CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE)

Nonresidential Opaque Envelope

Measure Number: 2016-NR-ENV1-F

NONRESIDENTIAL ENVELOPE

2016 CALIFORNIA BUILDING ENERGY EFFICIENCY STANDARDS

California Utilities Statewide Codes and Standards Team

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TABLE OF CONTENTS

List of Tables

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EXECUTIVE SUMMARY

Introduction

The Codes and Standards Enhancement (CASE) initiative presents recommendations to support California Energy Commission's (CEC) efforts to update California's Building Energy Efficiency Standards (Title 24) to include new requirements or to upgrade existing requirements for various technologies. The four California Investor Owned Utilities (IOUs) – Pacific Gas and Electric Company, San Diego Gas and Electric, Southern California Edison and Southern California Gas Company – and Los Angeles Department of Water and Power (LADWP) sponsored this effort. The program goal is to prepare and submit proposals that will result in cost-effective enhancements to energy efficiency in buildings. This report and the code change proposal presented herein is a part of the effort to develop technical and cost-effectiveness information for proposed regulations on building energy efficient design practices and technologies.

The overall goal of this CASE Report is to propose a code change for Nonresidential Opaque Envelope standards. The report contains pertinent information that justifies the code change including:

- Description of the code change proposal, the measure history, and existing standards (Section 2);
- Market analysis, including a description of the market structure for specific technologies, market availability, and how the proposed standard will impact building owners and occupants, builders, and equipment manufacturers, distributers, and sellers (Section 3);
- Methodology and assumption used in the analyses energy and electricity demand impacts, cost-effectiveness, and environmental impacts (Section 4);
- Results of energy and electricity demand impacts analysis, Cost-effectiveness Analysis, and environmental impacts analysis (Section 5); and
- Proposed code change language (Section 6).

Scope of Code Change Proposal

The Nonresidential Opaque Envelope measure will affect the following areas identified in Table 1.

Table 1: Scope of Code Change Proposal

Standards Requirements (see note below)	Compliance Option	Appendix	Modeling Algorithms	Simulation Engine	Forms
Ps	N/A	JA4*	N/A	N/A	N/A

Note: An (M) indicates mandatory requirements, (Ps) Prescriptive, (Pm) Performance.

* No changes planned to existing data; possible additional data added for new construction assemblies corresponding with prescriptive requirements, if needed

Measure Description

The proposed measure would revise the prescriptive opaque envelope requirements for all nonresidential and high-rise residential buildings. These requirements would also provide the baseline requirements for the standard design building in the performance method.

Section 2 of this report provides detailed information about the code change proposal. ***Section 2.2 Summary of Changes to Code Documents (page 3)*** provides a section-by-section description of the proposed changes to the standards, appendices, alternative compliance manual and other documents that will be modified by the proposed code change. See the following tables for an inventory of sections of each document that will be modified:

- Table 4: Scope of Code Change Proposal (page 4)
- Table 5: Sections of Standards Impacted by Proposed Code Change (page 4)
- Table 6: Appendices Impacted by Proposed Code Change (page 4)
- Table 7: Sections of ACM Impacted by Proposed Code Change (page 4)

Detailed proposed changes to the text of the building efficiency standards, the reference appendices, and are given in ***Section 0***

Proposed Language of this report. This section proposes modifications to language with additions identified with underlined text and deletions identified with ~~struck out~~ text.

Market Analysis and Regulatory Impact Assessment

The expected impacts of the proposed code change on various stakeholders are summarized below:

- **Impact on builders:** the proposed change will have a small effect on builders that build with metal building roofs. The filled cavity insulation method is less common than a single layer of insulation in standing seam metal building roofs. However, this technique is readily available using today's materials and construction techniques. Other building components are not affected by the measure.
- **Impact on building designers:** The only impact is an increased stringency for some envelope components, but the design process remains the same.
- **Impact on occupational safety and health:** The proposed code change does not alter any existing federal, state, or local regulations pertaining to safety and health, including rules enforced by California Division of Occupational Safety and Health. All existing health and safety rules will remain in place. Complying with the proposed code changes is not anticipated to have any impact on the safety or health occupants or those involved with the construction, commissioning, and ongoing maintenance of the building.
- **Impact on building owners and occupants:** This change will have minor positive effects on building occupants, through increased comfort due to increased insulation and more stable interior surface temperatures. For building owners and occupants who pay energy bills, the energy cost savings are higher than the cost of the measure over the buildings expected life of 30 years, so both owners and renters are expected to experience net cost savings over the life of the building.
- **Impact on equipment retailers (including manufacturers and distributors):** There is no significant impact on manufacturers, since the materials that form the basis of recommended prescriptive levels are already used and widely available.
- **Impact on energy consultants:** The proposal is not expected to have a significant impact on energy consultants.
- **Impact on building inspectors:** As compared to the overall code enforcement effort, this measure has negligible impact on the effort required to enforce the building codes. There is little impact on building inspectors, other than to verify that wall continuous insulation levels have been installed and that roof deck insulation uses the proper attachments.
- **Statewide Employment Impacts:** As a whole, the proposed changes to Title 24 are expected to result in positive job growth as noted below in Section 3.5.
- **Impacts on the creation or elimination of businesses in California:** This measure should not eliminate any businesses in California. It has a slight potential for business creation for companies that install construction assemblies that are underutilized in California (metal building roofs with filled cavity or liner systems for insulation).

- **Impacts on the potential advantages or disadvantages to California businesses:** Businesses skilled in the installation of continuous insulation on the exterior of walls, and those skilled with a variety of insulation techniques for metal building walls, may have an advantage.
- **Impacts on the potential increase or decrease of investments in California:** As described in Section 3.5 of this report, the California Air Resources Board (CARB) economic analysis of greenhouse gas reduction strategies for the State of California indicates that higher levels of energy efficiency and 33 percent Renewable Portfolio Standard (RPS) will increase investment in California by about 3 percent in 2020 compared to 20% RPS and lower levels of energy efficiency. After reviewing the CARB analysis, the Statewide CASE Team concluded that the majority of the increased investment of the more aggressive strategy is attributed to the benefits of efficiency (CARB 2010b Figures 7a and 10a). The specific code change proposal presented in this report is not expected to have an appreciable impact on investments in California.
- **Impacts on incentives for innovations in products, materials or processes:** Updating Title 24 standards will encourage innovation through the adoption of new technologies to better manage energy usage and achieve energy savings. The steel framing industry has mentioned that insulation products have not improved much over the last few code cycles. The inclusion of the filled cavity system may move the metal building roof industry towards new and innovative techniques for insulation. The increased requirements for continuous insulation may move the market to a greater number of available products, as well as increased R-value per inch for insulation longer them, given the limits for continuous insulation for walls.
- **Impacts on the State General Fund, Special Funds and local government:** The proposed measure is not expected to have an appreciable impact on the State General Fund, Special Funds, or local government funds.
- **Cost of enforcement to State Government and local governments:** All revisions to Title 24 will result in changes to Title 24 compliance determinations. State and local code officials will be required to learn how buildings can comply with the new provisions included in the 2016 Standards, however the Statewide CASE Team anticipates that the cost of training is part of the regular training activates that occur every time the code is updated. These proposed changes would not affect the complexity of the code significantly. Therefore, on-going costs are not expected to change significantly.
- **Impacts on migrant workers; persons by age group, race, or religion:** This proposal and all measures adopted by CEC into Title 24, Part 6 do not advantage or discriminate in regards to race, religion or age group.
- **Impact on Homeowners (including potential first time home owners):** The proposal does not impact residential buildings. There is no expected impact on homeowners.
- **Impact on Renters:** This proposal is advantageous to renters as it reduces the cost of utilities which are typically paid by renters. Since the measure saves more energy cost on a monthly basis than the measure costs on the mortgage as experiences by the landlord, the pass-through of added mortgage costs into rents is less than the energy cost savings experienced by renters.

- **Impact on Commuters:** This proposal and all measures adopted by CEC into Title 24, Part 6 are not expected to have an impact on commuters.

Statewide Energy Impacts

Table 2 shows the estimated energy savings over the first twelve months of implementation of the Nonresidential Opaque Envelope measure.

Table 2: Estimated First Year Energy Savings

	First Year Statewide Savings			First Year TDV Savings	
	Electricity Savings (GWh)	**Power Demand Reduction (MW)**	**Natural Gas Savings (MMtherms)**	**TDV Electricity Savings (Million kBTU)**	**TDV Natural Gas Savings (Million kBTU)**
Nonresidential Buildings	14.0	12.6	1.6	27.3	11.9
High-rise Residential Buildings	0.26	0.26	0.061	0.20	0.19
TOTAL	14.3	12.5	1.66	27.5	12.1

Section 4.6.1 discusses the methodology and Section 5.1.1 shows the results for the per unit energy impact analysis.

Cost-effectiveness

Results of the per unit Cost-effectiveness Analyses for the following constructions are presented in Table 25 through Table 31 on pages 33 through 38of this report:

- Nonresidential metal-framed Roofs
- Nonresidential wood-framed roofs
- Nonresidential metal-framed walls
- Nonresidential wood-framed walls
- High-rise residential metal-framed roofs
- High-rise residential metal-framed walls

Each building component was analyzed individually and varied using a building that exactly conforms to the minimum prescriptive requirements of Title 24-2013 (compliance margin of zero). Each recommended change was modeled in every California climate zone to determine which climate zone(s) result in a cost effective change in the Standards.

Based on the results of the Cost-effectiveness Analysis for the proposed code change, the Planning B/C Ratio is greater than 1.0 in every California climate zone and construction for which a change is proposed. This means that the more stringent requirements will result in cost savings relative to the existing conditions. While the measure is cost effective in every climate zone, the magnitude of cost-effectiveness varies. The recommended code changes for metal building roofs and wood-framed roofs have a very high Planning B/C Ratios of 3 to greater than 10, depending on climate zone. The Planning B/C Ratio of changes to metal building walls for high-rise residential buildings is effectively high as well. All proposed changes have a Planning B/C ratio over 1.3. The Statewide CASE Team evaluated potential changes to the stringency of standards for high-rise residential wood-framed walls. However, based on the results of the analysis there are no recommended changes to the standards for high-rise residential wood-framed walls.

The TDV Energy Costs Savings are the present valued energy cost savings over the 30 year period of analysis using CEC's TDV methodology. The Total Incremental Cost represents the incremental initial construction and maintenance costs of the proposed measure relative to construction practice that result in minimal compliance with the 2013 Title 24 Standards. Costs incurred in the future (such as periodic maintenance costs or replacement costs) are discounted by a 3 percent real discount rate, per the CEC Life-Cycle Cost (LCC) Methodology. The Planning Benefit to Cost (B/C) Ratio is the incremental TDV Energy Costs Savings divided by the Total Incremental Costs. When the B/C ratio is greater than 1.0, the added cost of the measure is more than offset by the discounted energy cost savings and the measure is deemed to be cost effective. For a detailed description of the Cost-effectiveness Methodology see Section 4.7 of this report.

Greenhouse Gas and Water Related Impacts

For more a detailed and extensive analysis of the possible environmental impacts from the implementation of the proposed measure(s), please refer to Section 5.3 of this report.

Greenhouse Gas Impacts

Table 3 presents the estimated avoided greenhouse gas (GHG) emissions of the proposed code change. The table presents the first year savings and the savings for the 30 year period of analysis. Assumptions used in developing the GHG savings are provided in Section 4.7.1 of this report.

Table 3: Estimated First Year Statewide Greenhouse Gas Emissions Impacts

	Avoided GHG Emissions ($MTCO_2e$/yr)
Nonresidential	4,942
High-Rise Residential	93
TOTAL	5,035

Section 4.8.1 discusses the methodology and section 5.3.1 shows the results of the greenhouse gas emission impacts analysis.

Water Use and Water Quality Impacts

The proposed measure is not expected to have any impacts on water use or water quality, excluding impacts that occur at power plants.

Acceptance Testing

No acceptance tests are required for this measure.

1. INTRODUCTION

The Codes and Standards Enhancement (CASE) initiative presents recommendations to support California Energy Commission's (CEC) efforts to update California's Building Energy Efficiency Standards (Title 24) to include new requirements or to upgrade existing requirements for various technologies. The four California Investor Owned Utilities (IOUs) – Pacific Gas and Electric Company, San Diego Gas and Electric, Southern California Edison and Southern California Gas Company – and Los Angeles Department of Water and Power (LADWP) sponsored this effort. The program goal is to prepare and submit proposals that will result in cost-effective enhancements to energy efficiency in buildings. This report and the code change proposal presented herein is a part of the effort to develop technical and cost-effectiveness information for proposed regulations on building energy efficient design practices and technologies.

The overall goal of this CASE Report is to propose a code change for Nonresidential Opaque Envelope standards. The report contains pertinent information that justifies the code change.

Section 2 of this CASE Report provides a description of the measure, how the measure came about, and how the measure helps achieve the state's zero net energy (ZNE) goals. This section presents how the Statewide CASE Team envisions the proposed code change would be enforced and the expected compliance rates. This section also summarized key issues that the Statewide CASE Team addressed during the CASE development process, including issues discussed during a public stakeholder meeting that the Statewide CASE Team hosted in May 2014.

