Moderate Project (10-50k sf)	Reviewer Hrs	Design Firm Hrs
	Costing is for a 30k sf bldg.		
	Review type: In-house review by design firm (reviewer not on project team)		
1	**Design Review Kickoff**		
a	Obtain checklists for project (CEC website).	0	2
b	Designer reviews checklists and considers incorporating elements for this project. Check off each applicable item.	0	16
2	**Mid- and End-CD phase**		
a	Obtain checklists for project (CEC website).	0	2
b	Reviewer reviews checklists and consider incorporating elements for this project. Check off each applicable item. Checklists will include confirming that critical elements of the energy models are reflected in the plans and specifications utilizing the Energy Model Verification checklist.	0	24
c	At end of CD phase, print out all energy model Compliance Reports, including Performance, Envelope, Lighting, Mechanical and Ventilation reports. Confirm that all required signatures and initials are made.	0	3
3	**Permit confirmation form**		
a	Interface with commissioning provider	0	2
b	Sign and submit confirmation form	0	2
4	Not used.	0	0
	Total Hours	**0**	**51**
5	Cost	$ -	$ 7,650
6	**Total Cost (all parties)**	**$ 7,650**	

Figure 34: Design Review Cost Breakdown – Moderate Projects

Large or Complex (>50k sf)		Reviewer Hrs	Designer Hrs
Costing is for a 100k sf bldg.			
Review type: Independent 3rd party reviewer.			
1	**Design Review Kickoff**		
a	Obtain checklists for project (CEC website or from reviewer).	2	2
b	Designer provides SD documents to reviewer (drawings, OPR, BOD).	0	2
d	Reviewer with SD documents in hand, prepare project specific checklists and review notes for improving energy efficiency beyond code.	16	0
e	Project meeting preparation, travel and meeting to discuss reviewer recommendations (reviewer with designer).	8	4
f	Designer reviews checklists and recommendations. Consider incorporating elements for this project. Check off each applicable item.	0	20
2	**Late CD phase**		
a	Obtain checklists for project (CEC website or from reviewer).	2	2
b	Designer reviews CD checklists and ensures the design is complying.	0	6
c	Designer provides late CD documents (including energy model inputs in the Energy Model Verification Checklist) to reviewer (drawings, OPR, BOD).	0	4
d	Reviewer review documents for code issues and any other energy improvements. Issue a report and checklist. Confirm that critical elements of the energy models are reflected in the plans and specifications.	32	0
e	Designer responds to reviewer comments in writing with disposition on each comment.	0	24
f	Adjudicate comments not agreed upon.	3	3
g	Designer prepares final agreed upon review report and checklist ready for permitting. Alternatively, the reviewer performs this task.	0	4
h	At end of CD phase, print out final energy model Compliance Reports, including Performance, Envelope, Lighting, Mechanical and Ventilation reports. Confirm that all required signatures and initials are made.	0	4
3	**Permit confirmation form**		
a	Interface with commissioning provider	2	2
b	Designer signs and submits confirmation form. Alternatively the reviewer performs this task.	0	3
4	Not used.	0	0
	Total Hours	**65**	**80**
5	Labor Cost	$ 9,750	$ 12,000
6	Expenses (copies of drawings and specs to reviewer)		$ 400
7	**Total Cost (all parties)**	**$ 22,150**	
Costs are one-time review costs at the beginning of the project.			

Figure 35: Design Review Cost Breakdown: Large Projects

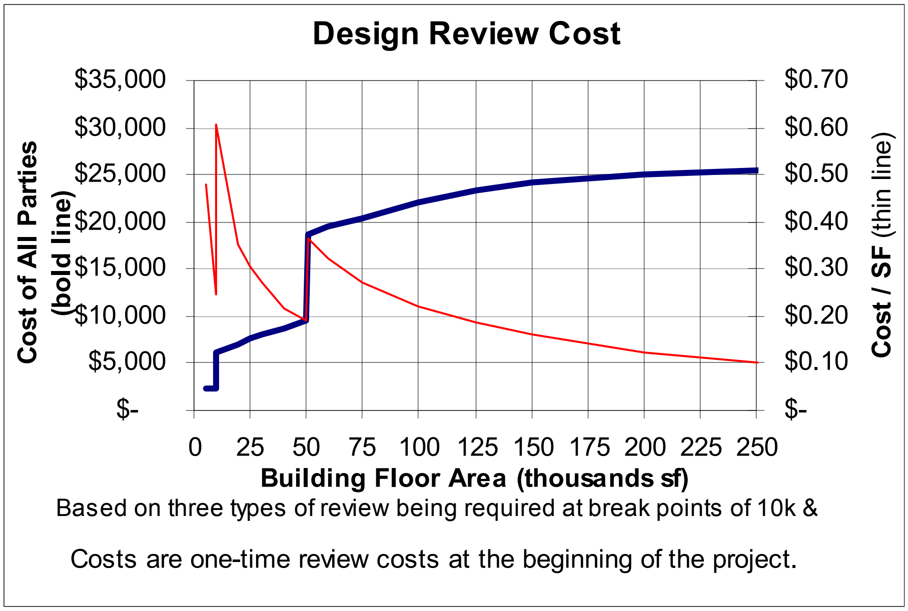

Figure 36: Design Review Cost

7.5 New Certificate of Compliance Forms – DESC-1C and DESC-2C

CERTIFICATE **DESIGN REVIE**	**DESC-1C**
	(Page x of xx)
Project Name/Addr	
Climate Zone:	sf):
Reviewer's Name:	
Enforcement Agenc	
Enforcement Agenc	

DATE OF DESIG	/ /	
Owner/Owner's Re		Date:
Design Engineer (P		Date:
Design Reviewer (F		Date:

DATE OF CD CH	/ /
CHECKLISTS COM	
GENERAL CHECKLIST - COMPLETED BY ALL BUILDINGS	YES □ NO □
HVAC SIMPLE	YES □ NO □
HVAC COMPLEX	YES □ NO □

Owner/Owner's Representative (Print Name):	Signature:	Date:
Design Engineer (Print Name):	Signature:	Date:
Design Reviewer (Print Name):	Signature:	Date:

CERTIFICATE OF COMPLIANCE and DESIGN REVIEW CHECKLIST	**DESC-1C**
DESIGN REVIEW KICKOFF	**(Page x of xx)**

Project Name/Address:

General Information

Climate Zc ... ɛd Area (sf):

Reviewer's

Enforceme

Enforceme ... e: Date

DATE OF	___/___/___
CHECKLI	**YES** □ **NO** □

LIST OF

DOCUME

DESIGN I

PROJEC

DESIGN

HVAC SYSTEM SELECTION:

UNRESOLVED DESIGN ISSUES:

OTHER COMMENTS:

COORDINATION:	
TARGET CD REVIEW DATE:	
TARGET PERMIT SUBMITTAL DATE:	

Owner/Owner's Representative (Print Name):	Signature:	Date:
Design Engineer (Print Name):	Signature:	Date:
Design Reviewer (Print Name):	Signature:	Date:

CERTIFICATE OF COMPLIANCE and DESIGN REVIEW CHECKLIST **DESC-2C**

CONSTRUCTION DOCUMENTS **(Page x of xx)**

Project Name/Address:

General Information

Climate Zone:	Building Type:	Conditioned Area (sf):
Reviewer's Name:	Reviewer's Agency:	

Note: Design Review for each system/subsystem must be submitted

Enforcement Agency:	Permit Number:

Enforcement Agency U

Code Section					Notes
FENESTRATION PROD					
116(a)2	A fenest accorda Ufactor				
116(a)3	A fenest accorda use the (Excepti				
143(a)5.A	Total ar than 40 times th greater				
143(a)5.B-C	Window gain no TABLE 143-B, or TABLE 143-C			N/A	
143(a)6.A, B, C	Skylights shall have an area no greater than 5 percent of the gross exterior roof area; a U-factor no greater than in Table 143-A, 143-B or 143-C; a SHGC no greater than in Table 143-A, 143-B or 143-C.			N/A	
115(a)5	Before an occupancy permit is granted site-built fenestration products in other then low-rise residential buildings shall be certified as meeting the AR for Code Compliance, as specified by the Reference Nonresidential Appendix NA7. A Certificate of Acceptance shall be submitted to the enforcement agency that certifies that the fenestration product meets the acceptance requirements.			N/A	

JOINTS AND OTHER OPENINGS					
117	Joints and other openings in the building envelope that are potential sources of air leakage shall be caulked, gasketed, weather stripped, or otherwise sealed to limit infiltration and exfiltration			N/A	
INSULATION AND ROOF					
118(a) - 118 (i)	Products r (a) Certific (b) Conditi Insulation (c) Flame (d) Install (e) Placem (f) Demisir (g) Insulat comply wi (h) Effectiv comply wi (i) Roofing Emittance Section 10				
143(a)1.C	Exterior rc assembly TABLE 143				
143(a)2	Exterior w greater th 143-B, or T				
143(a)4	External fl U-factor no greater than the applicable value in TABLE 143-A, TABLE 143-B, or TABLE 143-C.			N/A	
LIGHTING					
LIGHTING CONTROL DEVICES, BALLASTS AND LUMINAIRES					
119(d)	Occupant sensors, motion sensors, and vacancy ssensors shall be capable of automatically turning off all the lights in an area no more than 30 minutes after the area has been vacated.				

119(e)	Multi-level occupant sensors shall have an automatic OFF function that turns off all the lights, and either an automatic or a manually controlled ON function capable of meeting all the multi-level and uniformity requirements. The first stage shall be capable of activating between 30-70 percent of the lighting power in a room either through an automatic or manual action, and may be a switching or dimming system. After that event occurs the device shall be capable of all of the following actions when manually called to do so by the occupant: [illegible] 100 perce [illegible]				
131(b)	The genera [illegible] larger and [illegible] shall have [illegible] shall have [illegible] and 70% [illegible] lights to b [illegible] illuminan [illegible] dimming [illegible] alternate [illegible]				
119(k)	Dimmers [illegible] reducing [illegible] when the [illegible]				
119(m)	LEDs used [illegible] minimum [illegible]				
131(a)1	Each area [illegible] an indepe [illegible] accessible [illegible] see the lig [illegible] either ma [illegible] sensor.				
131(d)1	All indoor [illegible] controls t [illegible] may be oc [illegible] system, automatic time switch or other device capable of automatically shutting off the lighting.				
131(d)4	Offices 250 square feet or smaller; multipurpose rooms of less than 1000 square feet, and classrooms and conference rooms of any size, shall be equipped with occupant sensor(s) to shut off the lighting.				
146(a)	The actual indoor lighting power of the proposed building area is the total watts of all planned permanent and portable lighting systems as calculated under subsection (a). This must be no greater than the allowed indoor lighting power calculated under subsection (c).				