Section 3 presents the market analysis, including a review of the current market structure, a discussion of product availability, and the useful life and persistence of the proposed measure. This section offers an overview of how the proposed standard will impact various stakeholders including builders, building designers, building occupants, equipment retailers (including manufacturers and distributors), energy consultants, and building inspectors. Finally, this section presents estimates of how the proposed change will impact statewide employment.

Section 4 describes the methodology and approach the Statewide CASE Team used to estimate energy, demand, costs, and environmental impacts. Key assumptions used in the analyses can be also found in Section 4.

Results from the energy, demand, costs, and environmental impacts analysis are presented in Section 5. The Statewide CASE Team calculated energy, demand, and environmental impacts using two metrics: (1) per unit, and (2) statewide impacts during the first year buildings complying with the 2016 Title 24 Standards are in operation. Time Dependent Valuation (TDV) energy impacts, which accounts for the higher value of peak savings, are presented for the first year both per unit and statewide. The incremental costs, relative to existing conditions are presented as are present value of year TDV energy cost savings and the overall cost impacts over the 30-year period of analysis.

The report concludes with specific recommendations for language for the Standards, Appendices, Alternate Calculation Manual (ACM) Reference Manual and Compliance Forms.

2. MEASURE DESCRIPTION

2.1 Measure Overview

2.1.1 Measure Description

The proposed measure would apply to all newly-constructed nonresidential and high-rise residential buildings in California. The updates to the prescriptive requirements are tailored for each climate zone, and will also serve as the basis for the standard design in the performance method.

The proposed change would modify prescriptive requirements and the standard design (reference for comparison) for the performance approach of the Standards. In addition, the proposed requirement would require minor updates to Reference Appendix JA4 to accommodate any new construction assemblies that are the basis of the prescriptive requirements.

This proposed measure does not provide requirements for new systems or equipment, does not modify modeling algorithms, and does not change or expand the scope of the Standards.

The proposed code change would provide updates to Tables 140.3-B and 140.3-C in the Standards, and minor updates to Reference Appendix JA4, if needed.

The list below provides a summary of how each Title 24 documents will be modified by the proposed change (underline indicates new language being added, strikethrough indicates existing language being deleted):

- **Standards:** The proposed code change will modify Section 140.3 of the Standards. The proposed language will modify Tables 140.3-B and 140.3-C.
- **Appendices:** The proposed code change may include modification to Reference Appendix JA4 to the Standards.
- **Nonresidential Alternative Calculation Method (ACM) Reference Manual:** The proposed code change will modify section 5.5 /Nonresidential ACM Reference Manual. The only change will be to modify the standard design construction assemblies and associated U-factors for roofs, walls and floors to be consistent with the new proposed prescriptive requirements.
- **Compliance Forms:** There are no significant changes to the applicable compliance forms as a result of this measure.

2.1.2 Measure History

The opaque building envelope standards have been periodically updated to remain consistent with current construction practice and costs. The last time the opaque envelope standards were updated was during the 2008 Title 24 code update cycle. Most recently, mandatory minimum insulation requirements (120.8) were included for the first time in the 2013 code update cycle. This measure does not alter the mandatory insulation requirements. Rather, the proposal updates the prescriptive requirements, where changes were determined to be cost effective.

There are no preemption concerns with this measure.

Historically, there have been separate requirements for different classes of construction, reflecting the different effectiveness and associated costs of different construction techniques. For example, building energy use with a wood-framed or metal-framed wall is not compared to a similar building with a mass wall, since requirements other than efficiency often influence the required class of construction. Since this measure is updating the prescriptive requirements, the Statewide CASE Team followed this same procedure for revising the opaque envelope requirements.

Newer construction techniques have arisen, such as structurally integrated panels (SIP) and insulated concrete forms. The analysis for this measure primarily reviewed widely used constructions for cost effectiveness, as the basis for the recommended levels.

2.1.3 Existing Standards

The nonresidential and high-rise residential opaque envelope standards have been included in the Title 24 Standards since their inception in the 1970s. The Standards have evolved to cover prescriptive insulation requirements by climate zone based on industry-standard techniques for calculating the U-factor of construction assemblies.

ASHRAE 90.1 also includes envelope requirements by climate zone. However, there is an imperfect correlation between ASHRAE and Title 24 climate zones, and the calculation assumptions for U-factors of a given assembly are not consistent between the codes, even though the methodologies are the same or similar and are consistent with ASHRAE guidelines.

2.1.4 Alignment with Zero Net Energy Goals

The building envelope is a foundational element for energy efficiency, because of its persistence. It can reduce loads to a level that makes a larger number of efficient and innovative heating and cooling technologies more effective. Moreover, because it is not easy to retrofit the building opaque envelope, advances in building envelope code stringency are consistent with long-term CPUC goals to eventually make ***existing*** buildings net-zero energy.

2.1.5 Relationship to Other Title 24 Measures

In the sense that any requirements for improved construction assemblies and lower U-factors decrease building heating and cooling loads, there are interactive effects with any other nonresidential measure. However, since individual measures are evaluated from the standpoint of a 2013 Title 24 baseline, there are no direct impacts to other CASE measure development efforts.

2.2 Summary of Changes to Code Documents

The sections below provide a summary of how each Title 24 documents will be modified by the proposed change. See Section 6 of this report for detailed proposed revisions to code language.

2.2.1 Catalogue of Proposed Changes

Scope

Table 4 identifies the scope of the code change proposal. This measure will impact the following areas (marked by a "Yes").

Table 4: Scope of Code Change Proposal

Mandatory	Prescriptive	Performance	Compliance Option	Trade-Off	Modeling Algorithms	Forms
N/A	Yes	N/A	N/A	N/A	N/A	N/A

Standards

The proposed code change will modify the sections of the California Building Energy Efficiency Standards (Title 24, Part 6) identified in Table 5.

Table 5: Sections of Standards Impacted by Proposed Code Change

Title 24, Part 6 Section Number	Section Title	Mandatory (M) Prescriptive (Ps) Performance (Pm)	Modify Existing (E) New Section (N)
140.3	Prescriptive Envelope Requirements	Ps	E

Appendices

The proposed code change will modify the sections of the indicated appendices presented in Table 6. If an appendix is not listed, then the proposed code change is not expected to have an effect on that appendix.

Table 6: Appendices Impacted by Proposed Code Change

APPENDIX NAME		
Section Number	**Section Title**	**Modify Existing (E) New Section (N)**
JA4	U-factor, C-factor, and Thermal Mass Data	E

Nonresidential Alternative Calculation Method (ACM) Reference Manual

The proposed code change will modify the sections of the Residential or Nonresidential Alternative Calculation Method References identified in Table 7. Other than updating the standard design construction assemblies to reflect any changes to prescriptive requirements in 140.3 that occur, no changes expected. The changes would occur in Section 5.5 of the Nonresidential ACM Reference Manual.

Table 7: Sections of ACM Impacted by Proposed Code Change

Nonresidential Alternative Calculation Method Reference		
Section Number	**Section Title**	**Modify Existing (E) New Section (N)**
5.5	Building Envelope	E

Simulation Engine Adaptations

The proposed code change can be modeled using the current simulation engine. Changes to the simulation engine are not necessary.

2.2.2 Standards Change Summary

This proposal would modify the following sections of the Building Energy Efficiency standards as shown below. See Section 6 of this report for the detailed proposed revisions to the standards language.

Changes in Scope

No changes to the scope of Title 24.

Changes in Mandatory Requirements

No changes to mandatory requirements.

Changes in Prescriptive Requirements

SECTION 140.3 – PRESCRIPTIVE REQUIREMENTS FOR BUILDING ENVELOPES

Subsection 140.3(a): The proposed code change will modify Section 140.3 of the Standards. The proposed language will modify Tables 140.3-B and 140.3-C.

2.2.3 Standards Reference Appendices Change Summary

This proposal would modify the following sections of the Standards Appendices as shown below. See Section 6 of this report for the detailed proposed revisions to the text of the reference appendices.

JOINT APPENDICIES

JA4 - U-factor, C-factor, and Thermal Mass Data: Add a new construction to the metal building roofs table, Reference Appendix JA4, Table 4.2.7, to accommodate the proposed prescriptive requirement for the filled cavity insulation method for metal building roofs, U-factor of 0.041.

2.2.4 Nonresidential Alternative Calculation Method (ACM) Reference Manual Change Summary

This proposal would modify the following sections of the Alternative Calculation Method (ACM) Reference Manual as shown below. See Section 6 of this report for the detailed proposed revisions to the text of the Alternative Calculation Method (ACM) Reference Manual.

CHAPTER 5: BUILDING DESCRIPTORS REFERENCE

Chapter 5.5 Building Envelope Data: Update the standard design construction assemblies to reflect any changes to prescriptive requirements in 140.3 that occur.

2.2.5 Compliance Forms Change Summary

No changes to the compliance forms are necessary.

2.2.6 Simulation Engine Adaptations

No changes to the simulation engine necessary.

2.2.7 Other Areas Affected

No other areas affected.

2.3 Code Implementation

2.3.1 Verifying Code Compliance

There is no impact on code compliance, other than ensuring that the as-designed construction assemblies match compliance documents.

Some stakeholders noted that nearly all designs that are not tied to specific green building incentives or LEED do not exceed the minimum Title 24 prescriptive envelope requirements. Therefore, it is reasonable to assume that some new construction projects will meet only mandatory minimum requirements and tradeoff with increased efficiency of non-envelope components to meet compliance.

2.3.2 Code Implementation

Code compliance for this measure should not be more difficult than current building envelope code compliance, as it is only a strengthening of current code requirements.

Some building representatives have indicated that there are limits to the amount of exterior insulation that can be placed on the exterior of a steel-framed wall. Thicker rigid insulation panels have attachment difficulties and other issues. Building trade association representatives have also raised potential fire issues at the interface between a framed wall and a window opening, indicating that any exposed insulation could lead to rapid spread of a fire, if present. However, fire protection is not an issue that is addressed in Title 24 Part 6 issue, and should be readily addressed with appropriate design and construction details.

Verification of insulation is not trivial, as it may require access to the wall cavity; however, insulation verification onsite is not currently required for nonresidential code compliance, and this proposal does not propose to change the existing code verification and compliance requirements.

2.3.3 Acceptance Testing

No new acceptance testing is required for this measure.

2.4 Issues Addressed During CASE Development Process

The Statewide CASE Team solicited feedback from a variety of stakeholders when developing the code change proposal presented in this report. In addition to personal outreach to key stakeholders, the Statewide CASE Team conducted a public stakeholder meeting to discuss the proposals. The issues that were addressed during development of the code change proposal are summarized below.

The biggest issue raised by stakeholders is the practical limit of exterior rigid insulation for steel-framed walls. The consensus was that a practical limit of 3” exists, due to attachment and other issues. The Statewide CASE Team addressed this issue by considering any additional design costs associated with thicker insulation, and by considering costs associated with exterior insulation finishing systems (EIFS).

Some stakeholders noted that ASHRAE is assuming a fixed insulation R-value of R-5/inch for all rigid continuous insulation. The analysis presented in this report assumes industry-standard values for rigid polystyrene, extruded polystyrene and polyisocyanurate insulation. For rigid polyisocyanurate insulation, the Statewide CASE Team is using a fixed R-value of R-6.2 per inch, consistent with current products on the market.

Some stakeholders noted that the U-factor values for ASHRAE 90.1 and Title 24 are not consistent, and some asserted that the ASHRAE 90.1 U-factor values for steel-framed walls are closer to tested values. There is no recommendation to modify the construction assembly calculation assumptions to conform to ASHRAE.

One stakeholder asked whether the Statewide CASE Team could consider a range of internal load gains when performing the LCC analysis with the different prototypes. While this makes sense from a technical standpoint, the prescriptive standards for building envelope are not designed to be a “one size fits all” approach that is optimal for all types of buildings and conditions. Therefore, while this was investigated through sensitivity analysis, since a single recommendation for a given construction assembly type and climate zone is required, the approach is to use a single prototype to represent nonresidential buildings and a single prototype to represent high-rise residential buildings.

3. MARKET ANALYSIS

The Statewide CASE Team performed a market analysis with the goals of identifying current technology availability, current product availability, and market trends. The Statewide CASE Team considered how the proposed standard may impact the market in general and individual market players. The Statewide CASE Team gathered information about the incremental cost of complying with the proposed measure. Estimates of market size and measure applicability were identified through research and outreach with key stakeholders including utility program staff, CEC, and a wide range of industry players who were invited to participate in a public stakeholder meeting that the Statewide CASE Team hosted in May 2014.

3.1 Market Structure

The market for commercial construction consists of different construction classes for different building needs, including fire rating and seismic requirements. While these non-energy requirements were not evaluated in terms of cost effectiveness, they nevertheless affect the selection of building construction type. Historically, and with this analysis, different construction types (for example, wood-framed walls, metal-framed walls and mass walls) are not compared against one another, and there are separate requirements for each.

It should be noted that for the 2013 Title 24 Standards, the type of wall construction, roof construction and above-grade floor construction has been fixed for the performance method, to provide a more stable baseline for comparison for compliance analysis.

3.2 Market Availability and Current Practices

For wall-framed construction, current practice with metal-framed walls is to place insulation either between metal studs, or on the exterior of the assembly as continuous insulation. Some designers in temperate coastal climates do not specify continuous insulation for commercial buildings. When continuous insulation is specified, between one inch and three inches of rigid insulation is applied. Greater thicknesses beyond three inches have problems with attachment and with reaching the studs.

For wood-framed walls, continuous insulation can be applied to the exterior as well; with some construction types for smaller buildings, there is a trend towards moving to thicker studs (2x6) and not using continuous insulation. For mass walls, a common practice is to partially grout CMU (concrete masonry unit) walls and to reinforce the un-grouted portion with steel for structural integrity. In temperate climates where no insulation is needed; for inland climates, insulation with furring strips is used.

Polyisocyanurate and expanded polystyrene foam (EPS) are two common continuous insulation materials used to meet Title 24 requirements. These products are widely available, and polyisocyanurate (polyiso) typically has an insulation value at or near R-6.2 per inch.

For wood-framed rafter roofs, a common practice is to install batt insulation underneath the rafters up to the full depth of the framing.

For metal building roofs, commonly installed options are screw-down roofs, with insulation draped between the purlins, or standing seam metal roofs.

3.3 Useful Life, Persistence, and Maintenance

The expected useful life of building envelope insulation systems is 30 years, per California Energy Commission guidelines. Actual performance can degrade over time if there are problems with accumulated moisture within the assembly. In many cases, the insulation will persist much longer than 30 years, for the life of the building, with little degradation in performance.

The methodology the Statewide CASE Team used to determine the costs associated with incremental maintenance costs, relative to existing conditions, is presented in Section 4.7.1. The incremental maintenance costs of the proposed code change are presented in Section 5.2.1.

3.4 Market Impacts and Economic Assessments

3.4.1 Impact on Builders

This change will impact builders primarily through more widespread adoption of the “filled cavity” insulation technique for metal building roofs. The other recommended prescriptive requirements do not require any change in construction techniques or practices, and can be readily achieved with insulation products currently in use.

3.4.2 Impact on Building Designers

This change will not impact building designers significantly. The performance method is widely used and provides a great array of design options for compliance. Incremental costs of insulation products are expected to be below $1.00/SF of conditioned floor area in most cases, due to this measure.

3.4.3 Impact on Occupational Safety and Health

The proposed code change does not alter any existing federal, state, or local regulations pertaining to safety and health, including rules enforced by the California Department of Occupational Safety and Health (Cal/OSHA). All existing health and safety rules will remain in place. Complying with the proposed code change is not anticipated to have any impact on the safety or health occupants or those involved with the construction, commissioning, and ongoing maintenance of the building.

3.4.4 Impact on Building Owners and Occupants

This change will have minor positive effects on building occupants, through increased comfort due to increased insulation and more stable interior surface temperatures. For building owners, there is the possibility of a small increase in building costs, as with any Standards update, due to increased first costs of insulation products. The incremental costs are expected to be below $0.50/SF for any envelope changes, or a conditioned floor area basis.

3.4.5 Impact on Retailers (including manufacturers and distributors)

There is no significant impact on manufacturers, since the materials that form the basis of recommended prescriptive levels are already used and widely available.

3.4.6 Impact on Energy Consultants

The proposal is not expected to have a significant impact on energy consultants.

3.4.7 Impact on Building Inspectors

As compared to the overall code enforcement effort, this measure has negligible impact on the effort required to enforce the building codes. There is little impact on building inspectors, other than to verify that wall continuous insulation levels have been installed and that roof deck insulation uses the proper attachments.

3.4.8 Impact on Statewide Employment

As a whole, the proposed changes to Title 24 are expected to result in positive job growth as noted below in Section 3.5.

3.5 Economic Impacts

The proposed Title 24 code changes, including this measure, are expected to increase job creation, income, and investment in California. As a result of the proposed code changes, it is anticipated that less money will be sent out of state to fund energy imports, and local spending is expected to increase due to higher disposable incomes due to reduced energy costs.

These economic impacts of energy efficiency are documented in several resources including the California Air Resources Board's (CARB) Updated Economic Analysis of California's Climate Change Scoping Plan, which compares the economic impacts of several scenario cases (CARB, 2010b). CARB include one case (Case 1) with a 33% renewable portfolio standard (RPS) and higher levels of energy efficiency compared to an alternative case (Case 4) with a 20% RPS and lower levels of energy efficiency. Gross state production (GSP) , personal income, and labor demand were between 0.6% and 1.1% higher in the case with the higher RPS and more energy efficiency (CARB 2010b, Table 26). While CARB's analysis does not report the benefits of energy efficiency and the RPS separately, we expect that the benefits of the package of measures are primarily due to energy efficiency. Energy efficiency measures are expected to reduce costs by $2,133 million annually (CARB 2008, pC-117) whereas the RPS implementation is expected to cost $1,782 million annually, not including the benefits of GHG and air pollution reduction (CARB 2008, pC-130).

Macroeconomic analysis of past energy efficiency programs and forward-looking analysis of energy efficiency policies and investments similarly show the benefits to California's economy of investments in energy efficiency (Roland-Holst 2008; UC Berkeley 2011).

This measure is not anticipated to have a large economic impact on the industry because it functions as a reduction in full load equivalent energy consumption. In most cases, the impacted areas are anticipated to use the same products and methods to comply with this proposed measure as the previous current controls requirements, so there is no anticipated economic impact.

3.5.1 Creation or Elimination of Jobs

CARB's economic analysis of higher levels of energy efficiency and 33% RPS implementation estimates that this scenario would result in a 1.1% increase in statewide labor demand in 2020 compared to 20% RPS and lower levels of energy efficiency (CARB 2010b, Tables 26 and 27). CARB's economic analysis also estimates a 1.3% increase in small business employment levels in 2020 (CARB 2010b, Table 32).

3.5.2 Creation or Elimination of Businesses within California

No significant change is expected due to this measure.

3.5.3 Competitive Advantages or Disadvantages for Businesses within California

CARB's economic analysis of higher levels of energy efficiency and 33% RPS implementation (as described above) estimates that this scenario would result in 0.6% additional GSP in 2020 compared to 20% RPS and lower levels of energy efficiency (CARB 2010b, Table ES-2). We expect that higher GSP will drive additional business creation in California. In particular, local small businesses that spend a much larger proportion of revenue on energy than other businesses (CARB 2010b, Figures 13 and 14) should disproportionately benefit from lower energy costs due to energy efficiency standards. Increased labor demand, as noted earlier, is another indication of business creation.

Businesses more skilled in construction techniques installing continuous insulation, and in installing metal building roofs with the filled cavity or liner systems, will have a slight competitive advantage.

3.5.4 Increase or Decrease of Investments in the State of California

California businesses would benefit from an overall reduction in energy costs. This could help California businesses gain competitive advantage over businesses operating in other states or countries and an increase in investment in California, as noted below.

3.5.5 Incentives for Innovation in Products, Materials, or Processes

The steel framing industry has mentioned that insulation products have not improved much over the last few code cycles. The inclusion of the filled cavity system may move the metal building roof industry towards new and innovative techniques for insulation. The increased requirements for continuous insulation may move the market to a greater number of available products, as well as increased R-value per inch for insulation longer them, given the limits for continuous insulation for walls.

3.5.6 Effects on the State General Fund, State Special Funds and Local Governments

There is no significant additional burden expected on state agencies, other than the documentation required for the compliance manuals for this measure, and subsequent training and support efforts.

3.5.6.1 Cost of Enforcement

Cost to the State

State government already has budget for code development, education, and compliance enforcement. While state government will be allocating resources to update the Title 24 Standards, including updating education and compliance materials and responding to questions about the revised Standards, these activities are already covered by existing state budgets. The costs to state government are small when compared to the overall costs savings and policy benefits associated with the code change proposals.

The cost to the State should be minimal for this measure, since the construction techniques that correspond to the revised prescriptive requirements involve no significant change from standard practice. One minor change would be the inclusion of the filled cavity (and possibly liner system) in the Reference Joint Appendices, and code officials might be asked about the new construction assemblies in light of the proposed requirements.

Cost to Local Governments

All revisions to Title 24 will result in changes to Title 24 compliance determinations. Local governments will need to train permitting staff on the revised Title 24 Standards. While this re-training is an expense to local governments, it is not a new cost associated with the 2016 code change cycle. The building code is updated on a triennial basis, and local governments plan and budget for retraining every time the code is updated. There are numerous resources available to local governments to support compliance training that can help mitigate the cost of retraining. As noted earlier, although retraining is a cost of the revised Standards, Title 24 Standards are expected to increase economic growth and income with positive impacts on local revenue.

The cost to local governments should be minimal because the compliance verification and enforcement requirements are not changing.

3.5.6.2 Impacts on Specific Groups of Persons

The proposed changes to Title 24 are not expected to have a differential impact on any of the following groups relative to the state population as a whole:

- Migrant Workers
- Persons by age
- Persons by race
- Persons by religion
- Commuters

4. METHODOLOGY

This section describes the methodology and approach the Statewide CASE Team used to estimate energy, demand, costs, and environmental impacts. The Statewide CASE Team calculated the impacts of the proposed code change by comparing existing conditions to the conditions if the proposed code change is adopted. This section of the CASE Report goes into more detail on the assumptions about the existing and proposed conditions, prototype buildings, and the methodology used to estimate energy, demand, cost, and environmental impacts.

4.1 Existing Conditions

To assess the energy, demand, costs, and environmental impacts, the Statewide CASE Team compared current design practices to design practices that would comply with the proposed requirements.

There is an existing Title 24 standard that covers the building system in question, so the existing conditions assume a building complies minimally with the 2013 Title 24 Standards.

Existing conditions for all parameters were modified, when necessary, to achieve exact conformance with the minimum 2013 Title 24 requirements for the specific climate zone, and then the process was replicated for each of the 16 climate zones. Table 33 through Table 39 on pages 39 through 42 of this report present the assemblies used for the existing condition in each construction type in each climate zone.

4.2 Proposed Conditions

The proposed conditions are defined as the design conditions that will comply with the range of efficiency levels evaluated for the code change proposal.

The approach is to vary the U-factor of each envelope component, one at a time, while holding all other inputs constant, to evaluate its effect. For example, the U-factor for a wall might be varied from its existing level (0.082) to different levels (0.070, 0.055, etc.) that correspond to discrete construction assemblies that (a) are feasible to build and (b) have available cost data. Table 33 through Table 39 on pages 39 through 42 of this report present the assemblies used for the proposed condition in each construction type in each climate zone. The proposed conditions (i.e., assemblies used to verify the proposed efficiency levels are cost effective and feasible) were derived as a result of the parametric analysis described in Section 4.3.1.

4.3 Prototype Building(s)

CEC provided guidance on the type of prototype buildings that must be modeled. According to CEC guidelines, the prototype buildings for this analysis were developed as shown below.

Nonresidential

Two prototypes were used to evaluate different construction assemblies in the lifecycle cost analysis and simulation models. See the Appendix C: Prototype Summary for Energy Savings Estimates for details of the building prototypes.

The first prototype is a single-story medium retail building that is based on the United States Department of Energy (DOE) medium retail building prototype and the same building used in the reference tests for nonresidential compliance software seeking certification.

Due to the variety of building types available, some sensitivity tests were done to examine the effect of internal load levels (from occupants, lights and equipment) on the effectiveness of increased opaque envelope insulation. However, one set of modeling assumptions will form the basis for the prescriptive recommendations.

The second prototype is a hotel building with four stories, with 42,554 square feet (SF) of conditioned floor area, and a mix of guestroom spaces (residential) and common spaces (nonresidential). Residential spaces (guestrooms) comprise 27,271 SF of the conditioned floor area in the hotel building. This prototype was used to evaluate prescriptive envelope assemblies for residential units of nonresidential buildings (high-rise residential and hotel/motel guestrooms). These rooms are characterized with a twenty-four hour occupancy and lower internal gains on a per square foot basis than the nonresidential building prototype.

Table 8 presents the details of the prototype buildings used in the analysis. One prototype is used for determining recommended nonresidential opaque envelope requirements, and one prototype is used for determining recommended high-rise residential opaque envelope requirements. The office building prototype conditions were used in confirming that nonresidential opaque envelope requirements are suitable for a range of building types.

Table 8: Prototype Buildings used for Energy, Demand, Cost, and Environmental Impacts Analysis

	Occupancy Type (Residential, Retail, Office, etc.)	Area (Square Feet)	Number of Stories	Other Notes
Prototype 1	Retail	24,692	1	See Appendix for details
Prototype 2	Hotel	42,554	4	27,271 SF residential spaces; remainder is nonresidential
Prototype 3	Office	24,692	1	Based on retail prototype envelope

4.3.1 Parametric Analysis Scope

For this study, the approach was to model each prototype in each climate zone with a number of varying U-factors (insulation levels), for each construction assembly type listed in the Standards tables. In this sense, we are comparing mass walls with mass walls, and steel-framed walls with steel-framed walls, etc. The table below shows a representative set of parametric runs that were used in the parametric energy simulations to evaluate the energy change associated with different efficiency levels. Regressions of TDV energy use against U-factor were developed for each building envelope component, and used to determine the energy savings associated with each discrete construction assembly in the cost study.

Table 9: Parametric Analysis Scope

Dimension	Parameter Name	Number of Variations	Description
1	Prototype	2	medium office or retail; high-rise residential (hotel)
2	Climate Zone	16	varies baseline opaque envelope components
3	Construction Studied	Up to 9	five wall types analyzed; two roof types; two floor types (not on grade). The first priority was roofs and light wall construction, with mass wall and floor constructions evaluated as a second priority.
4	Insulation Levels	4	minimum of 3 insulation levels for each construction type studied
Total		Up to 1152	

4.4 Climate Dependence

Since the envelope requirements are dependent on climate zone, a lifecycle cost analysis was performed for each of the 16 CEC climate zones that form the basis of the variation in prescriptive requirements. The weather file for each climate zone corresponds to the representative city from Reference Appendix JA2 of the Standards.