150(k)7.A-B	High efficacy luminaires shall be switched separately from low efficacy luminaires, and exhaust fans switched separately from lights.				
DAYLIGHT CONTROLS					
119(f)	Automatic daylighting control devices shall be capable of reducing the power consumption of the general lighting in the controlled area by at least t2/3 in response to daylight and shall reduce power in a manner to prevent flicker and premature light failure (if controlling incandescent or fluorescent lamps).				
Best Pra	*The locations of all photo sensors are shown on the plans. Height and position criteria are also shown. Photo sensors*				
Best Pra					
131(c)					
131(c)					
Best Pra					
Best Practice	*types and orientation (e.g., a single zone should not include east and south facing glass or have a section of tall window-wall and another wall section of smaller windows).*				
Best Practice	*Specifications state that sensor and dimming settings are set up and calibrated after furniture and final finishes and all lighting equipment are installed and operational.*				
Best Practice	*Requirements for time of day lighting level measurements are included in acceptance requirements. Lighting level tests are required to be conducted at full sun, partial cloudy and full darkness.*				

Best Practice	*A complete step by step sequence of operation is included defining the lighting levels (max and min), zones, interaction with occupants, interaction with occupancy and time-clock controls, and interaction with lighting on-off or dimming switches.*				
Best Practice	*Interface with BAS or other lighting control systems is defined and is fully compatible for all features of the sequenc controls*				
Best Practice	*Any req included specifica degrada fluoresc output p output. dimmin*				
Best Practice	*Dayligh emerge and em*				
119(k)4-5	In a din not be a of turni Any dir control dimmer				
RETAIL LIGHTING					
131(e)	Floor ar lighting A or les				
131(g)	Retail s... demand responsive automatic lighting controls that uniformly reduce lighting power by at least 15%.				
OUTDOOR LIGHTING CONTROLS AND EQUIPMENT					
132(a)	All permanently installed outdoor luminaires employing lamps rated over 100 watts shall have a lamp efficacy of at least 60 lumens per watt or be controlled by a motion sensor.				
132(c)1	All permanently installed outdoor lighting shall be controlled by a photocontrol or astronomical time switch that automatically turns off the outdoor lighting when daylight is available.				

132(c)2	For lighting of building facades, parking lots, sales and non-sales canopies, all outdoor sales areas, and student pickup/drop-off zones where two or more luminaires are used, an automatic time switch shall be installed that is capable of (1) turning off the lighting when not needed and (2) reducing the lighting power (in watts) by at least 50 percent but not exceeding 80 percent or providing continuous dimming through a range that includes 50 percent through 80 percent reduction.				
SERVICE HOT WATER HEATING					
113(b)	Equipm Applian 111.				
113(c)2	SHW sy heat tra the syst				
123	Pipe ins				
Code Section					**Notes**
HVAC EQUIPMENT SE					
112(a)	Equipm Table 1				
144 (g)	Electric space h				
144 (i)	No more chilled capacit				
Best Practice	*In drier c required, to pre-cool outside air and cool the air flowing over the DX condensing unit. Pre-cooled air is then dehumidified across the unitary cooling coil.*				
Best Practice	*In semi-arid climates, two-stage evaporative cooling has been evaluated in lieu of mechanical refrigeration.*				
Best Practice	*Heat recovery chillers or bundles are incorporated for domestic hot water or low temperature heating water for space heating or for outdoor air pre-heating and heating coils designed for the lower temperature water.*				

HVAC ZONING						
Best Practice	*Zone each air handler to serve only areas with common loads by time of day, e.g., cardinal perimeter faces of the building (or for smaller buildings group S; W and N; E), interior, etc., to allow more aggressive control and reset strategies and improve comfort. Have different AHU's serving core vs. perimeter areas.*					
Best Practice	*The design accommodates partial occupancy energy savings when the owner's requirements or narrative describe any possibility of partial occupancy, by zoning air handlers by floor or by part of a floor, or by incorporating controlled floor dampers, or VAV air terminals going totally shut v... numb... entire...*					
DESIGN - EQUIPME...						
144(a)	Mech... small... equip... cooli... the re...					
Best Practices (Fan Sizing)	*Fans ... accou... issues... appe...*					
Best Practices (Central Plant Sizing)	*The h... desig... witho... techn...*					
CONTROLS						
122(a) and (b)	The s... condi... an in... temp... appli... 1. Wh... shall be capable of being set down to 55oF or lower. 2. Where used to control cooling, thermostatic controls shall be capable of being set up to 85oF or higher. 3. Where used to control both comfort heating and cooling, thermostatic controls shall meet Items 1 and 2 and shall be capable of providing a temperature range or dead band of at least 5oF. 4. Thermostatic controls for all unitary single zone, air conditioners, heat pumps, and furnaces, shall comply with the setback thermostat requirements of Section 112(c) or, if equipped with DDC to the Zone level, with the Automatic Demand Shed Controls of Section 122(h).					

Best Practice	*Each wall mounted thermostat is located away from potential sources that would adversely affect the reading (close to copiers, direct sunlight, below or above a supply air diffuser or convector, etc.). Compare thermostat location drawings with furniture layout drawings if available. Each thermostat is located in an average representative location for the zone. Any thermostats mounted on exterior walls are installed in sealed and insulated junction boxes.*				
Best Practice	*Corner office should always have their own thermostats and air terminal boxes and fin-tube radiators.*				
Best Practice	*Multiple open are stats an select th and simu*				
122(e)1	Each spa shut off override occupar				
122(e)2.A	Shut off systems operate heating mechan				
122(e)2.B	Shut off systems operate cooling mechan				
Best Practice	*Lighting and shu design in controls*				
122(f)	Outdoor installed with dampers that automatically close upon fan shutdown.				
122 (h)	HVAC systems with DDC to the Zone level shall be programmed to allow centralized demand shed for non-critical zones.				
122(g)	Each space-conditioning system serving multiple zones with a combined conditioned floor area of more than 25,000 square feet shall be designed, installed, and controlled to serve isolation areas.				
144(d)	Space conditioning zone controls shall be provided (in each zone) to prevent reheating, recooling and simultaneous heating and cooling.				

Best Practice	*Control sequences and primary features to be set up are listed for equipment operated by all stand-alone packaged controls. Unoccupied sequences should be included.*				
Best Practice	*Control sequences exist for each piece of equipment listed in the equipment schedule that is monitored or controlled by the building automation system (BAS). Unoccupied sequences should be included.*				
Best Practice	*Outside air temperature sensors should be in a commer[...] or some*				
VENTILATION RATES					
121(a)2	The out / assum / shall b / Section				
121(b)2.A-B	Each sp / 121(b)1 / capabl / larger / applica / per per				
Best Practice	*The mir / handle*				
Best Practice	*Heat re / heat wh*				
DEMAND CONTROL V					
121(c)3	HVAC s / have de / econon / density / purpos / per 100 / single [...] system with DDC controls to the zone level.				
121(c)4.A-B	For each system with DCV, CO2 sensors (located in the room between 3 ft and 6 ft above the floor or at the anticipated height of the occupants heads) shall be installed in each room that meets the criteria of Section 121(c)3B with no less than one sensor per 10,000 ft² of floor space. When a zone or a space is served by more than one sensor, signal from any sensor indicating that CO2 is near or at the setpoint within a space, shall trigger an increase in ventilation to the space.				

121(c)4.E	When the system is operating during hours of expected occupancy, the controls shall maintain system outdoor air ventilation rates no less than the rate listed in TABLE 121-A times the conditioned floor area for spaces with CO2 sensors, plus the rate required by Section 121(b)2 for other spaces served by the system, or the exhaust air rate whichever is greater;				
ALL HVAC SYSTEMS					
144(e)	Econo with a mecha				
Best Practice	*Econo* *drive c* *major*				
Best Practice	*Barom* *than r*				
Best Practice	*Outdo* *prope* *measu* *Avera*				
DUCT DESIGN					
Best Practice	*Ducts* *restric* *Identi* *pressu* *pressu*				
Best Practice	*Duct b* *requir* *aid in*				
Best Practice	*Fans discharge into duct sections that remain straight for as long as possible (ideally 10 duct diameters) to reduce fan inefficiencies from system effects.*				
Best Practice	*Duct velocities are generally below 2,000 fpm for ducts in ceiling plenums, 1500 fpm for exposed ducts and 3500 fpm in mechanical rooms and non-noise sensitive shafts.*				
Best Practice	*Duct friction rates are generally less than 0.25" WC per 100 lineal feet nearer the fan, 0.15 to 0.20" in the main ducts and 0.08 to 0.12" WC /100' nearer the end of the system.*				

Best Practice	*Turning vane symbols are shown on the drawings, but the key doesn't provide details. There are over 10 configurations of turning vanes a contractor can pick from with a resulting pressure drop that varies by a factor of 4. Reference to SMACNA provides no definitive guidance. Please provide specific requirements in the drawings or spec optic unle If sin a tra pres (whi radiu to 2. and lowe spac*				
ACCEPTANCE AND					
125(a)	Acce cons				
CALGREEN 5.410.2	CX S CALG docu				
CALGREEN 5.410.2.4	Testi proc docu				
Best Practice	*Identify any constructability issues identified during Design Review:*				

CERTIFICATE OF COMPLIANCE and DESIGN REVIEW CHECKLIST	**DESC-2C**
CONSTRUCTION DOCUMENTS	**(Page x of xx)**

Project Name/Address:

General Information

Climate Zone:	Building Type:	Conditioned Area (sf):
Reviewer's Na[...]		Reviewer's Agency:
		[...]ted

Enforcement A[...]

Enforcement A[...] | [...]Date

CONTROLS

Code Section				Practice	**Notes**
SIMPLE HVAC					
144(c)2.A.					
144(l)					
Best Practices (Fan Sizing)	*Fans appear to be correctly sized for application, accounting for a factor of safety, diversity and redundancy issues. The results of a quick cfm per square foot calculation appear reasonable. Calculations greater than 0.9 cfm/sf in*				
Best Practice	*Thermostatic expansion valves (TXVs) are specified, rather than fixed-orifice types, in roof top DX units. TXVs make units more tolerant to refrigerant charge variations by maintaining unit efficiency over a wide range of under-or over-charged conditions.*				

CERTIFICATE OF COMPLIANCE and DESIGN REVIEW CHECKLIST	**DESC-2C**
CONSTRUCTION DOCUMENTS	**(Page x of xx)**

Project Name/Address:

General Information

Climate Zone:	Building Type:	Conditioned Area (sf):
Reviewer's Name:		Reviewer's Agency:

Note: Design Review for each system/subsystem must be submitted

Enforcement Agency:

Enforcement Agency (

Code Section						**Notes**
FAN SYSTEMS						
144(c)2.B.iii.	For VA\ motor (30% of when s design					
Best Practice	*Except f sized fo reheat (pressur limitatio undersi*					
Best Practice	*To facil. specifications require or drawings show that the VAV boxes are divided up into "isolation" areas, if the owner's requirements or narrative describe any possibility of partial occupancy. "Isolation areas are a floor or group of floors, or parts of a floor, etc. in which time of day occupancy or special environmental factors are common among all the boxes. Specifications state that these isolation areas will have their own time of day schedules, setbacks, set points, etc. All boxes can be commanded or scheduled totally shut together.*					

Best Practice	*The VAV box utilizes a "dual maximum" control logic which uses a cooling minimum cfm setpoint equal to the larger of the following: the minimum where the box can still provide stable control, and the minimum required to maintain the minimum ventilation rate. This will usually be lower than the typical non-dual max heating set point. The heating has two set points—min and max, with the maximum being near the typical non-dual max heating set point. (Advanced VAV System Design Guide, CEC 2003, p. 59. free download).*				
144(c)2.B.	VAV: fan power at design conditions for total system horsepower over 25 hp shall be less than 1.25 W/cfm of				
Best Practic (Fan Siz					
Best Pra					
144(c)					
144(c)					
144(c)4	less shall be ECM or shall have a minimum motor efficiency of 70 percent when rated in accordance with NEMA Standard MG 1-2006 at full load rating conditions				
Best Practices (VAV Box Sizing)	*Except for very noise sensitive locations, all VAV boxes are sized for a pressure drop very near 0.5" WC (including reheat coil). (From an energy perspective this balances pressure drop energy and minimum flow set point limitations: oversized boxes can't turn down as much and undersized boxes waste fan energy).*				

Best Practice	*No-fan powered boxes are used, unless necessary. If fan powered boxes are needed, parallel boxes rather than series are generally preferred.*				
Best Practice	*In VAV systems, duct static pressure is reset to meet the requirements of only the zone requiring the most pressure (air terminal box nearest its design max cfm). This has been required for systems with DDC in ASHRAE 90.1 since 1999 (6.5.3.2.3), and thus by any project going for LEED certification, since ASHRAE 90.1 is a minimum prerequisite. It is also required in the prescriptive path of CA Title 24 144 (c)2D.*				
Best Practice	*In variable air vo… not reset, the fixe… lowest possible v… diversity of the a… controlling pressu… fan to the last ter… duct run. If 3/4 o… sensors in each b… below set point. … determining the …*				
Best Practice	*Ducts utilize low … restrictive branch… Identify possible … pressure drop. Br… pressure drop, wh…*				
Best Practice	*Duct branches wi… requirements hav… aid in TAB work.*				
SUPPLY AIR TEMPERATURE (SA…					
144(f)	Mechanical spa… heated or coolec… controls that au… representative b… temperature and by at least 25% of the difference between the design SAT and the design room air temperature. Air distribution systems serving zones that are likely to have constant loads, such as interior zones, shall be designed for the air flows resulting from the fully reset SAT.				
Best Practice	*The SAT setpoint is reset on appropriate parameters, such as the combination of outside air temperature and terminal box cooling demand. SAT is reset to minimize reheat during cool weather (reset upward) and reduce chiller operation during warm weather (reset downward).*				

Best Practice	*A requirement is provided for the parameters used in the SAT reset algorithm to be user adjustable from the workstation.*				
Best Practice	*SAT resets off terminal box or valve demand should not rely on a lone worst device, but average a few worst devices, lest one bad device drive the entire system. The current worst devices are identified on the operator's workstation.*				
Best Practice	*SAT reset is coordinated with duct static pressure reset, with priority given to the reset that will save more energy*				
Best Practice	*Interior zone air flows are sized so the likely peak loads can be met at air temperatures higher than the minimum design temperatu[re. (This allows supply air temperature to] be reset higher a[...] perimeter zones v[...] zones).*				
HEAT REJECTION EQUIPMENT					
Table 112-G	Performance req[...] (cooling towers [...]				
144(h)	Heat rejection sy[...] larger shall have[...] of full speed or l[...] automatically ch[...] fluid temperatur[...] the heat rejectio[...]				
Best Practice	*Cooling tower st[...] 1) directly from a[...] set point, or 2) from a tower l[...] based on a head[...] bulb and tower a[...] a regression of lo[...] dry bulb.*				
Best Practice	*A higher conden[...] 18F rather than t[...] The cooling towe[...]*				
Best Practice	*Oversized cooling tower or low approach tower capacity is incorporated.*				
Best Practice	*Cooling tower capacity is optimized by using the following stages: 1) running condenser water over all towers with fans off, 2) starting all fans on low speed, and 3) ramping all fans up together. (Multiple fans running on low speed use less energy than a single fan at high speed, due to the cube law of power to flow).*				

Best Practice	*For the cooling tower bypass, a 2-way valve should be used in the bypass line rather than a 3-way valve, in order to reduce the pressure drop. The 2-way valve is sized so that no water will go over the tower when in full bypass.*				
Best Practice	*For DX air handlers with water-cooled condensers, the entering condenser water temperature is reset based on outdoor wet bulb or surrogate conditions.*				
Best Practice	*When cool weather cooling loads cannot be met by 100% outside air economizing, a plate and frame heat exchanger is used in parallel with the chiller to chill the water directly from the c*				
HYDRONIC SYSTEMS - C					
144(j)1	HVAC chil for variab pump flov percent o flow requ proper op				
144(j)2	When a cl chiller, pr any chille shut off w operating the purpo be consid				
Best Practice	*Chillers ar the curren sequence*				
Best Practice	*Total kW/ operating water tem at each co*				
Best Practice	*Sequence cycling wi are clearly described in the sequences. Installation of equipment and piping are consistent with the sequence.*				
Best Practice	*Chiller size selections were made understanding that often a larger chiller at part load is more efficient than a smaller chiller at full load, not accounting for pumping power, and thus having a small chiller to "start the day" may not be most efficient.*				

Best Practice	*Variable primary chilled water evaporator flow is used or was considered. In variable flow primary have the following guidelines been addressed: 1- Select for a minimum evaporator flow limit that is ≤ 60 % of chiller's design flow rate. 2- Make sure the valves and controllers are matched to the chillers limitations on flow-rate change during staging. 3- All chiller's evaporators have the same evaporator p… valve for hig… flow curve a… (a butterfly … reliable flow… evaporator … paddle flow… operating ch… another one… staring the r… stable opera…*				
Best Practice	*Chiller with … considered.*				
Best Practice	*Variable flo… chiller conde… effective in s… than in high…*				
144(j)3	When a hot… provisions … is automati… while still n… boiler(s).				
Best Practice	*Heating wat… temperature… water coils are correspondingly "oversized"). Normally HWRT should be less than 135F, which makes the HWST be about 160F and 35F dT coils.*				
Best Practice	*Boiler staging control is incorporated to take advantage of boiler part load efficiencies and to optimize total plant efficiency.*				

Best Practice	*The continuous turn-down ratio or size of the smallest chiller or boiler is in line with the lowest expected heating and cooling load that will occur frequently or be experienced for any significant length of time (assessed by asking the designer for the results of their calculations, and taking into account off-season and off-hours operation and the less than fully occupied condition that may exist for years). Some cycling is expected at the lowest loads, but cycling should be limited to manufacturer recommendations.*				
144(j)4	Chilled and hot water systems with a design capacity exceedi [illegible] water ([illegible] reset su [illegible] represe [illegible]				
Best Practice	*Chilled [illegible] temperc [illegible] dehumi [illegible] savings [illegible]*				
HYDRONIC SYSTEMS - [illegible]					
144(j)6.A	Individu [illegible] having [illegible] control [illegible] that wil [illegible] 30% of [illegible] pumps [illegible] differer [illegible]				
Best Practice	*In varia [illegible] only exc [illegible] or a bal [illegible] flowrate [illegible] overhea [illegible] is to be [illegible]*				
144(j)6.B	Systems [illegible] central [illegible] measured at or near the most remote heat exchanger or the heat exchanger requiring the greatest differential pressure. Systems with DDC of individual coils with central control panel, the static pressure set point shall be reset based on the valve requiring the most pressure, and the setpoint shall be no less than 80 percent open. The pressure sensor(s) may be mounted anywhere.				
Best Practice	*For each hydronic flow sensor, the location is shown on the drawings with detail notes indication length of straight pipe required up and down stream of that sensor.*				

Best Practice	*Hydronic loop pressure is reset based on heating or cooling valve position in most demand. A typical sequence could be: reset the differential set point until at least two heating (cooling) coil valves are at least 90% open. Using two valves, rather than one, reduces the change that a rogue zone (such as Tstat above a copy machine) will drive the set point inappropriately.*				
Best Practice	*There are pump impeller trim requirements for non-VFD controlled motors over 5 hp, if throttling more than 20 percent is requ… 20 hp controll… required at de… trimmed (VFD… loss at 70% sp… requirement t… be covered by…*				
Best Practices (Pump Sizing)	*A check of the… oversized. The… schedules can… (PD), which ca… and pipe leng…* *• Coils: Contro… PD* *• Main piping… w.c. for each e… effective pipe… actual foot of…* *• Runouts to… w.c. for each e… effective pipe… foot of length,…*				
Best Practices (Pump Sizing)	*Pumps are no… not exceed the… additional safety factor is needed, since the normal coil load diversity provides the pump safety factor).*				
HYDRONIC SYSTEMS - HYDRONIC HEAT PUMP					
144(j)7	Hydronic heat pumps connected to a common heat pump water loop with central devices for heat rejection and heat addition shall have controls that are capable of providing a heat pump water supply temperature dead band of at least 20°F between initiation of heat rejection and heat adc…				

HYDRONIC SYSTEMS - BAL/	
Best Practice	*The sequence valve layout systems, prop overflow of p review of the*
Best Practice	*Single line flo major system and the typic exhaust air). air or water t pumps, valve*
Best Practice	*Balancing va installed on t are a constar speed adjust:*
Best Practice	*In constant fl are shown at or floor branc that are not s at all coils. Sp screws at finc found in the specifications.*

7.6 Building Types Not Modeled in eQUEST

A college building has also been included in the analysis by estimating savings through a comparison with the large office building of energy end uses (see Figure 37 below). Data on energy end uses used for this comparison is from the California Commercial End-Use Survey, Statewide Results, 2006 (Tables 8-3 and 8-5). College sector savings were then estimated as a ratio of Large Office savings using the ratio of the College's electrical and gas energy use indices to Large Office, multiplied by the Large Office savings.

		kWh/sf/yr				kBtu/sf/yr	All Fuels
		Relevant End Uses [2]				Gas	For Adjacent
Building Type		Heat	Cool	Vent	Total	Space Heating	End Uses kBtu/sf/yr
OS	Office-Small	0.20	2.61	1.29	4.10	8.6	22.6
OL	**Office-Large**	**0.49**	**3.57**	**3.06**	**7.12**	**17.2**	**41.5**
RE	Restaurant	0.05	5.76	3.24	9.05	7.7	38.6
RL	Retail	0.08	2.21	1.81	4.10	3.0	17.0
SC	School	0.13	1.17	0.96	2.26	10.0	17.7
CO	**College**	**0.77**	**1.91**	**2.05**	**4.73**	**19.8**	**35.9**

Figure 37: Energy Use Intensities of Building Types Included in Design Review Evaluation

In addition, not all building sectors were included in the energy analysis. The following clarifies why these other building types were not modeled in eQUEST.