4.5 Time Dependent Valuation

The TDV (Time Dependent Valuation) of savings is a normalized format for comparing electricity and natural gas savings that takes into account the cost of electricity and natural gas consumed during different times of the day and year. The TDV values are based on long term discounted costs (30 years for all residential measures and nonresidential envelope measures and 15 years for all other nonresidential measures). In this case, the period of analysis used is 30 years. The TDV energy estimates are based on present-valued cost savings but are normalized in terms of "TDV kBTUs" so that the savings are evaluated in terms of energy units and measures with different periods of analysis can be combined into a single value.

The CEC derived TDV values for each climate zone (CEC 2014).Due to the timing of pre-rulemaking activities for the 2016 code change cycle, the Statewide CASE Team had to produce the first iteration of the code change proposal before CEC had released the 2016 TDV values. As such, the Statewide CASE Team conducted its parametric analysis using 2013 TDV values. The parametric analysis resulted in the proposed efficiency levels, and the lifecycle cost analysis for each construction type by climate zone. The analysis showed that the recommended efficiency levels are very cost effective, with Planning benefit to cost ratios (B/C) of 3 to 5 or higher in many cases.

After the 2016 TDV dataset was made available, the Statewide CASE Team identified several proposed efficiency levels that had B/C ratios under 1.5 and re-ran the cost-effectiveness analysis using the 2016 TDV values to ensure that all of the proposed changes remain cost effective using the 2016 TDV. The 2016 TDV dataset was used to calculate these statewide impacts presented in this report.

The TDV energy impacts are presented in Section 5.1 of this report, and the statewide TDV cost impacts are presented in Section 5.2.

4.6 Energy Impacts Methodology

The Statewide CASE Team calculated per unit impacts and statewide impacts associated with all new construction, alterations, and additions during the first year buildings complying with the 2016 Title 24 Standards are in operation. The energy impacts were calculated by applying the energy savings estimates for each analyzed building type, and by applying construction estimates to the savings per square foot estimates.

4.6.1 Per Unit Energy Impacts Methodology

The Statewide CASE Team estimated the electricity and natural gas savings associated with the proposed code change. The energy savings were calculated on a per-square-foot of building component exterior area (wall area, floor area, roof area). Then, the square footage of wall area is converted to a square footage of floor area using representative building dimensions and number of floors.

The impacts of energy savings on a per unit basis were calculated directly through the energy simulations.

Analysis Tools

The compliance tool available for the 2013 Title 24 Standards, CBECC-Com, version 2, was used to estimate energy savings in the lifecycle cost analysis. This tool uses EnergyPlus 8.0 as the simulation engine. No enhancements are needed to estimate energy savings for the prototype buildings. A later release of CBECC-Com, version 3 beta, that uses the 2016 TDV dataset and EnergyPlus 8.1 as the simulation engine, was used for the statewide impact analysis, and used to re-run a subset of lifecycle cost simulation cases to confirm that the recommended levels are appropriate.

Key Assumptions

As mentioned, the CEC provided a number of key assumptions to be used in the energy impacts analysis (CEC 2011). Some of the assumptions included in the CEC's Lifecycle Cost Methodology Guidelines (LCC Methodology) include hours of operation, weather data, and prototype building design. The key assumptions used in the per unit energy impacts analysis that are not already included in the assumptions provided in the LCC Methodology, are presented in Table 10.

Table 10: Key assumptions for per unit Energy Impacts Analysis

Parameter	Assumption	Source	Notes
Compliance Type	80% of nonresidential construction either use the performance method or use prescriptive with same baseline as the performance method	Approximation for statewide impact	n/a
Residential Construction	50% of multi-family construction is high-rise residential	Estimate from res construction forecast; no HRR data was available	
TDV	The 2013 TDV dataset used for LCC analysis is corroborated by re-running analysis with the 2016 TDV dataset for a subset of the cases where the benefit to cost ratio was close to 1	Energy simulation results and B/C ratios	The 2016 TDV data set was used for the statewide impact.

4.6.2 Statewide Energy Impacts Methodology

First Year Statewide Impacts

The proposed code change applies to all new construction, additions and alterations. Energy savings were first determined per square foot of envelope component (SF wall, SF roof), and then converted to an energy savings per square foot of conditioned floor area. Then, construction forecasts was applied to determine savings per climate zone across a range of representative building types (office, retail, school, warehouse, etc.) that comprise the construction forecast.

The Statewide CASE Team calculated the statewide savings in 2017 (the first year the standards take effect) by multiplying the per unit savings by the statewide new construction forecast for 2017.

The CEC Demand Analysis Office provided the Statewide CASE Team with the residential and nonresidential new construction forecast for 2017, broken out by building type and forecast climate zones (FCZ). The Statewide CASE Team translated this data to building climate zones (BCZ) using the same weighting of FCZ to BCZ as the previous code update cycle (2013), as presented in Table 13.

The projected nonresidential new construction forecast is presented in Table 14. Table 11 provides a more complete definition of the various space types used in the forecast, and Table 12 presents the assumed percent of new construction that would be impacted by the proposed code change.

The Statewide CASE Team used the mid scenario of forecasted residential new construction for statewide savings estimates. The projected new residential construction forecast, presented by BCZ is presented below in Table 15. This measure only applies to high-rise residential buildings. Low-rise residential and single family residential construction is not impacted. It was assumed that 50% of the multi-family buildings indicated in the Residential New Construction Forecast, are high-rise residential.

Table 11: Description of Space Types used in the Nonresidential New Construction Forecast

OFF-SMALL	Offices less than 30,000 ft^2
OFF-LRG	Offices larger than 30,000 ft^2
REST	Any facility that serves food
RETAIL	Retail stores and shopping centers
FOOD	Any service facility that sells food and or liquor
NWHSE	Nonrefrigerated warehouses
RWHSE	Refrigerated Warehouses
SCHOOL	Schools K-12, not including colleges
COLLEGE	Colleges, universities, community colleges
HOSP	Hospitals and other health-related facilities
HOTEL	Hotels and motels
MISC	All other space types that do not fit another category

For the statewide impact analysis, an assumption was made that 70% of new construction projects use the performance method for compliance. When the performance method is used, the Nonresidential ACM Reference Manual specifies a fixed baseline construction of Wood Framed and Other for roofing and metal-framed for walls. Therefore, these construction types are used in the impact analysis because they affect the compliance margin regardless of the construction type studied. For the prescriptive method, we assumed that a fraction of the remaining 30% of new construction buildings use the same construction type as the performance method. Overall, we assumed that 80% of the nonresidential buildings are compared against the performance baseline, and the remaining 20% are affected by the prescriptive requirements for metal building roofs or wood-framed walls.

For the building type breakdown, we did not include refrigerated warehouse in the impact, since this is a special building type with covered process loads that cannot be easily modeled by compliance software.

Table 12: Percent of New Construction Impacted by the Proposed Measure

Building Square Footage Assumptions by Space Type	Metal-framed Roofs	Wood-framed Roofs	Metal-framed Walls	Wood-framed Walls
Office-Small	20%	80%	80%	20%
Restaurant	20%	80%	80%	20%
Retail	20%	80%	80%	20%
Food	20%	80%	80%	20%
Non-refrigerated Warehouse	20%	80%	80%	20%
Refrigerated Warehouse	N/A	N/A	N/A	N/A
School	20%	80%	80%	20%
College	20%	80%	80%	20%
Hospital	N/A	N/A	N/A	N/A
Miscellaneous	20%	80%	80%	20%
Office-Large	20%	80%	80%	20%
High-rise Residential Buildings	20%	80%	80%	20%

Table 13. Translation from FCZ to BCZ

Source: CEC Demand Analysis Office

Forecast Climate Zones (FCZ)	Building Standards Climate Zones (BCZ)																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Grand Total
1	22.5%	20.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	9.8%	33.1%	0.2%	0.0%	0.0%	13.8%	100%
2	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	22.0%	75.7%	0.0%	0.0%	0.0%	2.3%	100%
3	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	21.0%	22.8%	54.5%	0.0%	0.0%	1.8%	100%
4	0.2%	13.7%	8.4%	46.0%	8.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	22.8%	0.0%	0.0%	0.0%	0.0%	100%
5	0.0%	4.2%	89.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	6.6%	0.0%	0.0%	0.0%	0.0%	100%
6	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	100%
7	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	75.8%	7.1%	0.0%	17.1%	100%
8	0.0%	0.0%	0.0%	0.0%	0.0%	40.4%	0.0%	51.1%	8.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%	100%
9	0.0%	0.0%	0.0%	0.0%	0.0%	7.0%	0.0%	24.5%	57.9%	0.0%	0.0%	0.0%	0.0%	6.7%	0.0%	4.0%	100%
10	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	74.9%	0.0%	0.0%	0.0%	12.3%	7.9%	4.9%	100%
11	0.0%	0.0%	0.0%	0.0%	0.0%	33.0%	0.0%	24.8%	42.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100%
12	0.0%	0.0%	0.0%	0.0%	0.0%	0.9%	0.0%	20.2%	75.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.7%	100%
13	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	69.6%	0.0%	0.0%	28.8%	0.0%	0.0%	0.0%	1.6%	0.1%	0.0%	100%
14	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100%
15	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	99.9%	0.0%	100%
16	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100%
17	3.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	97.1%	100%

Table 14: Estimated New Nonresidential Construction in 2017 by Climate Zone and Building Type (Million Square Feet)

Source: CEC Demand Analysis Office

Climate Zone	New Construction in 2017 (Million Square Feet)												
	OFF-SMALL	REST	RETAIL	FOOD	NWHSE	RWHSE	SCHOOL	COLLEGE	HOSP	HOTEL	MISC	OFF-LRG	TOTAL
1	0.058	0.016	0.041	0.014	0.040	0.002	0.046	0.018	0.028	0.031	0.094	0.069	0.457
2	0.227	0.088	0.630	0.163	0.327	0.031	0.244	0.163	0.200	0.350	0.742	1.140	4.306
3	0.728	0.408	2.913	0.677	2.518	0.183	1.000	0.625	0.729	1.400	3.894	4.952	20.026
4	0.484	0.190	1.586	0.413	0.595	0.071	0.541	0.408	0.490	0.890	1.641	2.935	10.245
5	0.094	0.037	0.308	0.080	0.116	0.014	0.105	0.079	0.095	0.173	0.319	0.570	1.990
6	0.811	0.825	3.072	0.756	2.649	0.122	0.659	0.649	0.508	0.571	4.144	2.264	17.030
7	0.959	0.300	1.635	0.502	1.004	0.013	0.772	0.448	0.325	1.059	3.077	1.253	11.347
8	1.078	1.106	4.241	1.034	3.588	0.162	0.856	0.931	0.773	0.872	5.860	3.186	23.686
9	0.971	0.916	3.975	0.937	3.287	0.119	0.600	1.095	1.127	1.329	5.376	5.675	25.408
10	1.372	0.707	2.995	0.839	2.630	0.074	0.883	0.580	0.528	1.056	8.010	1.496	21.170
11	0.333	0.088	0.770	0.268	0.875	0.089	0.504	0.156	0.239	0.197	0.737	0.629	4.885
12	1.710	0.502	3.656	1.014	3.157	0.202	1.687	0.678	1.048	1.480	3.637	4.721	23.493
13	0.668	0.205	1.606	0.544	1.706	0.286	1.401	0.390	0.520	0.359	1.884	0.817	10.387
14	0.224	0.138	0.609	0.162	0.527	0.025	0.156	0.128	0.115	0.185	1.472	0.431	4.171
15	0.349	0.096	0.675	0.238	0.761	0.022	0.192	0.098	0.133	0.204	1.123	0.289	4.180
16	0.199	0.106	0.506	0.142	0.449	0.042	0.205	0.122	0.125	0.144	0.931	0.394	3.367
TOTAL	10.264	5.729	29.218	7.784	24.228	1.457	9.852	6.570	6.983	10.301	42.941	30.821	186.148

Table 15: Projected New Residential Construction in 2017 by Climate Zone[1]

Source: CEC Demand Analysis Office

Building Climate Zone	Single Family Starts	Multifamily Starts[2]
Climate Zone 1	695	47
Climate Zone 2	2,602	507
Climate Zone 3	5,217	3,420
Climate Zone 4	5,992	1,053
Climate Zone 5	1,164	205
Climate Zone 6	4,142	2,151
Climate Zone 7	6,527	2,687
Climate Zone 8	7,110	3,903
Climate Zone 9	8,259	8,023
Climate Zone 10	16,620	1,868
Climate Zone 11	5,970	217
Climate Zone 12	19,465	1,498
Climate Zone 13	13,912	770
Climate Zone 14	3,338	492
Climate Zone 15	3,885	433
Climate Zone 16	3,135	508
Total	**108,032**	**27,784**

1. CEC provided a low, middle, and high forecast. The Statewide CASE Team used the middle forecast for the statewide savings estimates. Statewide savings estimates do not include savings from mobile homes.
2. Includes high-rise and low-rise multi-family construction.