- Hospitals were excluded due to code exemptions,
- Grocery and refrigerated warehouse building types were eliminated due to the domination of refrigeration loads which are not part of this study, and
- Hotels were not included because the majority of the expected new floor area is in small motels where the energy use is dominated by individual room AC units, decreasing the likelihood that design review will offer significant benefit.

7.7 Bibliography

1. Khawaja, Sami, Allen Lee and Michelle Levy. May 10, 2007. **Statewide Codes and Standards Market Adoption and Noncompliance Rates.** Prepared for Southern California Edison, Final Report CPUC Program No. 1134-04. Quantec, LLC.
2. Levy, M., S. Khawaja and L. Benningfield. 2008. **Putting Codes Into Action: How Newly Updated Building Codes Translate Into Practice**. Quantec, LLC and The Benningfield Group.
3. Zing Communications, Inc. Market Research Report. **2007 Commercial Energy Code Compliance Study**. Sponsored by Architectural Products Magazine and the Lighting Controls Association.
4. Msuriello, H, S. Penney, M. Eldridge, and B. Foster.2010. American Council for an Energy-Efficient Economy. **Lessons Learned from Building Energy Code Compliance and Enforcement Evaluation Studies.** 2010 ACEEE Summer Study on Energy Efficiency in Buildings.
5. Ecotope. 2008. **Baseline Characteristics of the 2002-2004 Nonresidential Sector: Idaho, Montana, Oregon, and Washington – Progress Report**. Northwest Energy Efficiency Alliance.
6. Friedman, H., et al. 2009. **IEA Annex 47: Cost-Effective Commissioning for Existing and Low Energy Buildings. Final Report of Commissioning Costs and Benefits**. Prepared for U.S. Department of Energy. PECI.
7. Effinger, J. and H. Friedman. 2010. **The Right Measures: What Saves Energy in Existing Buildings**. ASHRAE Journal. October 2010.

7.8 Statewide Savings Analysis for Years 2014 through 2020

Office-Large	OL	(MWh)																
>30,000 P	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Statewide
OL_2014	2014	8.406	356.8	1654.4	930.2	169.2	864.4	530.9	1207.6	2328.8	274.2	212.1	2100.1	522.8	117.0	90.8	123.5	11491
OL_2015	2015	9.574	380.8	1535.5	1030.5	187.5	966.4	546.9	1321.8	2580.0	282.1	223.6	2274.7	535.9	119.3	100.6	130.5	12226
OL_2016	2016	8.378	371.4	1521.9	1005.7	182.9	931.2	563.3	1287.0	2470.3	290.1	225.4	2210.3	549.5	121.5	96.1	129.1	11964
OL_2017	2017	8.120	357.5	1567.1	949.8	172.8	864.1	580.2	1219.1	2297.3	298.4	230.2	2116.3	563.4	123.8	88.6	127.3	11564
OL_2018	2018	8.551	358.7	1598.1	946.2	172.1	872.0	597.5	1232.4	2322.5	306.9	236.3	2133.6	577.6	126.2	89.1	129.5	11707
OL_2019	2019	9.186	367.0	1617.5	969.1	176.3	912.0	615.3	1281.2	2430.8	315.6	244.4	2206.0	592.2	128.6	92.9	133.4	12091
OL_2020	2020	9.507	374.0	1636.4	988.8	179.9	934.5	633.6	1311.6	2494.0	324.6	252.1	2256.8	607.1	131.0	95.2	136.4	12366
Total		61.722	2566.2	######	6820.3	1240.7	6344.5	4067.6	8860.8	16923.7	2092.0	1624.1	15297.6	3948.4	867.4	653.4	909.7	83409
Average/yr		8.817	366.6	1590.1	974.3	177.2	906.4	581.1	1265.8	2417.7	298.9	232.0	2185.4	564.1	123.9	93.3	130.0	11916

Office-Small	OS	(MWh)																
<30,000 P	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Statewide
OS_2014	2014	18.311	101.4	330.2	243.7	44.3	337.1	354.6	462.6	863.9	232.8	149.9	649.8	361.6	62.3	25.4	75.3	4313
OS_2015	2015	18.818	100.6	314.1	242.1	44.0	350.6	380.1	478.1	902.1	243.2	145.5	647.4	363.3	63.6	26.5	77.3	4397
OS_2016	2016	18.745	97.5	310.2	231.9	42.2	333.4	381.4	464.2	878.1	241.0	134.7	622.2	336.4	63.4	25.5	76.2	4257
OS_2017	2017	18.910	97.5	313.4	231.0	42.0	315.4	373.1	447.7	841.8	236.1	128.1	607.4	310.9	62.7	24.0	74.2	4124
OS_2018	2018	19.191	98.6	318.6	233.0	42.4	314.6	377.8	448.2	842.9	238.2	127.1	609.7	306.1	63.1	24.0	74.3	4138
OS_2019	2019	19.475	99.8	322.1	235.6	42.9	318.4	385.7	453.1	854.6	242.8	127.7	616.4	307.7	63.8	24.3	75.2	4190
OS_2020	2020	19.729	100.8	325.3	238.0	43.3	321.6	393.2	457.8	866.0	246.6	128.8	623.8	310.6	64.5	24.7	76.1	4241
Total		######	696.2	2233.9	1655.2	301.1	2291.1	2646.0	3211.8	6049.4	1680.8	941.8	4376.7	2296.7	443.4	174.3	528.6	29660
Average/yr		19.026	99.5	319.1	236.5	43.0	327.3	378.0	458.8	864.2	240.1	134.5	625.2	328.1	63.3	24.9	75.5	4237

Restaurant	RE	(MWh)																
	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Statewide
RE_2014	2014	3.529	27.6	116.7	63.3	11.5	322.1	483.5	333.5	681.4	237.5	37.4	300.4	177.3	38.1	17.3	40.7	2892
RE_2015	2015	3.565	25.0	102.6	56.5	10.3	348.3	469.3	347.4	693.9	232.3	36.0	315.7	168.1	37.2	16.3	39.0	2901
RE_2016	2016	3.534	24.3	98.6	54.9	10.0	327.8	418.0	326.6	648.1	211.6	36.3	304.9	146.5	34.4	15.1	34.3	2695
RE_2017	2017	3.543	24.3	99.8	54.6	9.9	308.0	364.9	308.0	609.2	190.3	36.9	291.0	127.2	31.4	14.4	30.2	2504
RE_2018	2018	3.571	24.5	101.8	55.0	10.0	313.6	338.9	313.0	618.9	180.3	37.4	294.3	125.8	30.9	14.5	30.0	2493
RE_2019	2019	3.581	24.7	102.9	55.4	10.1	329.1	321.6	325.7	643.3	173.8	37.9	303.2	129.6	31.0	14.8	30.9	2538
RE_2020	2020	3.591	25.0	104.2	56.1	10.2	331.4	304.3	328.5	650.9	167.5	38.7	310.2	133.0	31.1	15.0	31.5	2541
Total		24.915	175.3	726.5	395.7	72.0	2280.3	2700.5	2282.8	4545.8	1393.2	260.6	2119.8	1007.4	234.1	107.6	236.6	18563
Average/yr		3.559	25.0	103.8	56.5	10.3	325.8	385.8	326.1	649.4	199.0	37.2	302.8	143.9	33.4	15.4	33.8	2652

Retail	RL	(MWh)																
	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Statewide
RL_2014	2014	13.354	124.1	416.5	318.9	58.0	719.9	851.2	891.2	1787.8	510.8	208.0	1007.2	516.4	104.6	47.3	107.1	7682
RL_2015	2015	8.464	115.3	417.0	304.8	55.5	709.8	881.1	868.8	1785.0	528.0	208.7	1017.9	538.0	102.8	49.5	105.8	7696
RL_2016	2016	7.055	111.5	418.4	296.1	53.9	624.6	907.3	770.4	1608.8	543.5	208.2	992.7	533.9	96.5	48.8	99.1	7321
RL_2017	2017	6.806	108.7	419.7	286.8	52.2	547.8	820.2	691.3	1449.7	506.2	209.5	950.2	512.1	91.2	46.3	91.6	6790
RL_2018	2018	6.938	108.5	422.5	285.3	51.9	535.0	803.8	678.5	1427.4	502.0	213.2	949.3	513.1	90.9	46.1	90.7	6725
RL_2019	2019	6.811	109.1	425.8	287.3	52.3	537.0	795.5	680.9	1441.5	501.7	217.7	965.1	523.2	91.4	46.9	92.0	6774
RL_2020	2020	6.977	110.0	429.1	289.2	52.6	538.0	789.0	683.7	1456.7	502.4	222.1	980.4	533.7	92.4	47.7	93.6	6827
Total		56.406	787.2	2949.0	2068.4	376.3	4212.2	5848.2	5264.7	10956.8	3594.6	1487.3	6862.8	3670.4	669.9	332.6	679.9	49816
Average/yr		8.058	112.5	421.3	295.5	53.8	601.7	835.5	752.1	1565.3	513.5	212.5	980.4	524.3	95.7	47.5	97.1	7117

School	SC	(MWh)																
	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Statewide
SC_2014	2014	4.581	22.6	74.8	52.1	9.5	83.4	101.3	134.6	245.8	100.4	61.8	219.1	125.9	21.4	7.9	18.6	1284
SC_2015	2015	4.618	22.9	78.9	52.5	9.5	82.9	110.0	134.6	251.0	109.2	68.7	229.1	142.2	22.9	8.4	19.5	1347
SC_2016	2016	4.659	23.3	80.2	53.6	9.7	83.6	117.9	136.5	260.0	115.3	69.1	232.6	141.5	23.7	8.7	19.8	1380
SC_2017	2017	4.699	23.6	79.1	54.5	9.9	85.1	127.4	138.5	266.7	122.8	69.5	235.6	140.6	24.1	9.1	20.0	1411
SC_2018	2018	4.741	24.0	79.1	55.8	10.2	87.5	138.3	143.6	281.1	132.2	71.6	240.9	144.0	25.3	9.6	20.7	1469
SC_2019	2019	4.786	24.6	80.3	57.6	10.5	89.7	149.4	147.4	292.7	141.8	74.5	247.7	149.8	26.2	10.1	21.3	1528
SC_2020	2020	4.827	25.0	81.2	58.8	10.7	91.7	159.5	151.6	304.6	150.1	76.8	253.4	153.8	27.1	10.5	21.8	1582
Total		32.910	166.1	553.6	384.8	70.0	603.9	903.8	986.8	1902.0	871.9	492.1	1658.4	997.7	170.6	64.2	141.8	10001
Average/yr		4.701	23.7	79.1	55.0	10.0	86.3	129.1	141.0	271.7	124.6	70.3	236.9	142.5	24.4	9.2	20.3	1429