For this measure, the stringency of the Standards is slightly different for the performance approach than it is for the prescriptive approach. For this reason, duplicate set of runs with the proposed 2016 changes were performed using the performance baseline and prescriptive baseline. It is assumed that the performance approach and prescriptive compliance approaches using the same construction types as the default assumptions in the performance method comprise about 75% of new construction. The medium retail prototype was used for nonresidential statewide impact estimates, and the four-story hotel prototype was used for the high-rise residential statewide savings estimates.

4.7 Cost-effectiveness Methodology

This measure proposes a prescriptive requirement. As such, a lifecycle cost analysis is needed to demonstrate that the measure is cost-effective over the 30 year period of analysis.

CEC’s procedures for calculating lifecycle cost-effectiveness are documented in LCC Methodology (CEC 2011). The Statewide CASE Team followed these guidelines when developing the Cost-effectiveness Analysis for this measure. CEC’s guidance dictated which costs were included in the analysis. Incremental construction assembly and maintenance costs over the 30 year period of analysis were included. The TDV energy cost savings from electricity and natural gas savings were considered. Each of these components is discussed in more detail below.

With increased building envelope efficiency, there can be opportunities to downsize heating and cooling equipment capacities, leading to additional savings. Traditionally this secondary benefit has not been considered in building envelope LCC analysis, and it was not considered here.

4.7.1 Incremental Cost Methodology

Cost estimates were derived from multiple sources, including RS Means and Costworks, 2014, and with and written estimates from regional distributors of insulation products. The costs for insulation products, after adjusting for inflation, are not predicted to change considerably between 2014 and the code adoption date of 2017.

Incremental Construction Cost Methodology

As requested by CEC, the Statewide CASE Team estimated the Current Incremental Construction Costs and Post-adoption Incremental Construction Costs. The Current Incremental Construction Cost (ΔCI_C) represents the cost of the incremental cost of the measure if a building meeting the proposed standard were built today. The Post-adoption Incremental Construction Cost (ΔCI_{PA}) represents the anticipated cost assuming full market penetration of the measure as a result of the new Standards, resulting in possible reduction in unit costs as manufacturing practices improve over time and with increased production volume of qualifying products the year the Standard becomes effective.

The post-adoption incremental construction cost is not expected to differ significantly from the current incremental construction cost, for most of the recommendations. However, it is expected that the labor component of the installation cost for the filled cavity construction technique will drop slightly over time, as builders become more familiar with this insulation technique.

Key assumptions used to derive cost are presented in Table 16.

Table 16: Key Assumptions for per unit Incremental Construction Cost

Parameter	Assumption	Source
Metal Roof Construction Type	Standing Seam Metal Roof	ASHRAE 90.1-2013, Title 24
Wood-Framed Roof Construction Type	Rafter Roof, 24” o.c., 2x6 to 2x10 framing	Title 24, Reference Appendix JA4
Rigid Roof Insulation	20 to 25 psi for rigid EPS and polyiso	
Labor Cost	Union Cost, Overhead and Profit	RS Means, Costworks 2014

Incremental Maintenance Cost Methodology

Maintenance cost is included in the lifecycle cost analysis. The present value (PV) of maintenance costs (savings) was calculated using a 3 percent discount rate (d) as directed in the LCC Methodology (CEC 2011). The PV of maintenance costs that occurs in the nth year is calculated as follows (where d is the discount rate of 3 percent):

$$\text{PV Maintenance Cost} = \text{Maintenance Cost} \times \left[\frac{1}{1+d}\right]^n$$

According to the LCC Methodology, incremental maintenance costs should be included in the lifecycle cost analysis. Upon review, the Statewide CASE Team determined that there is no incremental maintenance costs associated with the proposed code change.

4.7.2 Energy Cost Savings Methodology

The PV of the energy savings were calculated using the method described in the LCC Methodology. In short, the hourly energy savings estimates for the first year of building operation were multiplied by the 2013 TDV cost values to arrive at the PV of the cost savings over the period of analysis. The 30-year nonresidential TDV values were used in the savings analysis; the same values currently in effect with the CBECC-Com compliance software. A unique set of hourly TDV values has been provided by the CEC for each of the 16 climate zones. As discussed in Section 4.5, due to the timing of pre-rulemaking activities for the 2016 code change cycle, the Statewide CASE Team had to complete the parametric analysis, which informed the stringency of the proposed standards and confirmed that the proposed standards are cost effective, using 2013 TDV. The analysis showed that the recommended efficiency levels are very cost effective, with Planning benefit to cost ratios (B/C) of 3 to 5 or higher in many cases. The lifecycle cost analysis was repeated with the 2016 TDV cost values for a subset of the cases where the benefit-to-cost (B/C) ratio was close to 1 (below approximately 1.5), to confirm that the recommended efficiency levels were still cost effective using the newer 2016 TDV dataset.

The statewide energy cost savings presented in this report were developed using the 2016 TDV values.

4.7.3 Cost-effectiveness Methodology

The Statewide CASE Team calculated the cost-effectiveness using the LCC Methodology. According to CEC's definitions, a measure is cost effective if it reduces overall lifecycle cost from the current base case (existing conditions). The LCC Methodology clarifies that absolute lifecycle cost of the proposed measure does not need to be calculated. Rather, it is necessary to calculate the change in lifecycle cost from the existing conditions to the proposed conditions.

If the change in lifecycle cost is negative then the measure is cost-effective, meaning that the present value of TDV energy savings is greater than the cost premium, or the proposed measure reduces the total lifecycle cost as compared to the existing conditions. Propane TDV costs are not used in the evaluation of energy efficiency measures.

The Planning Benefit-to-Cost (B/C) Ratio is another metric that can be used to evaluate cost-effectiveness. The B/C Ratio is calculated by dividing the total present value TDV energy cost savings (the benefit) by the present value of the total incremental cost (the cost). If the B/C Ratio is greater than 1.0 (i.e. the present valued benefits are greater than the present valued costs over the period of analysis), then the measure is cost effective.

4.8 Environmental Impacts Methodology

4.8.1 Greenhouse Gas Emissions Impacts Methodology

Greenhouse Gas Emissions Impacts Methodology

The Statewide CASE Team calculated avoided GHG emissions assuming an emission factor of 353 metric tons of carbon dioxide equivalents ($MTCO_2e$) per GWh of electricity savings. As described in more detail in Appendix A, the electricity emission factor represents savings from avoided electricity generation and accounts for the GHG impacts if the state meets the Renewable Portfolio Standard (RPS) goal of 33 percent renewable electricity generation by 2020. Avoided GHG emissions from natural gas savings were calculated using an emission factor of 5,303 $MTCO_2e$/million therms (U.S. EPA 2011).

4.8.2 Water Use and Water Quality Impacts Methodology

No significant water savings are expected from this measure. A reduction in cooling energy use for large buildings with water-cooled central plants will reduce water use slightly, by reducing cooling tower energy use. The Statewide CASE Team did not assess the quantitative impact of water savings.

4.8.3 Material Impacts Methodology (Optional)

The Statewide CASE Team did not assess the quantitative material impacts of the proposed code change.

4.8.4 Other Impacts Methodology

Higher levels of infiltration can lead improved occupant comfort by moderating interior surface temperatures of walls and ceilings. With increased use of continuous insulation, this can potentially inhibit air infiltration, another indirect benefit. More importantly, in some cases, the increased levels of insulation will reduce peak cooling and heating loads, and can lead to downsizing of HVAC equipment, a significant first cost savings. Since reduction in required capacity of heating and cooling equipment depends upon discrete equipment sizes, the amount of this savings, if any, will vary among projects, and was not considered in this study.

5. Analysis and Results

Results from the energy, demand, cost, and environmental impacts analyses are presented in this section.

As describe in Section 4.3.1, a large number of insulation options for a number of construction assemblies were evaluated for this measure. Therefore, there is a lot of data used to determine recommendations for this measure. This report does not present all data generated during the parametric analysis. Rather, it presents the important outcomes of the detailed analysis. Before presenting the results, a brief summary of the findings is presented below:

- For metal building roofs, the ASHRAE 90.1 construction assembly of a filled cavity, with R-19 and R-10 batt layers of insulation, is cost effective for all climates. This would reduce the current construction U-factor from a standing seam metal roof from 0.065 to 0.041.
- For wood-framed roofs, a moderate increase in insulation level is cost effective for most climate zones. The greatest potential gains come for the mild south coast climate zones (climate zones 6, 7, and 8), where current insulation requirements are minimal.
- For metal-framed walls in high-rise residential buildings, a higher level of insulation than the current requirement is cost-effective. Two inches of rigid polyisocyanurate is shown to be cost effective, compared to the current level of R-13 batt and R-5 continuous insulation, or R-8 of continuous insulation.
- For nonresidential buildings, a slight increase in required continuous insulation is recommended for metal-framed walls in climate zones 1, 6 and 7, to R-12 (two inches of polyisocyanurate insulation, or equivalent).
- No significant changes are recommended for wood-framed walls, given the fairly high stringency in the current Standards. For wood-framed walls, cavity insulation is moderately effective in reducing cooling and heating loads, and inland climate zones already require continuous insulation.
- No changes are recommended for mass walls at this time.

5.1 Energy Impacts Results

5.1.1 Per Unit Energy Impacts Results

Per unit energy and demand impacts of the proposed measure are presented in Table 17 and Table 18 for nonresidential and high-rise residential buildings, respectively. Per unit savings for the first year are expected to be in the range of 0.01 and 0.26 kilowatt-hours per square foot per year (kWh/SF-yr), and 0.005 to 0.026 therms/SF-year. Demand savings are expected to be between 0.004 and 0.15 Watts per SF, depending on climate zone, with climate zone 1 having the smallest demand savings, and climate zone 15 having the greatest demand savings.

For building opaque envelope requirements, TDV values electricity energy savings during peak periods more heavily. For example, for climate zone 6, electricity savings are 1.3% for the measure (kWh), while TDV electricity savings are 2.2% of the building total. The values in the tables presented below were calculated using 2016 TDV values.

Table 17: First Year Energy Impact per Square Foot – Nonresidential Buildings

Climate Zone	Per Unit First Year Savings			Per Unit First Year TDV Savings[3]	
	Electricity Savings[1] (kWh/SF-yr)	Demand Savings (W/SF)	Natural Gas Savings (Therms/SF-yr)	TDV Electricity Savings[2] (kBTU/SF)	TDV Natural Gas Savings[2] (kBTU/SF)
Climate Zone 1	0.009604	0.00407	0.025970	0.3699	4.4841
Climate Zone 2	0.049098	0.06677	0.010838	3.2805	1.9545
Climate Zone 3	0.014774	0.01751	0.010269	1.0339	1.8521
Climate Zone 4	0.044294	0.04641	0.008819	2.29293	1.61407
Climate Zone 5	0.013659	0.01303	0.010582	0.7335	1.8715
Climate Zone 6	0.068558	0.05008	0.010248	3.21163	1.88037
Climate Zone 7	0.062492	0.07002	0.008633	3.39111	1.53689
Climate Zone 8	0.080161	0.07857	0.006613	4.0795	1.2245
Climate Zone 9	0.088548	0.08590	0.007533	4.39283	1.38817
Climate Zone 10	0.091520	0.07857	0.007728	4.30939	1.42461
Climate Zone 11	0.111835	0.10096	0.011062	5.3787	2.0283
Climate Zone 12	0.083988	0.08305	0.011116	4.0709	2.0491
Climate Zone 13	0.142572	0.11196	0.009697	5.9732	1.7958
Climate Zone 14	0.134023	0.10178	0.008357	5.5294	1.5346
Climate Zone 15	0.260351	0.15104	0.004672	9.235	0.888
Climate Zone 16	0.051948	0.03868	0.019252	2.4097	3.4843

1. Site electricity savings. Does not include TDV of electricity savings.
2. Calculated using CEC's 2016 TDV factors.

Table 18: First Year Energy Impact per Square Foot – High-rise Residential Buildings

Climate Zone	Per Unit First Year Savings			Per Unit First Year TDV Savings[3]	
	Electricity Savings[1] (kWh/SF-yr)	Demand Savings (W/SF)	Natural Gas Savings (Therms/SF-yr)	TDV Electricity Savings[2] (kBTU/SF)	TDV Natural Gas Savings[2] (kBTU/SF)
Climate Zone 1	0.01636	0.00081	0.00994	0.217	1.095
Climate Zone 2	0.01727	0.01122	0.00596	0.393	0.682
Climate Zone 3	0.01213	0.00400	0.00557	0.217	0.636
Climate Zone 4	0.01189	0.00770	0.00424	0.278	0.493
Climate Zone 5	0.01437	0.00583	0.00585	0.255	0.651
Climate Zone 6	0.00732	0.03381	0.00262	0.211	0.309
Climate Zone 7	0.00633	0.00363	0.00182	0.154	0.206
Climate Zone 8	0.01355	0.01140	0.00248	0.358	0.294
Climate Zone 9	0.01810	0.02141	0.00306	0.624	0.361
Climate Zone 10	0.02139	0.02086	0.00333	0.622	0.393
Climate Zone 11	0.02636	0.01694	0.00567	0.645	0.667
Climate Zone 12	0.02057	0.01474	0.00574	0.522	0.677
Climate Zone 13	0.02872	0.02127	0.00472	0.712	0.561
Climate Zone 14	0.02552	0.01749	0.00570	0.587	0.675
Climate Zone 15	0.05309	0.03084	0.00151	1.154	0.185
Climate Zone 16	0.01470	0.00774	0.01074	0.307	1.233

5.1.2 Statewide Energy Impacts Results

First Year Statewide Energy Impacts

The statewide energy impacts of the proposed changes for nonresidential buildings and high-rise residential buildings are presented in Table 19 and Table 20, respectively. During the first year buildings complying with the 2016 Title 24 Standards are in operation, the proposed measure is expected to reduce annual statewide electricity use by over 14 GWh/yr. The first year statewide natural gas savings are over 1.6 million therms. The first year statewide savings were calculated using 2016 TDV values.