College	CO	(MWh)																
	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Statewide
CO_2014	2014	3.786	51.9	183.9	132.6	24.1	182.3	149.3	218.9	473.5	94.0	50.3	262.4	150.1	28.3	12.2	27.9	2045
CO_2015	2015	3.810	50.1	184.0	126.0	22.9	192.3	131.2	233.1	508.7	86.0	48.8	266.2	153.8	29.8	12.2	29.9	2079
CO_2016	2016	3.828	46.8	183.3	114.4	20.8	189.2	105.2	230.6	504.5	73.6	47.2	260.0	148.8	29.4	12.1	29.4	1999
CO_2017	2017	3.860	46.1	184.2	111.7	20.3	172.1	90.6	213.8	472.7	64.9	42.2	244.8	134.9	27.8	11.8	27.8	1870
CO_2018	2018	3.909	47.3	186.1	115.4	21.0	164.2	88.6	207.9	468.5	63.5	40.5	243.2	131.7	28.0	11.8	27.9	1850
CO_2019	2019	3.967	49.8	188.8	123.5	22.5	164.6	86.7	207.7	473.5	63.3	41.9	251.6	137.1	28.0	11.9	28.5	1883
CO_2020	2020	4.048	55.0	193.1	140.6	25.6	170.9	101.4	214.6	489.4	70.8	44.6	266.9	142.7	29.0	12.1	29.3	1990
Total		27.209	346.9	1303.3	864.2	157.2	1235.7	752.9	1526.5	3390.8	516.2	315.5	1795.0	999.1	200.3	84.2	200.7	13716

Figure 38: Electric Savings from Design Review by Climate Zone for All New Construction

Office-Large	OL	(thousands of therms)															
>30,000 P	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Statewide
OL_2014	2014	0.4	25.0	86.2	42.2	8.6	34.7	17.9	40.8	90.9	11.4	11.2	110.1	24.9	5.1	1.4	7.8	519
OL_2015	2015	0.5	26.6	80.0	46.8	9.5	38.8	18.5	44.7	100.7	11.7	11.8	119.3	25.5	5.2	1.5	8.2	549
OL_2016	2016	0.4	26.0	79.3	45.7	9.3	37.4	19.0	43.5	96.4	12.1	11.8	115.9	26.2	5.3	1.5	8.1	538
OL_2017	2017	0.4	25.0	81.7	43.1	8.8	34.7	19.6	41.2	89.7	12.4	12.1	111.0	26.8	5.4	1.4	8.0	521
OL_2018	2018	0.4	25.1	83.3	43.0	8.7	35.0	20.2	41.6	90.7	12.7	12.4	111.9	27.5	5.5	1.4	8.2	528
OL_2019	2019	0.5	25.7	84.3	44.0	9.0	36.6	20.8	43.3	94.9	13.1	12.8	115.7	28.2	5.6	1.4	8.4	544
OL_2020	2020	0.5	26.2	85.3	44.9	9.1	37.5	21.4	44.3	97.3	13.5	13.2	118.3	28.9	5.7	1.5	8.6	556
Total		3.1	179.5	580.2	309.6	63.1	254.6	137.5	299.4	660.6	86.9	85.4	802.2	188.0	37.7	10.0	57.3	3755
Average/yr		0.4	25.6	82.9	44.2	9.0	36.4	19.6	42.8	94.4	12.4	12.2	114.6	26.9	5.4	1.4	8.2	536

Office-Small	OS	(thousands of therms)																
<30,000 P	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Statewide
OS_2014	2014	0.1	0.3	0.8	0.5	0.1	0.3	0.3	0.4	0.9	0.3	0.3	1.4	0.7	0.1	0.0	0.3	7
OS_2015	2015	0.1	0.3	0.8	0.5	0.1	0.3	0.3	0.4	0.9	0.3	0.3	1.4	0.7	0.1	0.0	0.3	7
OS_2016	2016	0.1	0.3	0.7	0.5	0.1	0.3	0.3	0.4	0.9	0.3	0.3	1.4	0.7	0.1	0.0	0.3	7
OS_2017	2017	0.1	0.3	0.8	0.5	0.1	0.3	0.3	0.4	0.9	0.3	0.3	1.3	0.6	0.1	0.0	0.3	7
OS_2018	2018	0.1	0.3	0.8	0.5	0.1	0.3	0.3	0.4	0.9	0.3	0.3	1.4	0.6	0.1	0.0	0.3	7
OS_2019	2019	0.1	0.3	0.8	0.5	0.1	0.3	0.3	0.4	0.9	0.3	0.3	1.4	0.6	0.1	0.0	0.3	7
OS_2020	2020	0.1	0.3	0.8	0.5	0.1	0.3	0.3	0.4	0.9	0.3	0.3	1.4	0.6	0.1	0.0	0.3	7
Total		0.5	2.3	5.4	3.5	0.7	2.1	2.1	2.9	6.3	1.9	2.1	9.7	4.6	0.8	0.1	2.3	47
Average/yr		0.1	0.3	0.8	0.5	0.1	0.3	0.3	0.4	0.9	0.3	0.3	1.4	0.7	0.1	0.0	0.3	7

Restaurant	RE	(thousands of therms)																
	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Statewide
RE_2014	2014	0.2	1.4	4.4	2.1	0.4	5.0	6.3	5.1	12.1	4.5	1.3	10.7	5.7	1.1	0.2	2.7	63
RE_2015	2015	0.2	1.3	3.9	1.9	0.4	5.4	6.1	5.4	12.4	4.4	1.3	11.2	5.4	1.1	0.2	2.5	63
RE_2016	2016	0.2	1.2	3.7	1.8	0.4	5.1	5.4	5.0	11.6	4.0	1.3	10.8	4.7	1.0	0.2	2.2	59
RE_2017	2017	0.2	1.2	3.8	1.8	0.4	4.8	4.7	4.8	10.9	3.6	1.3	10.3	4.1	0.9	0.1	2.0	55
RE_2018	2018	0.2	1.2	3.8	1.8	0.4	4.8	4.4	4.8	11.0	3.4	1.3	10.5	4.1	0.9	0.2	2.0	55
RE_2019	2019	0.2	1.2	3.9	1.8	0.4	5.1	4.2	5.0	11.5	3.3	1.4	10.8	4.2	0.9	0.2	2.0	56
RE_2020	2020	0.2	1.3	3.9	1.8	0.4	5.1	4.0	5.1	11.6	3.2	1.4	11.0	4.3	0.9	0.2	2.1	56
Total		1.3	8.9	27.4	13.0	2.6	35.2	35.1	35.2	81.0	26.4	9.3	75.3	32.5	6.9	1.1	15.4	407
Average/yr		0.2	1.3	3.9	1.9	0.4	5.0	5.0	5.0	11.6	3.8	1.3	10.8	4.6	1.0	0.2	2.2	58

Retail	RL	(thousands of therms)																
	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Statewide
RL_2014	2014	0.64	4.19	10.49	6.99	1.42	4.46	4.44	6.20	14.38	4.37	5.12	24.72	11.51	2.13	0.34	6.44	108
RL_2015	2015	0.40	3.90	10.50	6.69	1.36	4.40	4.60	6.05	14.35	4.52	5.13	24.99	11.99	2.09	0.35	6.36	108
RL_2016	2016	0.34	3.77	10.54	6.50	1.32	3.87	4.73	5.36	12.94	4.65	5.12	24.37	11.90	1.97	0.35	5.96	104
RL_2017	2017	0.32	3.67	10.57	6.29	1.28	3.39	4.28	4.81	11.66	4.33	5.16	23.33	11.41	1.86	0.33	5.51	98
RL_2018	2018	0.33	3.67	10.64	6.26	1.27	3.31	4.19	4.72	11.48	4.30	5.24	23.30	11.44	1.85	0.33	5.45	98
RL_2019	2019	0.32	3.69	10.72	6.30	1.28	3.33	4.15	4.74	11.59	4.29	5.35	23.69	11.66	1.86	0.33	5.53	99
RL_2020	2020	0.33	3.72	10.81	6.34	1.29	3.33	4.12	4.76	11.71	4.30	5.46	24.06	11.89	1.88	0.34	5.63	100
Total		2.68	26.60	74.28	45.37	9.24	26.10	30.51	36.65	88.10	30.76	36.59	168.46	81.81	13.64	2.37	40.88	714
Average/yr		0.38	3.80	10.61	6.48	1.32	3.73	4.36	5.24	12.59	4.39	5.23	24.07	11.69	1.95	0.34	5.84	102

School	SC	(thousands of therms)																
	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Statewide
SC_2014	2014	0.5	3.1	7.6	4.6	0.9	3.3	3.4	3.8	8.0	3.5	4.3	15.1	7.9	1.2	0.2	2.6	70
SC_2015	2015	0.5	3.1	8.1	4.7	1.0	3.3	3.7	3.8	8.2	3.8	4.8	15.8	8.9	1.3	0.2	2.8	74
SC_2016	2016	0.5	3.2	8.2	4.8	1.0	3.3	4.0	3.9	8.5	4.0	4.8	16.1	8.9	1.4	0.2	2.8	75
SC_2017	2017	0.5	3.2	8.1	4.8	1.0	3.4	4.3	3.9	8.7	4.3	4.8	16.3	8.8	1.4	0.2	2.8	77
SC_2018	2018	0.5	3.3	8.1	5.0	1.0	3.5	4.6	4.1	9.2	4.6	5.0	16.6	9.0	1.4	0.2	2.9	79
SC_2019	2019	0.5	3.4	8.2	5.1	1.0	3.6	5.0	4.2	9.6	4.9	5.2	17.1	9.4	1.5	0.2	3.0	82
SC_2020	2020	0.5	3.4	8.3	5.2	1.1	3.7	5.4	4.3	10.0	5.2	5.3	17.5	9.6	1.6	0.2	3.1	84
Total		3.7	22.8	56.5	34.2	7.0	24.1	30.3	27.9	62.2	30.3	34.1	114.5	62.6	9.8	1.3	20.1	541
Average/yr		0.5	3.3	8.1	4.9	1.0	3.4	4.3	4.0	8.9	4.3	4.9	16.4	8.9	1.4	0.2	2.9	77