Table 19: First Year Statewide Energy Impacts – Nonresidential Buildings

Climate Zone	Electricity Savings (GWh)	Power Demand Reduction (MW)	Natural Gas Savings (MMtherms)	Statewide TDV Electricity Savings (Million kBTU)	Statewide TDV Natural Gas Savings (Million kBTU)	Statewide TDV Energy Savings (Million kBTU)
Climate Zone 1	0.004	0.002	0.011	0.006	0.078	0.084
Climate Zone 2	0.194	0.264	0.043	0.528	0.315	0.843
Climate Zone 3	0.275	0.326	0.191	0.784	1.405	2.189
Climate Zone 4	0.414	0.434	0.083	0.873	0.615	1.488
Climate Zone 5	0.025	0.024	0.019	0.054	0.138	0.193
Climate Zone 6	1.128	0.824	0.169	2.152	1.260	3.412
Climate Zone 7	0.643	0.720	0.089	1.420	0.644	2.064
Climate Zone 8	1.829	1.793	0.151	3.789	1.137	4.926
Climate Zone 9	2.132	2.068	0.181	4.306	1.361	5.667
Climate Zone 10	1.841	1.580	0.155	3.529	1.167	4.696
Climate Zone 11	0.524	0.473	0.052	1.027	0.387	1.414
Climate Zone 12	1.849	1.828	0.245	3.648	1.836	5.484
Climate Zone 13	1.430	1.123	0.097	2.439	0.733	3.172
Climate Zone 14	0.534	0.406	0.033	0.897	0.249	1.147
Climate Zone 15	1.035	0.600	0.019	1.495	0.144	1.639
Climate Zone 16	0.167	0.125	0.062	0.316	0.457	0.773
TOTAL	14.03	12.59	1.600	27.264	11.925	39.189

Table 20: First Year Statewide Energy Impacts – High-rise Residential Buildings

Climate Zone	Electricity Savings (GWh)	Power Demand Reduction (MW)	Natural Gas Savings (MMtherms)	Statewide TDV Electricity Savings (Million kBTU)	Statewide TDV Natural Gas Savings (Million kBTU)	Statewide TDV Energy Savings (Million kBTU)
Climate Zone 1	0.00046	0.00002	0.00028	0.0002	0.0008	0.0010
Climate Zone 2	0.00526	0.00341	0.00181	0.0033	0.0057	0.0089
Climate Zone 3	0.0249	0.00820	0.01143	0.0122	0.0356	0.0477
Climate Zone 4	0.00751	0.00487	0.002.68	0.0048	0.0085	0.0133
Climate Zone 5	0.00176	0.00072	0.00072	0.0009	0.0022	0.0030
Climate Zone 6	0.00944	0.04363	0.00339	0.0074	0.0109	0.0183
Climate Zone 7	0.01021	0.00585	0.00293	0.0068	0.0090	0.0158
Climate Zone 8	0.03174	0.02671	0.00581	0.0228	0.0188	0.0416
Climate Zone 9	0.08711	0.10309	0.01475	0.0820	0.0474	0.1293
Climate Zone 10	0.02398	0.02339	0.00373	0.0190	0.0120	0.0310
Climate Zone 11	0.00343	0.00221	0.00074	0.0023	0.0024	0.0047
Climate Zone 12	0.01849	0.01325	.00516	0.0128	0.0166	0.0294
Climate Zone 13	0.01327	0.00982	.00218	0.0090	0.0071	0.0160
Climate Zone 14	0.00754	0.00517	0.00168	0.0047	0.0054	0.0102
Climate Zone 15	0.0138	0.00802	0.00039	0.0082	0.0013	0.0095
Climate Zone 16	0.00449	0.00236	0.00327	0.0026	0.0103	0.0128
TOTAL	0.263	0.26	0.061	0.1988	0.1939	0.3926

5.2 Cost-effectiveness Results

5.2.1 Incremental Cost Results

The total incremental cost includes the incremental cost during initial construction and the present value of the incremental maintenance cost over the 30 year period of analysis. Incremental cost typically ranged between less than $0.20 per square foot of building component, up to $1.40 per square foot of building component.

Incremental Construction Cost Results

Incremental costs were determined by gathering cost estimates from distributors for a variety of roof and wall assemblies that span the range of efficiency levels encountered in buildings. The costs include material, labor, overhead and profit, and are presented in summary form below in Table 21 through Table 24.

Table 21: Metal Building Wall Insulation Costs

Description	Insulation R-value	Assembly U-factor	Total O&P
Wall Insulation, R-13 batt insulation	13 b	0.217	$ 0.80
Wall Insulation, R-13 batt +1" EPS	13+R-5	0.104	$ 2.05
Wall Insulation, R-13 batt + 1" polysio	15+R-6.2	0.093	$ 2.20
Polyiso, rigid, 1" thick, foil faced	5.6	0.128	$ 1.40
Polyiso, rigid, 2" thick, foil faced	12.4	0.069	$ 1.78
Polyiso, rigid, foil faced, 3" thick	18.6	0.048	$ 2.83
EPS, rigid, 25 psi, 2" thick, R10	10	0.082	$ 2.06
EPS, rigid, 25 psi, 3" thick, R15	15	0.058	$ 2.52
Expanded polystyrene,, 1" thick, R4	5	0.139	$ 1.25
Expanded polystyrene,, 2" thick, R8	8	0.098	$ 1.52
R-13 cavity+ 2" polyiso	11.2	0.089	$ 2.53
R-13 cavity+ 3" polyiso	16.8	0.060	$ 3.58

Table 22: Wood-Framed Wall Insulation Costs

Construction Assembly	Insulation R-value	U-factor	Material	Labor	Fasteners	Total O&P
2x4, R-11 batt	11	0.11	0.385	0.42		$ 0.93
2x4,R-13 batt	13	0.102	0.594	0.42		$ 1.14
2x4 R-15 batt	15	0.095	0.70	0.42		$ 1.25
2x6, R-19 batt	19	0.074	0.66	0.42		$ 1.21
2x6.R-21 batt	21	0.069	0.8	0.42		$ 1.35
2x4, R-13 batt + R-5 c.i. (EPS)	13+5ci	0.068	0.6342	0.3000	0.0620	$ 1.93
2x4, R-13-batt + R-6.2 c.i (polyiso)	13+6.2ci	0.063	0.491563	0.3	0.062	$ 1.99
2x4, R-13 batt + R-10 c.i. (EPS)	13+10ci	0.051	1.2684	0.4000	0.0786	$ 2.99
2x4, R-13-batt + R-12.4 c.i (polyiso)	13+12.4ci	0.045	0.8027	0.4000	0.0786	$ 2.49

Table 23: Metal Building Roof Insulation Costs

Roof Type	Details	Insulation	U-factor	First Cost + Markup
Standing Seam Roof	Single Layer of Insulation draped	R-11 batt	0.092	$ 0.69
	over purlins and compressed. Thermal	R-13 batt	0.083	$ 0.89
	blocks at supports (R-5)	R-19 batt	0.065	$ 0.96
Standing Seam Roof	Double layer of insulation. Thermal	R-11 + R-11	0.06	$ 1.37
	blocks at supports (R-5)	R-13 + R-13	0.055	$ 1.79
		R-11 + R-19	0.051	$ 1.65
		R-13 + R-19	0.049	$ 1.85
		R-19 + R-19	0.046	$ 1.92
Standing Seam Roof	Single Layer + 1" polyiso	R-19,R-6.2c.i	0.0463	$ 2.22
	Single Layer + 2" polyiso	R-19,R-12.4c.i.	0.0360	$ 2.75
Filled Cavity with Thermal Blocks	Long Tab Banded	R-19 + R-10	0.041	$ 1.81

Table 24: Wood-Framed Roof Insulation Costs

Roof Batt Insulation	Details	U-factor	Insulation Costs	*Framing Increment**	Labor Costs	First Cost + Markup
R-11	2x6	0.075	0.385	0.00	0.42	$ 0.81
R-13	2x6	0.067	0.594	0.00	0.42	$ 1.01
R-15	2x6	0.06	0.70	0.00	0.42	$ 1.12
R-19	2x6	0.054	0.66	0.00	0.42	$ 1.08
R-21	2x6	0.049	0.8	0.00	0.42	$ 1.22
R-19	2x8	0.049	0.66	0.50	0.42	$ 1.58
R-21	2x8	0.046	0.8	0.50	0.42	$ 1.72
R-25	2x10	0.039	0.66	1.00	0.50	$ 2.16
R-30	2x10	0.034	1.1	1.00	0.50	$ 2.60
R-38	2x12	0.027	1.375	1.75	0.50	$ 3.63

* Framing costs are for illustrative purposes only, since construction assemblies with higher framing depth is not used when comparing against the current construction.

Notes:

- All assemblies are 24” o.c.
- All costs are installed costs, $/SF, with overhead and profit markup included
- Comparisons for LCC analysis are only made for the framing depth used in the current prescriptive requirements

- For example: for CZ6 (Torrance, Los Angeles), the current requirement corresponds to 2x6 framing. The assemblies considered range from R-11 to R-21, 2x6 framing, with or without continuous insulation
- Continuous Insulation of EPS or polyiso considered

The difference between the Current Incremental Cost and the Post-adoption Measure Cost is not expected to be significant for this measure, given the maturity of the market, and the fact that the proposed construction assemblies can already be built using currently available products. It is possible that continuous rigid insulation products could decrease slightly, given the requirements for continuous insulation in the code for wall and roof assemblies.

For this measure, we do not expect installed costs to change appreciably between now and January 2017, given the wide availability of the product and given that the technology has been readily established.

Incremental Maintenance Cost Results

No incremental maintenance costs are relevant to the proposed measure.

5.2.2 Energy Cost Savings Results

Energy Cost Savings Results

The per unit TDV energy cost savings over the 30 year period of analysis are presented in Table 25 through Table 31. Given data regarding the new construction forecast for 2017, the Statewide CASE Team estimates that TDV energy cost savings (30 year) of all buildings built during the first year the 2016 Standards are in effect will be over $6 million.

5.2.3 Cost-effectiveness Results

Results per square foot Lifecycle Cost-effectiveness Analyses are presented in Table 25 through Table 31. These values were derived using 2013 TDV values. The analysis showed that the recommended efficiency levels are very cost effective, with the Planning B/C ratio well over 1 for every proposed change.

After the 2016 TDV dataset was made available, the Statewide CASE Team identified several proposed efficiency levels that had B/C ratios under 1.5 and re-ran the cost-effectiveness analysis using the 2016 TDV values to demonstrate that all of the proposed changes remain cost effective using the 2016 TDV.

The Statewide CASE Team chose to re-run the assemblies for nonresidential wood-framed walls to demonstrate the impact of using 2016 TDV values as opposed to 2013 TDV values. The results of the analysis that uses 2016 TDV factors are shown in Table 32. Comparing the results using 2013 TDV (Table 28) to the results of using 2016 TDV (Table 32), it is evident that the new TDV has a small impact on the overall results. In climate zone 1 the B/C ratios are 1.36 and 1.35 using 2013 TDV and 2016 TDV, respectively. In climate zone 11 the B/C ratios are 1.39 and 1.41 using the 2013 TDV and 2016 TDV, respectively. Even the proposed changes with the lowest B/C rations are still cost effective using 2016 TDV.

The proposed insulation levels reduce total lifecycle costs over the 30 year period of analysis relative to the 2013 Title 24 Standards. The proposed code change is cost-effective in every climate zone.

As mentioned, the proposed efficiency levels were derived by completing a parametric analysis that evaluated the cost effectiveness of a number of potential efficiency levels. Each potential stringency was coupled with an assembly that is feasible to deploy given today's construction practices. The tables below present the cost effectiveness results of the stringency that the Statewide CASE Team recommends adopting. Table 33 through Table 39 present the current (2013 Title 24) and proposed efficiency levels and the associated assemblies that were modeled for the analysis.