College	CO	(thousands of therms)																
	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Statewide
CO_2014	2014	0.3	6.3	16.6	10.4	2.1	12.7	8.7	12.8	32.0	6.8	4.6	23.8	12.4	2.1	0.3	3.0	155
CO_2015	2015	0.3	6.1	16.6	9.9	2.0	13.4	7.7	13.6	34.4	6.2	4.4	24.2	12.7	2.2	0.3	3.3	157
CO_2016	2016	0.3	5.7	16.6	9.0	1.8	13.2	6.2	13.5	34.1	5.3	4.3	23.6	12.3	2.2	0.3	3.2	152
CO_2017	2017	0.3	5.6	16.6	8.8	1.8	12.0	5.3	12.5	32.0	4.7	3.8	22.2	11.1	2.1	0.3	3.0	142
CO_2018	2018	0.3	5.7	16.8	9.1	1.8	11.4	5.2	12.2	31.7	4.6	3.7	22.1	10.9	2.1	0.3	3.0	141
CO_2019	2019	0.3	6.0	17.1	9.7	2.0	11.4	5.1	12.2	32.0	4.6	3.8	22.9	11.3	2.1	0.3	3.1	144
CO_2020	2020	0.3	6.7	17.4	11.1	2.3	11.9	5.9	12.6	33.1	5.1	4.1	24.2	11.8	2.2	0.3	3.2	152
Total		2.4	42.0	117.7	68.0	13.8	85.9	44.1	89.4	229.3	37.2	28.7	163.1	82.4	15.1	2.2	21.9	1043

Figure 39: Natural Gas Savings from Design Review by Climate Zone for All New Construction

Office-Large	OL	(10^6 TDV kBtu)																
>30,000 P	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Statewide
OL_2014	2014	0.21	8.72	40.45	22.74	4.14	20.71	12.72	29.26	56.42	6.64	5.33	52.74	13.13	2.94	2.28	3.11	282
OL_2015	2015	0.24	9.31	37.54	25.19	4.58	23.15	13.10	32.03	62.51	6.83	5.62	57.13	13.46	3.00	2.53	3.29	300
OL_2016	2016	0.21	9.08	37.21	24.59	4.47	22.31	13.50	31.18	59.85	7.03	5.66	55.51	13.80	3.05	2.41	3.26	293
OL_2017	2017	0.20	8.74	38.31	23.22	4.22	20.70	13.90	29.54	55.66	7.23	5.78	53.15	14.15	3.11	2.23	3.21	283
OL_2018	2018	0.22	8.77	39.07	23.13	4.21	20.89	14.32	29.86	56.27	7.44	5.93	53.58	14.51	3.17	2.24	3.27	287
OL_2019	2019	0.23	8.97	39.54	23.69	4.31	21.85	14.74	31.04	58.89	7.65	6.14	55.40	14.87	3.23	2.33	3.37	296
OL_2020	2020	0.24	9.14	40.01	24.17	4.40	22.39	15.18	31.78	60.43	7.86	6.33	56.68	15.25	3.29	2.39	3.44	303
Total		1.56	62.74	272.12	166.74	30.33	152.00	97.45	214.68	410.03	50.69	40.79	384.20	99.16	21.78	16.41	22.95	2044
Average/yr		0.22	8.96	38.87	23.82	4.33	21.71	13.92	30.67	58.58	7.24	5.83	54.89	14.17	3.11	2.34	3.28	292

Office-Small	OS	(10^6 TDV kBtu)																
<30,000 P	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Statewide
OS_2014	2014	0.46	2.64	8.59	6.34	1.15	8.75	9.20	12.11	22.62	6.09	3.98	17.27	9.61	1.66	0.68	1.88	113
OS_2015	2015	0.47	2.62	8.17	6.30	1.15	9.10	9.87	12.52	23.62	6.37	3.87	17.21	9.66	1.69	0.70	1.93	115
OS_2016	2016	0.47	2.53	8.07	6.03	1.10	8.65	9.90	12.15	22.99	6.31	3.58	16.54	8.94	1.68	0.68	1.90	112
OS_2017	2017	0.47	2.54	8.15	6.01	1.09	8.19	9.69	11.72	22.04	6.18	3.41	16.15	8.27	1.67	0.64	1.85	108
OS_2018	2018	0.48	2.56	8.29	6.06	1.10	8.17	9.81	11.73	22.07	6.24	3.38	16.21	8.14	1.68	0.64	1.86	108
OS_2019	2019	0.49	2.59	8.38	6.13	1.11	8.26	10.01	11.86	22.37	6.35	3.40	16.39	8.18	1.70	0.65	1.88	110
OS_2020	2020	0.49	2.62	8.46	6.19	1.13	8.35	10.21	11.99	22.67	6.46	3.42	16.58	8.26	1.72	0.66	1.90	111
Total		3.33	18.11	58.10	43.05	7.83	59.47	68.68	84.08	158.37	44.00	25.03	116.34	61.05	11.79	4.63	13.21	777
Average/yr		0.48	2.59	8.30	6.15	1.12	8.50	9.81	12.01	22.62	6.29	3.58	16.62	8.72	1.68	0.66	1.89	111

Restaurant	RE	(10^6 TDV kBtu)																
	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Statewide
RE_2014	2014	0.08	0.68	2.87	1.56	0.28	7.18	10.78	7.98	16.30	5.68	0.93	7.47	4.41	0.95	0.43	0.95	69
RE_2015	2015	0.08	0.61	2.52	1.39	0.25	7.76	10.46	8.31	16.60	5.56	0.90	7.85	4.18	0.93	0.41	0.91	69
RE_2016	2016	0.08	0.60	2.42	1.35	0.25	7.30	9.31	7.81	15.50	5.06	0.90	7.59	3.64	0.86	0.38	0.80	64
RE_2017	2017	0.08	0.60	2.45	1.34	0.24	6.86	8.13	7.37	14.57	4.55	0.92	7.24	3.17	0.78	0.36	0.70	59
RE_2018	2018	0.08	0.60	2.50	1.35	0.25	6.99	7.55	7.49	14.80	4.31	0.93	7.32	3.13	0.77	0.36	0.70	59
RE_2019	2019	0.08	0.61	2.53	1.36	0.25	7.33	7.17	7.79	15.39	4.16	0.94	7.54	3.22	0.77	0.37	0.72	60
RE_2020	2020	0.08	0.61	2.56	1.38	0.25	7.38	6.78	7.86	15.57	4.01	0.96	7.72	3.31	0.77	0.37	0.73	60
Total		0.58	4.31	17.87	9.73	1.77	50.81	60.18	54.60	108.73	33.32	6.48	52.74	25.06	5.82	2.68	5.50	440
Average/yr		0.08	0.62	2.55	1.39	0.25	7.26	8.60	7.80	15.53	4.76	0.93	7.53	3.58	0.83	0.38	0.79	63

Retail	RL	(10^6 TDV kBtu)																
	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Statewide
RL_2014	2014	0.35	3.48	11.68	8.94	1.63	19.20	22.71	25.21	50.58	14.45	6.11	29.58	15.17	3.07	1.39	2.81	216
RL_2015	2015	0.22	3.23	11.69	8.55	1.55	18.93	23.50	24.58	50.50	14.94	6.13	29.89	15.80	3.02	1.45	2.78	217
RL_2016	2016	0.19	3.13	11.73	8.30	1.51	16.66	24.20	21.79	45.51	15.38	6.11	29.15	15.68	2.83	1.43	2.60	206
RL_2017	2017	0.18	3.05	11.77	8.04	1.46	14.61	21.88	19.56	41.01	14.32	6.15	27.91	15.04	2.68	1.36	2.41	191
RL_2018	2018	0.18	3.04	11.85	8.00	1.46	14.27	21.44	19.19	40.38	14.20	6.26	27.88	15.07	2.67	1.35	2.38	190
RL_2019	2019	0.18	3.06	11.94	8.06	1.47	14.32	21.22	19.26	40.78	14.19	6.39	28.34	15.37	2.69	1.38	2.42	191
RL_2020	2020	0.18	3.08	12.03	8.11	1.47	14.35	21.05	19.34	41.21	14.21	6.52	28.79	15.67	2.71	1.40	2.46	193
Total		1.48	22.07	82.69	58.00	10.55	112.35	155.99	148.94	309.96	101.69	43.68	201.54	107.79	19.67	9.77	17.86	1404
Average/yr		0.21	3.15	11.81	8.29	1.51	16.05	22.28	21.28	44.28	14.53	6.24	28.79	15.40	2.81	1.40	2.55	201

School	SC	(10^6 TDV kBtu)																
	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Statewide
SC_2014	2014	0.12	0.63	2.07	1.44	0.26	2.40	2.91	4.38	7.99	3.26	2.05	7.26	4.17	0.71	0.26	0.50	40
SC_2015	2015	0.12	0.64	2.18	1.45	0.26	2.38	3.16	4.38	8.16	3.55	2.28	7.59	4.71	0.76	0.28	0.52	42
SC_2016	2016	0.12	0.65	2.22	1.48	0.27	2.40	3.39	4.44	8.45	3.75	2.29	7.70	4.69	0.78	0.29	0.53	43
SC_2017	2017	0.13	0.65	2.19	1.51	0.27	2.45	3.66	4.50	8.67	3.99	2.30	7.80	4.66	0.80	0.30	0.54	44
SC_2018	2018	0.13	0.66	2.19	1.55	0.28	2.52	3.98	4.67	9.14	4.30	2.37	7.98	4.77	0.84	0.32	0.55	46
SC_2019	2019	0.13	0.68	2.22	1.59	0.29	2.58	4.30	4.79	9.52	4.61	2.47	8.20	4.96	0.87	0.33	0.57	48
SC_2020	2020	0.13	0.69	2.25	1.63	0.30	2.64	4.59	4.93	9.91	4.88	2.54	8.39	5.09	0.90	0.35	0.58	50
Total		0.88	4.60	15.33	10.66	1.94	17.37	25.99	32.09	61.85	28.35	16.30	54.92	33.04	5.65	2.12	3.79	315
Average/yr		0.13	0.66	2.19	1.52	0.28	2.48	3.71	4.58	8.84	4.05	2.33	7.85	4.72	0.81	0.30	0.54	45