Table 25: Cost-effectiveness Summary, Nonresidential Metal Building Roofs[1]

Climate Zone	Benefit: TDV Energy Cost Savings[2] (2017 PV$/SF)	Cost: Total Incremental Cost[3] (2017 PV$/SF)	Change in Lifecycle Cost[4] (2017 PV$)	Benefit to Cost Ratio[5]
Climate Zone 1	$3.22	$0.85	$2.37	3.78
Climate Zone 2	$5.09	$0.85	$4.24	5.98
Climate Zone 3	$3.32	$0.85	$2.47	3.90
Climate Zone 4	$4.64	$0.85	$3.79	5.46
Climate Zone 5	$3.04	$0.85	$2.19	3.58
Climate Zone 6	$4.16	$0.85	$3.31	4.90
Climate Zone 7	$3.61	$0.85	$2.76	4.25
Climate Zone 8	$5.00	$0.85	$4.15	5.89
Climate Zone 9	$6.00	$0.85	$5.15	7.06
Climate Zone 10	$6.02	$0.85	$5.17	7.08
Climate Zone 11	$7.46	$0.85	$6.61	8.77
Climate Zone 12	$6.46	$0.85	$5.61	7.60
Climate Zone 13	$8.04	$0.85	$7.19	9.46
Climate Zone 14	$7.83	$0.85	$6.98	9.21
Climate Zone 15	$9.63	$0.85	$8.78	11.33
Climate Zone 16	$7.47	$0.85	$6.62	8.79

1. Relative to existing conditions. All cost values presented in 2017 dollars.
2. Present value of TDV cost savings equals TDV electricity savings plus TDV natural gas savings; $\Delta TDV\$ = \Delta TDV\$E + \Delta TDV\$G$.
3. Total incremental cost equals incremental construction cost (post adoption) plus present value of incremental maintenance cost; $\Delta C = \Delta CI_{PA} + \Delta CM$.
4. Negative values indicate the measure is cost-effective. Change in lifecycle cost equals cost premium minus TDV energy cost savings; $\Delta LCC = \Delta C - \Delta TDV\$$
5. The benefit to cost ratio is the TDV energy costs savings divided by the total incremental costs; $B/C = \Delta TDV\$ \div \Delta C$. The measure is cost effective if the B/C ratio is greater than 1.0.

Table 26: Cost-effectiveness Summary, Nonresidential Wood-framed Roofs[1]

Climate Zone	Benefit: TDV Energy Cost Savings[2] (2017 PV$/SF)	Cost: Total Incremental Cost[3] (2017 PV$/SF)	Change in Lifecycle Cost[4] (2017 PV$)	Benefit to Cost Ratio[5]
Climate Zone 1	$2.01	$1.38	$0.63	1.46
Climate Zone 2	$3.18	$1.38	$1.80	2.30
Climate Zone 3	$2.07	$1.38	$0.69	1.50
Climate Zone 4	$2.90	$1.38	$1.52	2.10
Climate Zone 5	$1.90	$1.38	$0.52	1.38
Climate Zone 6	$4.51	$0.42	$4.10	10.8
Climate Zone 7	$2.71	$0.21	$2.50	13.1
Climate Zone 8	$3.13	$1.38	$1.75	2.27
Climate Zone 9	$3.75	$1.38	$2.37	2.72
Climate Zone 10	$3.76	$1.38	$2.38	2.73
Climate Zone 11	$4.66	$1.38	$3.28	3.38
Climate Zone 12	$4.04	$1.38	$2.66	2.93
Climate Zone 13	$5.02	$1.38	$3.64	3.64
Climate Zone 14	$4.89	$1.38	$3.51	3.55
Climate Zone 15	$6.02	$1.38	$4.64	4.36
Climate Zone 16	$4.67	$1.38	$3.29	3.38

1. Relative to existing conditions. All cost values presented in 2017 dollars.
2. Present value of TDV cost savings equals TDV electricity savings plus TDV natural gas savings; $\Delta TDV\$ = \Delta TDV\$E + \Delta TDV\$G$.
3. Total incremental cost equals incremental construction cost (post adoption) plus present value of incremental maintenance cost; $\Delta C = \Delta CI_{PA} + \Delta CM$.
4. Negative values indicate the measure is cost-effective. Change in lifecycle cost equals cost premium minus TDV energy cost savings; $\Delta LCC = \Delta C - \Delta TDV\$$
5. The benefit to cost ratio is the TDV energy costs savings divided by the total incremental costs; $B/C = \Delta TDV\$ \div \Delta C$. The measure is cost effective if the B/C ratio is greater than 1.0.

Table 27: Cost-effectiveness Summary, Nonresidential Metal-framed Walls[1]

Climate Zone	Benefit: TDV Energy Cost Savings[2] (2017 PV$/SF)	Cost: Total Incremental Cost[3] (2017 PV$/SF)	Change in Lifecycle Cost[4] (2017 PV$)	Benefit to Cost Ratio[5]
Climate Zone 1	$0.65	$0.26	$0.39	2.51
Climate Zone 6	$0.52	$0.26	$0.26	1.99
Climate Zone 7	$0.42	$0.26	$0.16	1.61
All other Climate Zones	n/a	n/a	n/a	n/a

1. Relative to existing conditions. All cost values presented in 2017 dollars.
2. Present value of TDV cost savings equals TDV electricity savings plus TDV natural gas savings; $\Delta TDV\$ = \Delta TDV\$E + \Delta TDV\$G$.
3. Total incremental cost equals incremental construction cost (post adoption) plus present value of incremental maintenance cost; $\Delta C = \Delta CI_{PA} + \Delta CM$.
4. Negative values indicate the measure is cost-effective. Change in lifecycle cost equals cost premium minus TDV energy cost savings; $\Delta LCC = \Delta C - \Delta TDV\$$
5. The benefit to cost ratio is the TDV energy costs savings divided by the total incremental costs; $B/C = \Delta TDV\$ \div \Delta C$. The measure is cost effective if the B/C ratio is greater than 1.0.

Table 28: Cost-effectiveness Summary, Nonresidential Wood-framed Walls[1]

Climate Zone	Benefit: TDV Energy Cost Savings[2] (2017 PV$/SF)	Cost: Total Incremental Cost[3] (2017 PV$/SF)	Change in Lifecycle Cost[4] (2017 PV$)	Benefit to Cost Ratio[5]
Climate Zone 1	$0.15	$0.11	$0.04	1.36
Climate Zone 11	$0.68	$0.49	$0.19	1.38
All Other Climate Zones	n/a	n/a	n/a	n/a

1. Relative to existing conditions. All cost values presented in 2017 dollars.
2. Present value of TDV cost savings equals TDV electricity savings plus TDV natural gas savings; $\Delta TDV\$ = \Delta TDV\$E + \Delta TDV\$G$.
3. Total incremental cost equals incremental construction cost (post adoption) plus present value of incremental maintenance cost; $\Delta C = \Delta CI_{PA} + \Delta CM$.
4. Negative values indicate the measure is cost-effective. Change in lifecycle cost equals cost premium minus TDV energy cost savings; $\Delta LCC = \Delta C - \Delta TDV\$$
5. The benefit to cost ratio is the TDV energy costs savings divided by the total incremental costs; $B/C = \Delta TDV\$ \div \Delta C$. The measure is cost effective if the B/C ratio is greater than 1.0.

Table 29: Cost-effectiveness Summary, High-rise Residential Metal Building Roofs[1]

Climate Zone	Benefit: TDV Energy Cost Savings[2] (2017 PV$/SF)	Cost: Total Incremental Cost[3] (2017 PV$/SF)	Change in Lifecycle Cost[4] (2017 PV$)	Benefit to Cost Ratio[5]
Climate Zone 1	$ 6.62	0.85	$ 5.77	7.79
Climate Zone 2	$ 5.82	0.85	$ 4.97	6.85
Climate Zone 3	$ 4.24	0.85	$ 3.39	4.98
Climate Zone 4	$ 4.63	0.85	$ 3.78	5.44
Climate Zone 5	$ 5.04	0.85	$ 4.19	5.93
Climate Zone 6	$ 2.81	0.85	$ 1.96	3.31
Climate Zone 7	$ 1.84	0.85	$ 0.99	2.17
Climate Zone 8	$ 3.13	0.85	$ 2.28	3.68
Climate Zone 9	$ 4.23	0.85	$ 3.38	4.97
Climate Zone 10	$ 4.57	0.85	$ 3.72	5.37
Climate Zone 11	$ 6.23	0.85	$ 5.38	7.33
Climate Zone 12	$ 5.79	0.85	$ 4.94	6.81
Climate Zone 13	$ 6.23	0.85	$ 5.38	7.33
Climate Zone 14	$ 6.50	0.85	$ 5.65	7.65
Climate Zone 15	$ 4.68	0.85	$ 3.83	5.50
Climate Zone 16	$ 7.64	0.85	$ 6.79	8.99

1. Relative to existing conditions. All cost values presented in 2017 dollars.
2. Present value of TDV cost savings equals TDV electricity savings plus TDV natural gas savings; ΔTDV$ = ΔTDV$E + ΔTDV$G.
3. Total incremental cost equals incremental construction cost (post adoption) plus present value of incremental maintenance cost; $\Delta C = \Delta CI_{PA} + \Delta CM$.
4. Negative values indicate the measure is cost-effective. Change in lifecycle cost equals cost premium minus TDV energy cost savings; ΔLCC = ΔC – ΔTDV$
5. The benefit to cost ratio is the TDV energy costs savings divided by the total incremental costs; B/C = ΔTDV$ ÷ ΔC. The measure is cost effective if the B/C ratio is greater than 1.0.

Table 30: Cost-effectiveness Summary, High-rise Residential Wood-framed Roofs[1]

Climate Zone	Benefit: TDV Energy Cost Savings[2] (2017 PV$/SF)	Cost: Total Incremental Cost[3] (2017 PV$/SF)	Change in Lifecycle Cost[4] (2017 PV$)	Benefit to Cost Ratio[5]
Climate Zone 1	$5.79	$2.41	$3.39	2.41
Climate Zone 2	No change			
Climate Zone 3	$0.88	$0.44	$0.44	2.01
Climate Zone 4	No change			
Climate Zone 5	$1.05	$0.44	$0.61	2.39
Climate Zone 6	$0.59	$0.44	$0.15	1.33
Climate Zone 7	No change			
Climate Zone 8	No change			
Climate Zone 9	No change			
Climate Zone 10	No change			
Climate Zone 11	No change			
Climate Zone 12	No change			
Climate Zone 13	No change			
Climate Zone 14	No change			
Climate Zone 15	No change			
Climate Zone 16	No change			

1. Relative to existing conditions. All cost values presented in 2017 dollars.
2. Present value of TDV cost savings equals TDV electricity savings plus TDV natural gas savings; ΔTDV$ = ΔTDV$E + ΔTDV$G.
3. Total incremental cost equals incremental construction cost (post adoption) plus present value of incremental maintenance cost; $\Delta C = \Delta CI_{PA} + \Delta CM$.
4. Negative values indicate the measure is cost-effective. Change in lifecycle cost equals cost premium minus TDV energy cost savings; ΔLCC = ΔC – ΔTDV$
5. The benefit to cost ratio is the TDV energy costs savings divided by the total incremental costs; B/C = ΔTDV$ ÷ ΔC. The measure is cost effective if the B/C ratio is greater than 1.0.

Table 31: Cost-effectiveness Summary, High-rise Residential Steel Framed Walls

Climate Zone	Benefit: TDV Energy Cost Savings[2] (2017 PV$/SF)	Cost: Total Incremental Cost[3] (2017 PV$/SF)	Change in Lifecycle Cost[4] (2017 PV$)	Benefit to Cost Ratio[5]
Climate Zone 1	$ 0.68	$ 0.17	$ 0.51	4.00
Climate Zone 2	$ 0.68	$ 0.17	$ 0.51	4.00
Climate Zone 3	$ 0.54	$ 0.17	$ 0.37	3.18
Climate Zone 4	$ 0.43	$ 0.17	$ 0.26	2.50
Climate Zone 5	$ 0.44	$ 0.17	$ 0.27	2.62
Climate Zone 6	$ 0.25	$ 0.17	$ 0.08	1.44
Climate Zone 7	No Change	No change	No change	No change
Climate Zone 8	$ 0.32	$ 0.17	$ 0.15	1.86
Climate Zone 9	$ 0.49	$ 0.17	$ 0.32	2.86
Climate Zone 10	$ 0.52	$ 0.17	$ 0.35	3.04
Climate Zone 11	$ 0.73	$ 0.17	$ 0.56	4.32
Climate Zone 12	$ 0.73	$ 0.17	$ 0.56	4.29
Climate Zone 13	$ 0.69	$ 0.17	$ 0.52	4.07
Climate Zone 14	$ 0.69	$ 0.17	$ 0.52	4.07
Climate Zone 15	$ 1.81	$ 0.17	$ 1.64	10.67
Climate Zone 16	$ 0.82	$ 0.17	$ 0.65	4.83

1. Relative to existing conditions. All cost values presented in 2017 dollars.
2. Present value of TDV cost savings equals TDV electricity savings plus TDV natural gas savings; ΔTDV$ = ΔTDV$E + ΔTDV$G.
3. Total incremental cost equals incremental construction cost (post adoption) plus present value of incremental maintenance cost; $\Delta C = \Delta CI_{PA} + \Delta CM$.
4. Negative values indicate the measure is cost-effective. Change in lifecycle cost equals cost premium minus TDV energy cost savings; ΔLCC = ΔC – ΔTDV$
5. The benefit to cost ratio is the TDV energy costs savings divided by the total incremental costs; B/C = ΔTDV$ ÷ ΔC. The measure is cost effective if the B/C ratio is greater than 1.0.