College	CO	(10^6 TDV kBtu)																
	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Statewide
CO_2014	2014	0.10	1.27	4.50	3.24	0.59	4.37	3.58	5.30	11.47	2.28	1.26	6.59	3.77	0.71	0.31	0.70	50
CO_2015	2015	0.10	1.22	4.50	3.08	0.56	4.61	3.14	5.65	12.32	2.08	1.23	6.69	3.86	0.75	0.31	0.75	51
CO_2016	2016	0.10	1.14	4.48	2.80	0.51	4.53	2.52	5.59	12.22	1.78	1.18	6.53	3.74	0.74	0.30	0.74	49
CO_2017	2017	0.10	1.13	4.50	2.73	0.50	4.12	2.17	5.18	11.45	1.57	1.06	6.15	3.39	0.70	0.30	0.70	46
CO_2018	2018	0.10	1.16	4.55	2.82	0.51	3.93	2.12	5.04	11.35	1.54	1.02	6.11	3.31	0.70	0.30	0.70	45
CO_2019	2019	0.10	1.22	4.62	3.02	0.55	3.94	2.08	5.03	11.47	1.53	1.05	6.32	3.44	0.70	0.30	0.72	46
CO_2020	2020	0.10	1.34	4.72	3.44	0.63	4.10	2.43	5.20	11.86	1.72	1.12	6.70	3.58	0.73	0.30	0.74	49
Total		0.69	8.48	31.86	21.13	3.84	29.61	18.04	36.98	82.15	12.51	7.92	45.08	25.09	5.03	2.11	5.06	336

Figure 40: TDV-E Savings from Design Review by Climate Zone for All New Construction

Office-Large	OL	(10^6 TDV kBtu)															
>30,000 P(	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Statewide
OL_2014	2014	0.07	4.14	14.31	7.01	1.43	5.80	3.00	6.84	15.24	1.91	1.88	18.53	4.19	0.86	0.23	1.34	87
OL_2015	2015	0.08	4.42	13.28	7.76	1.58	6.49	3.09	7.49	16.89	1.96	1.98	20.07	4.29	0.87	0.26	1.42	92
OL_2016	2016	0.07	4.31	13.16	7.57	1.54	6.25	3.18	7.29	16.17	2.02	1.99	19.51	4.40	0.89	0.25	1.40	90
OL_2017	2017	0.07	4.15	13.55	7.15	1.46	5.80	3.28	6.91	15.04	2.08	2.04	18.68	4.51	0.91	0.23	1.38	87
OL_2018	2018	0.07	4.16	13.82	7.13	1.45	5.85	3.38	6.98	15.20	2.14	2.09	18.83	4.63	0.92	0.23	1.41	88
OL_2019	2019	0.08	4.26	13.99	7.30	1.49	6.12	3.48	7.26	15.91	2.20	2.16	19.47	4.75	0.94	0.24	1.45	91
OL_2020	2020	0.08	4.34	14.15	7.45	1.52	6.27	3.58	7.43	16.32	2.26	2.23	19.92	4.86	0.96	0.24	1.48	93
Total		0.53	29.77	96.26	51.37	10.46	42.59	22.99	50.20	110.76	14.57	14.37	135.01	31.64	6.35	1.68	9.89	628
Average/yr		0.08	4.25	13.75	7.34	1.49	6.08	3.28	7.17	15.82	2.08	2.05	19.29	4.52	0.91	0.24	1.41	90

Office-Small	OS	(10^6 TDV kBtu)															
<30,000 P(	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Statewide
OS_2014	2014	0.01	0.06	0.15	0.10	0.02	0.06	0.05	0.08	0.17	0.05	0.06	0.27	0.14	0.02	0.00	0.06	1
OS_2015	2015	0.01	0.06	0.14	0.09	0.02	0.06	0.06	0.08	0.18	0.05	0.06	0.27	0.14	0.02	0.00	0.06	1
OS_2016	2016	0.01	0.06	0.14	0.09	0.02	0.06	0.06	0.08	0.17	0.05	0.06	0.26	0.13	0.02	0.00	0.06	1
OS_2017	2017	0.01	0.06	0.14	0.09	0.02	0.06	0.06	0.08	0.16	0.05	0.05	0.25	0.12	0.02	0.00	0.06	1
OS_2018	2018	0.01	0.06	0.14	0.09	0.02	0.06	0.06	0.08	0.16	0.05	0.05	0.25	0.12	0.02	0.00	0.06	1
OS_2019	2019	0.01	0.06	0.15	0.09	0.02	0.06	0.06	0.08	0.17	0.05	0.05	0.26	0.12	0.02	0.00	0.06	1
OS_2020	2020	0.01	0.06	0.15	0.09	0.02	0.06	0.06	0.08	0.17	0.05	0.05	0.26	0.12	0.02	0.00	0.06	1
Total		0.08	0.42	1.01	0.65	0.13	0.41	0.40	0.54	1.18	0.35	0.39	1.82	0.87	0.15	0.02	0.43	9
Average/yr		0.01	0.06	0.14	0.09	0.02	0.06	0.06	0.08	0.17	0.05	0.06	0.26	0.12	0.02	0.00	0.06	1

Restaurant	RE	(10^6 TDV kBtu)															
	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Statewide
RE_2014	2014	0.03	0.24	0.77	0.37	0.07	0.89	1.12	0.92	2.17	0.81	0.24	1.92	1.03	0.20	0.03	0.47	11
RE_2015	2015	0.03	0.22	0.68	0.33	0.07	0.96	1.09	0.96	2.21	0.79	0.23	2.02	0.98	0.20	0.03	0.45	11
RE_2016	2016	0.03	0.22	0.65	0.32	0.06	0.90	0.97	0.90	2.07	0.72	0.23	1.95	0.85	0.18	0.03	0.40	10
RE_2017	2017	0.03	0.22	0.66	0.32	0.06	0.85	0.85	0.85	1.94	0.65	0.24	1.86	0.74	0.17	0.03	0.35	10
RE_2018	2018	0.03	0.22	0.67	0.32	0.06	0.86	0.79	0.86	1.97	0.61	0.24	1.88	0.73	0.16	0.03	0.35	10
RE_2019	2019	0.03	0.22	0.68	0.32	0.07	0.91	0.75	0.90	2.05	0.59	0.24	1.94	0.75	0.16	0.03	0.36	10
RE_2020	2020	0.03	0.22	0.69	0.32	0.07	0.91	0.71	0.91	2.08	0.57	0.25	1.98	0.77	0.17	0.03	0.37	10
Total		0.23	1.56	4.81	2.28	0.46	6.28	6.26	6.30	14.49	4.73	1.67	13.56	5.85	1.24	0.20	2.75	73
Average/yr		0.03	0.22	0.69	0.33	0.07	0.90	0.89	0.90	2.07	0.68	0.24	1.94	0.84	0.18	0.03	0.39	10

Retail	RL	(10^6 TDV kBtu)															
	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Statewide
RL_2014	2014	0.11	0.76	1.91	1.27	0.26	0.83	0.83	1.15	2.66	0.81	0.95	4.58	2.13	0.39	0.06	1.16	20
RL_2015	2015	0.07	0.71	1.91	1.22	0.25	0.82	0.86	1.12	2.66	0.84	0.95	4.62	2.22	0.39	0.07	1.15	20
RL_2016	2016	0.06	0.68	1.92	1.18	0.24	0.72	0.88	0.99	2.40	0.86	0.95	4.51	2.20	0.36	0.06	1.08	19
RL_2017	2017	0.06	0.67	1.92	1.14	0.23	0.63	0.80	0.89	2.16	0.80	0.95	4.32	2.11	0.34	0.06	0.99	18
RL_2018	2018	0.06	0.67	1.93	1.14	0.23	0.62	0.78	0.88	2.13	0.80	0.97	4.31	2.12	0.34	0.06	0.99	18
RL_2019	2019	0.06	0.67	1.95	1.15	0.23	0.62	0.77	0.88	2.15	0.80	0.99	4.38	2.16	0.34	0.06	1.00	18
RL_2020	2020	0.06	0.68	1.96	1.15	0.23	0.62	0.77	0.88	2.17	0.80	1.01	4.45	2.20	0.35	0.06	1.02	18
Total		0.48	4.83	13.50	8.25	1.68	4.87	5.69	6.79	16.33	5.70	6.77	31.17	15.14	2.52	0.44	7.38	132
Average/yr		0.07	0.69	1.93	1.18	0.24	0.70	0.81	0.97	2.33	0.81	0.97	4.45	2.16	0.36	0.06	1.05	19

School	SC	(10^6 TDV kBtu)															
	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Statewide
SC_2014	2014	0.09	0.55	1.35	0.82	0.17	0.60	0.62	0.69	1.45	0.63	0.78	2.76	1.44	0.22	0.03	0.48	13
SC_2015	2015	0.09	0.56	1.42	0.82	0.17	0.60	0.67	0.69	1.49	0.69	0.87	2.89	1.63	0.24	0.03	0.50	13
SC_2016	2016	0.09	0.57	1.45	0.84	0.17	0.60	0.72	0.70	1.54	0.73	0.87	2.93	1.62	0.25	0.03	0.51	14
SC_2017	2017	0.10	0.57	1.43	0.86	0.17	0.61	0.77	0.71	1.58	0.77	0.88	2.97	1.61	0.25	0.03	0.51	14
SC_2018	2018	0.10	0.58	1.43	0.88	0.18	0.63	0.84	0.74	1.66	0.83	0.90	3.04	1.65	0.26	0.04	0.53	14
SC_2019	2019	0.10	0.60	1.45	0.90	0.18	0.65	0.91	0.76	1.73	0.89	0.94	3.12	1.71	0.27	0.04	0.55	15
SC_2020	2020	0.10	0.61	1.47	0.92	0.19	0.66	0.97	0.78	1.80	0.95	0.97	3.19	1.76	0.28	0.04	0.56	15
Total		0.67	4.02	9.99	6.05	1.23	4.36	5.49	5.06	11.26	5.49	6.21	20.90	11.42	1.78	0.24	3.64	98
Average/yr		0.10	0.57	1.43	0.86	0.18	0.62	0.78	0.72	1.61	0.78	0.89	2.99	1.63	0.25	0.03	0.52	14

College	CO	(10^6 TDV kBtu)															
	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Statewide
CO_2014	2014	0.06	1.04	2.76	1.73	0.35	2.12	1.46	2.15	5.37	1.13	0.77	4.01	2.08	0.36	0.05	0.52	26
CO_2015	2015	0.06	1.01	2.76	1.64	0.33	2.24	1.28	2.29	5.77	1.04	0.75	4.07	2.14	0.38	0.05	0.56	26
CO_2016	2016	0.06	0.94	2.75	1.49	0.30	2.20	1.03	2.26	5.72	0.89	0.72	3.98	2.07	0.37	0.05	0.55	25
CO_2017	2017	0.06	0.93	2.76	1.46	0.30	2.00	0.89	2.10	5.36	0.78	0.65	3.74	1.87	0.35	0.05	0.52	24
CO_2018	2018	0.06	0.95	2.79	1.51	0.31	1.91	0.87	2.04	5.31	0.77	0.62	3.72	1.83	0.36	0.05	0.53	24
CO_2019	2019	0.06	1.00	2.83	1.61	0.33	1.92	0.85	2.04	5.37	0.76	0.64	3.85	1.90	0.35	0.05	0.54	24
CO_2020	2020	0.06	1.11	2.89	1.84	0.37	1.99	0.99	2.11	5.55	0.85	0.68	4.08	1.98	0.37	0.05	0.55	25
Total		0.41	6.97	19.53	11.28	2.30	14.37	7.37	14.99	38.45	6.23	4.84	27.45	13.87	2.54	0.37	3.78	175

Figure 41: TDV-G Savings from Design Review by Climate Zone for All New Construction

Office-Large	OL	(10^6 TDV $)																
>30,000 P	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Statewide
OL_2014	2014	0.03	1.14	4.87	2.65	0.50	2.36	1.40	3.21	6.38	0.76	0.64	6.34	1.54	0.34	0.22	0.40	33
OL_2015	2015	0.03	1.22	4.52	2.93	0.55	2.64	1.44	3.52	7.07	0.78	0.68	6.87	1.58	0.34	0.25	0.42	35
OL_2016	2016	0.03	1.19	4.48	2.86	0.54	2.54	1.48	3.42	6.77	0.81	0.68	6.68	1.62	0.35	0.24	0.41	34
OL_2017	2017	0.02	1.15	4.62	2.70	0.51	2.36	1.53	3.24	6.29	0.83	0.70	6.39	1.66	0.36	0.22	0.41	33
OL_2018	2018	0.03	1.15	4.71	2.69	0.50	2.38	1.57	3.28	6.36	0.85	0.71	6.44	1.70	0.36	0.22	0.42	33
OL_2019	2019	0.03	1.18	4.76	2.76	0.52	2.49	1.62	3.41	6.66	0.88	0.74	6.66	1.75	0.37	0.23	0.43	34
OL_2020	2020	0.03	1.20	4.82	2.81	0.53	2.55	1.67	3.49	6.83	0.90	0.76	6.82	1.79	0.38	0.23	0.44	35
Total		0.19	8.23	32.79	19.41	3.63	17.32	10.72	23.57	46.35	5.81	4.91	46.21	11.64	2.50	1.61	2.92	238
Average/yr		0.03	1.18	4.68	2.77	0.52	2.47	1.53	3.37	6.62	0.83	0.70	6.60	1.66	0.36	0.23	0.42	34

Office-Small	OS	(10^6 TDV $)																
<30,000 P	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Statewide
OS_2014	2014	0.04	0.24	0.78	0.57	0.10	0.78	0.82	1.08	2.03	0.55	0.36	1.56	0.87	0.15	0.06	0.17	10
OS_2015	2015	0.04	0.24	0.74	0.57	0.10	0.82	0.88	1.12	2.12	0.57	0.35	1.56	0.87	0.15	0.06	0.18	10
OS_2016	2016	0.04	0.23	0.73	0.54	0.10	0.78	0.89	1.09	2.06	0.57	0.32	1.50	0.81	0.15	0.06	0.17	10
OS_2017	2017	0.04	0.23	0.74	0.54	0.10	0.73	0.87	1.05	1.98	0.55	0.31	1.46	0.75	0.15	0.06	0.17	10
OS_2018	2018	0.04	0.23	0.75	0.55	0.10	0.73	0.88	1.05	1.98	0.56	0.31	1.46	0.73	0.15	0.06	0.17	10
OS_2019	2019	0.04	0.24	0.76	0.55	0.10	0.74	0.90	1.06	2.01	0.57	0.31	1.48	0.74	0.15	0.06	0.17	10
OS_2020	2020	0.05	0.24	0.77	0.56	0.10	0.75	0.91	1.07	2.03	0.58	0.31	1.50	0.75	0.15	0.06	0.17	10
Total		0.30	1.65	5.26	3.89	0.71	5.33	6.15	7.53	14.20	3.95	2.26	10.52	5.51	1.06	0.41	1.21	70
Average/yr		0.04	0.24	0.75	0.56	0.10	0.76	0.88	1.08	2.03	0.56	0.32	1.50	0.79	0.15	0.06	0.17	10

Restaurant	RE	(10^6 TDV $)																
	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Statewide
RE_2014	2014	0.01	0.08	0.32	0.17	0.03	0.72	1.06	0.79	1.64	0.58	0.10	0.84	0.48	0.10	0.04	0.13	7
RE_2015	2015	0.01	0.07	0.28	0.15	0.03	0.78	1.03	0.82	1.67	0.56	0.10	0.88	0.46	0.10	0.04	0.12	7
RE_2016	2016	0.01	0.07	0.27	0.15	0.03	0.73	0.92	0.78	1.56	0.51	0.10	0.85	0.40	0.09	0.04	0.11	7
RE_2017	2017	0.01	0.07	0.28	0.15	0.03	0.69	0.80	0.73	1.47	0.46	0.10	0.81	0.35	0.08	0.03	0.09	6
RE_2018	2018	0.01	0.07	0.28	0.15	0.03	0.70	0.74	0.74	1.49	0.44	0.10	0.82	0.34	0.08	0.03	0.09	6
RE_2019	2019	0.01	0.07	0.29	0.15	0.03	0.73	0.70	0.77	1.55	0.42	0.11	0.84	0.35	0.08	0.04	0.10	6
RE_2020	2020	0.01	0.07	0.29	0.15	0.03	0.74	0.67	0.78	1.57	0.41	0.11	0.86	0.36	0.08	0.04	0.10	6
Total		0.07	0.52	2.02	1.07	0.20	5.08	5.91	5.42	10.97	3.39	0.73	5.90	2.75	0.63	0.26	0.73	46
Average/yr		0.01	0.07	0.29	0.15	0.03	0.73	0.84	0.77	1.57	0.48	0.10	0.84	0.39	0.09	0.04	0.10	7

Retail	RL	(10^6 TDV $)																
	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Statewide
RL_2014	2014	0.04	0.38	1.21	0.91	0.17	1.78	2.09	2.35	4.74	1.36	0.63	3.04	1.54	0.31	0.13	0.35	21
RL_2015	2015	0.03	0.35	1.21	0.87	0.16	1.76	2.17	2.29	4.73	1.40	0.63	3.07	1.60	0.30	0.14	0.35	21
RL_2016	2016	0.02	0.34	1.21	0.84	0.16	1.55	2.23	2.03	4.26	1.45	0.63	3.00	1.59	0.28	0.13	0.33	20
RL_2017	2017	0.02	0.33	1.22	0.82	0.15	1.36	2.02	1.82	3.84	1.35	0.63	2.87	1.53	0.27	0.13	0.30	19
RL_2018	2018	0.02	0.33	1.23	0.81	0.15	1.33	1.98	1.79	3.78	1.33	0.64	2.86	1.53	0.27	0.13	0.30	18
RL_2019	2019	0.02	0.33	1.24	0.82	0.15	1.33	1.96	1.79	3.82	1.33	0.66	2.91	1.56	0.27	0.13	0.30	19
RL_2020	2020	0.02	0.33	1.25	0.82	0.15	1.33	1.94	1.80	3.86	1.34	0.67	2.96	1.59	0.27	0.13	0.31	19
Total		0.18	2.39	8.56	5.90	1.09	10.43	14.39	13.86	29.04	9.56	4.49	20.71	10.94	1.98	0.91	2.25	137
Average/yr		0.03	0.34	1.22	0.84	0.16	1.49	2.06	1.98	4.15	1.37	0.64	2.96	1.56	0.28	0.13	0.32	20

School	SC	(10^6 TDV $)																
	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Statewide
SC_2014	2014	0.02	0.10	0.30	0.20	0.04	0.27	0.31	0.45	0.84	0.35	0.25	0.89	0.50	0.08	0.03	0.09	5
SC_2015	2015	0.02	0.11	0.32	0.20	0.04	0.27	0.34	0.45	0.86	0.38	0.28	0.93	0.56	0.09	0.03	0.09	5
SC_2016	2016	0.02	0.11	0.33	0.21	0.04	0.27	0.37	0.46	0.89	0.40	0.28	0.95	0.56	0.09	0.03	0.09	5
SC_2017	2017	0.02	0.11	0.32	0.21	0.04	0.27	0.39	0.46	0.91	0.42	0.28	0.96	0.56	0.09	0.03	0.09	5
SC_2018	2018	0.02	0.11	0.32	0.22	0.04	0.28	0.43	0.48	0.96	0.46	0.29	0.98	0.57	0.10	0.03	0.10	5
SC_2019	2019	0.02	0.11	0.33	0.22	0.04	0.29	0.46	0.49	1.00	0.49	0.30	1.01	0.59	0.10	0.03	0.10	6
SC_2020	2020	0.02	0.12	0.33	0.23	0.04	0.29	0.49	0.51	1.04	0.52	0.31	1.03	0.61	0.11	0.03	0.10	6
Total		0.14	0.77	2.25	1.49	0.28	1.93	2.80	3.31	6.51	3.01	2.00	6.75	3.96	0.66	0.21	0.66	37
Average/yr		0.02	0.11	0.32	0.21	0.04	0.28	0.40	0.47	0.93	0.43	0.29	0.96	0.57	0.09	0.03	0.09	5

College	CO	(10^6 TDV $)																
	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Statewide
CO_2014	2014	0.01	0.21	0.65	0.44	0.08	0.58	0.45	0.66	1.50	0.30	0.18	0.94	0.52	0.10	0.03	0.11	7
CO_2015	2015	0.01	0.20	0.65	0.42	0.08	0.61	0.39	0.71	1.61	0.28	0.18	0.96	0.53	0.10	0.03	0.12	7
CO_2016	2016	0.01	0.19	0.64	0.38	0.07	0.60	0.32	0.70	1.60	0.24	0.17	0.93	0.52	0.10	0.03	0.12	7
CO_2017	2017	0.01	0.18	0.65	0.37	0.07	0.55	0.27	0.65	1.50	0.21	0.15	0.88	0.47	0.09	0.03	0.11	6
CO_2018	2018	0.01	0.19	0.65	0.39	0.07	0.52	0.27	0.63	1.48	0.21	0.15	0.87	0.46	0.09	0.03	0.11	6
CO_2019	2019	0.01	0.20	0.66	0.41	0.08	0.52	0.26	0.63	1.50	0.20	0.15	0.90	0.48	0.09	0.03	0.11	6
CO_2020	2020	0.01	0.22	0.68	0.47	0.09	0.54	0.30	0.65	1.55	0.23	0.16	0.96	0.50	0.10	0.03	0.11	7
Total		0.10	1.38	4.57	2.88	0.55	3.91	2.26	4.63	10.73	1.67	1.14	6.46	3.47	0.67	0.22	0.79	45

Figure 42: TDV-$ Savings from Design Review by Climate Zone for All New Construction