Table 32: Cost-effectiveness Summary, Nonresidential Wood-framed Walls, 2016 TDV[1]

Climate Zone	Benefit: TDV Energy Cost Savings[2] (2017 PV$/SF)	Cost: Total Incremental Cost[3] (2017 PV$/SF)	Change in Lifecycle Cost[4] (2017 PV$)	Benefit to Cost Ratio[5]
Climate Zone 1	$0.148	$0.11	$0.04	1.35
Climate Zone 11	$0.69	$0.49	$0.20	1.41
All Other Climate Zones	n/a	n/a	n/a	n/a

1. Relative to existing conditions. All cost values presented in 2017 dollars.
2. Present value of TDV cost savings equals TDV electricity savings plus TDV natural gas savings; $\Delta TDV\$ = \Delta TDV\$E + \Delta TDV\$G$.
3. Total incremental cost equals incremental construction cost (post adoption) plus present value of incremental maintenance cost; $\Delta C = \Delta CI_{PA} + \Delta CM$.
4. Negative values indicate the measure is cost-effective. Change in lifecycle cost equals cost premium minus TDV energy cost savings; $\Delta LCC = \Delta C - \Delta TDV\$$
5. The benefit to cost ratio is the TDV energy costs savings divided by the total incremental costs; $B/C = \Delta TDV\$ \div \Delta C$. The measure is cost effective if the B/C ratio is greater than 1.0.

Table 33: U-factors and Assemblies – Nonresidential Metal-Building Roofs

	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
Current	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
Assembly	R-19	R-19	R-19	R-19	R-19	R-19	R-19	R-19
Proposed	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041
Assembly	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC

	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Current	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
Assembly	R-19	R-19	R-19	R-19	R-19	R-19	R-19	R-19
Proposed	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041
Assembly	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC

Table 34: U-factors and Assemblies – Nonresidential Wood-framed Roofs

	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
Current	0.049	0.039	0.039	0.039	0.049	0.075	0.067	0.039
Assembly	R-19	R-25	R-25	R-25	R-19	R-11	R-13	R-25
Proposed	0.034	0.034	0.034	0.034	0.034	0.049	0.049	NC
Assembly	R-30	R-30	R-30	R-30	R-30	R-19	R-19	Same

	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Current	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039
Assembly	R-25	R-25	R-25	R-25	R-25	R-25	R-25	R-25
Proposed	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034
Assembly	R-30	R-30	R-30	R-30	R-30	R-30	R-30	R-30

Table 35: U-factors and Assemblies – Nonresidential Metal-framed Walls

	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
Current	0.098	0.062	0.082	0.062	0.098	0.098	0.098	0.062
Assembly	R-8 c.i.	R-14 c.i.	R-10 c.i.	R-14 c.i.	R-8 c.i.	R-8 c.i.	R-8 c.i.	R-14 c.i.
Proposed	0.069	N.C.	N.C.	N.C.	N.C.	0.069	0.069	N.C
Assembly	R-12.4	R-14 c.i.	R-10 c.i.	R-14 c.i.	R-8 c.i.	R-12.4	R-12.4	R-14 c.i.

	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Current	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062
Assembly	R-14 c.i.	R-14 c.i.	R-14 c.i.	R-14 c.i.	R-14 c.i.	R-14 c.i.	R-13+R-14 c.i.	R-14 c.i.
Proposed	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.
Assembly	R-12.4	R-12.4	R-12.4	R-12.4	R-12.4	R-12.4	R-12.4	R-12.4

Table 36: U-factors and Assemblies – Nonresidential Wood-framed Walls

	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
Current	0.102	0.059	0.110	0.059	0.102	0.110	0.110	0.102
Assembly	R-13	R-13+R-7 c.i.	R-11	R-14 c.i.	R-13	R-11	R-11	R-13
Proposed	0.095	N.C.	N.C.	N.C.	N.C	N.C	N.C	N.C
Assembly	R-15	same	same	same	same	same	same	same

	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Current	0.059	0.059	0.059	0.059	0.059	0.059	0.042	0.059
Assembly	R-13+R-7 c.i.	R-13+R-7 c.i.	R-13+R-7 c.i.	R-13+R-7 c.i.	R-13+R-7 c.i.	R-13+R-7 c.i.	R-13+R-14 c.i.	R-13+R-7 c.i.
Proposed	N.C	*0.045**	0.045	N.C	N.C	N.C	N.C	N.C
Assembly	Same	R-13+R-12.4 c.i.	R-13+R-12.4 c.i.	same	R-13+R-12.4 c.i.	R-13+R-12.4 c.i.	R-13+R-12.4 c.i.	R-13+R-12.4 c.i.

Table 37: U-factors and Assemblies – High-rise Residential Metal-framed Roofs

	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
Current	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
Assembly	R-19	R-19	R-19	R-19	R-19	R-19	R-19	R-19
Proposed	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041
Assembly	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC

	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Current	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
Assembly	R-19	R-19	R-19	R-19	R-19	R-19	R-19	R-19
Proposed	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041
Assembly	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC	R-19+ R-10 FC

Table 38: U-factors and Assemblies – High-rise Residential Metal-framed Walls

	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
Current	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105
Assembly	R-13+ R-5 c.i.	R-13+ R-5 c.i.	R-13+ R-5 c.i.	R-13+ R-5 c.i.	R-13+ R-5 c.i.	R-13+ R-5 c.i.	R-13+ R-5 c.i.	R-13+ R-5 c.i.
Proposed	0.069	0.069	0.069	0.069	0.069	0.069	N.C.	0.069
Assembly	R-12.4 ci	R-12.4 ci	R-12.4 ci	R-12.4 ci	R-12.4 ci	R-12.4 ci	Same	R-12.4 ci

	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Current	0.105	0.105	0.105	0.105	0.105	0.105	0.105	0.105
Assembly	R-13+ R-5 c.i.	R-13+ R-5 c.i.	R-13+ R-5 c.i.	R-13+ R-5 c.i.	R-13+ R-5 c.i.	R-13+ R-5 c.i.	R-13+ R-5 c.i.	R-13+ R-5 c.i.
Proposed	0.069	0.069	0.069	0.069	0.069	0.069	0.048	0.069
Assembly	R-12.4 ci	R-12.4 ci	R-12.4 ci	R-12.4 ci	R-12.4 ci	R-12.4 ci	R-18.6	R-12.4 ci

Table 39: U-factors and Assemblies – High-rise Residential Wood-framed Walls

	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8
Current	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059
Assembly	R-13+R-7 c.i.	R-13+R-7 c.i.	R-13+R-7 c.i.	R-13+R-7 c.i.	R-13+R-7 c.i.	R-13+R-7 c.i.	R-13+R-7 c.i.	R-13+R-7 c.i.
Proposed	N.C.	N.C.	N.C.	N.C.	N.C	N.C	N.C	N.C
Assembly	same	same	same	same	same	same	same	same

	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Current	0.059	0.059	0.042	0.059	0.059	0.042	0.042	0.042
Assembly	R-13+R-7 c.i.	R-13+R-7 c.i.	R-13+R-7 c.i.	R-13+R-7 c.i.	R-13+R-7 c.i.	R-13+R-7 c.i.	R-13+R-14 c.i.	R-13+R-7 c.i.
Proposed	N.C	*NC*	NC	N.C	N.C	N.C	N.C	N.C
Assembly	same	same	same	same	same	same	same	same

5.3 Environmental Impacts Results

5.3.1 Greenhouse Gas Emissions Results

Table 40 presents the estimated first year avoided GHG emissions of the proposed code change. During the first year the 2016 Standards are in effect the proposed measure will result in avoided GHG emissions of 5,035 $MTCO_2e$. The monetary value of avoided GHG emissions is included in TDV cost factors (TDV $) for each hour of the year and thus included in the Cost-effectiveness Analysis presented in this report.

Table 40: Estimated First Year Statewide Greenhouse Gas Emissions Impacts

	Avoided GHG Emissions[1] ($MTCO_2e$/yr)
Nonresidential	4,942
High-Rise Res	93
TOTAL	5,035

1. First year savings from buildings built in 2017; assumes 353 $MTCO_2e$/GWh and 5,303 $MTCO_2e$/MMTherms.

5.3.2 Water Use and Water Quality Impacts

Impacts on water use and water quality are presented in Table 41. No significant water savings are expected from this measure. A reduction in cooling energy use for large buildings with water-cooled central plants will reduce water use slightly, by reducing cooling tower energy use. The Statewide CASE Team did not assess the quantitative impact of water savings.

Table 41: Impacts of Water Use and Water Quality

	On-Site Water Savings[1] (gallons/yr)	Embedded Energy Savings[2] (kWh/yr)	Impact on Water Quality Material Increase (I), Decrease (D), or No Change (NC) compared to existing conditions			
			Mineralization (calcium, boron, and salts)	Algae or Bacterial Buildup	Corrosives as a Result of PH Change	Others
Impact (I, D, or NC)	D	D	NC	NC	NC	NC
Per Unit Impacts[3]			NC	NC	NC	NC
Statewide Impacts (first year)			NC	NC	NC	NC
Comment on reasons for your impact assessment	Cooling Tower Water Savings for select building types (large office, hotels)					

1. Does not include water savings at power plant
2. Assumes embedded energy factor of 10,045 kWh per million gallons of water.
3. Specify the type of unit such as per building, per square foot, per prototype building. For description of prototype buildings refer to Methodology section below.

5.3.3 Material Impacts Results (Optional)

The Statewide CASE Team did not assess the quantitative material impacts. The main material impacts of this measure would be a potential increase in the use of continuous insulation products (rigid polyisocyanurate and rigid EPS insulation). The agents used in manufacturing those products would likely be in greater use due to insulation requirements.

5.3.4 Other Impacts Results

Increased continuous insulation should improve occupant comfort by moderating the interior surface temperatures of walls and ceilings. Also, it can have a secondary impact of reducing cooling and heating loads to the extent that it allows for downsizing of HVAC equipment, resulting in capital cost savings. (Note that these savings are variable, depending on project, and not included in cost estimates.) Another potential benefit is the reduction in air infiltration, when specifying continuous insulation.

6. PROPOSED LANGUAGE

The proposed changes to the Standards, Reference Appendices, and the ACM Reference Manuals are provided below. Changes to the 2013 documents are marked with underlining (new language) and ~~strikethroughs~~ (deletions).

6.1 Standards

The Standards change primarily involves section 140.3 of the Standards.

SECTION 140.3 – PRESCRIPTIVE REQUIREMENTS FOR BUILDING ENVELOPES

A building complies with this section by being designed with and having constructed and installed either: (1) A building complies with this section by being designed with and having constructed and installed either: (1) envelope components that comply with each of the requirements in Subsection (a) for each individual component and the requirements of Subsection (c) where they apply; or (2) an envelope that complies with the overall requirements in Subsection (b) and the requirements of Subsection (c) where they apply.

(a) **Envelope Component Approach.**

1. **Exterior roofs and ceilings.** Exterior roofs and ceilings shall comply with each of the applicable requirements in this subsection:

   A. **Roofing Products.** Shall meet the requirements of Section 110.8 and the applicable requirements of Subsections i through ii:

      i. Nonresidential buildings:

         a. Low-sloped roofs in climate zones 1 through 16 shall have:

            1. A minimum aged solar reflectance of 0.63 and a minimum thermal emittance of 0.75; or

            2. A minimum Solar Reflectance Index (SRI) of 75.

            EXCEPTION 1 to Section 140.3(a)1Aia: Wood-framed roofs in climate zones 3 and 5 are exempt from the requirements of Section 140.3(a)1Aia if the roof assembly has a U-factor of ~~0.039~~ 0.034 or lower.

            ~~**EXCEPTION 2 to Section 140.3(a)1Aia:** Metal building roofs in climate zones 3 and 5 are exempt from the requirements if the roof assembly has a U-factor of 0.048 or lower.~~

            EXCEPTION ~~3~~ 2 to Section 140.3(a)1Aia: Roof constructions that have thermal mass with a weight of at least 25 lb/ft² over the roof membrane are exempt from the requirements of Section 140.3(a)1Aia.

            EXCEPTION ~~4~~ 3 to SECTION 140.3(a)1Aia: An aged solar reflectance less than 0.63 is allowed provided the maximum roof/ceiling U-factor in TABLE 140.3 is not exceeded.

         b. Steep-sloped roofs in climate zones 1 through 16 shall have a minimum aged solar reflectance of 0.20 and a minimum thermal emittance of 0.75, or a minimum SRI of 16.

      ii. High-rise residential buildings and hotels and motels:

         a. Low-sloped roofs in climate zones 10, 11, 13, 14 and 15 shall have a minimum aged solar reflectance of 0.55 and a minimum thermal emittance of 0.75, or a minimum SRI of 64.

EXCEPTION to Section 140.3(a)1Aiia: Roof constructions that have thermal mass with a weight of at least 25 lb/ft² over the roof membrane .

b. Steep-sloped roofs in climate zones 2 through 15 shall have a minimum aged solar reflectance of 0.20 and a minimum thermal emittance of 0.75, or a minimum SRI of 16.

~~TABLE 140.3 ROOF/CEILING INSULATION TRADEOFF FOR AGED SOLAR REFLECTANCE~~

~~Nonresidential~~					
~~Aged Solar Reflectance~~	~~Metal Building Climate Zone 1-16 U-factor~~	~~Wood framed and Other Climate Zone 1 &5 U-factor~~	~~Wood Framed and Other Climate Zone 2-4, 9-16 U-factor~~	~~Wood Framed and Other, Climate Zone 6 U-factor~~	~~Wood Framed and Other Climate Zone 7 & 8 U-factor~~
~~0.62-0.60~~	~~0.061~~	~~0.045~~	~~0.036~~	~~0.065~~	~~0.059~~
~~0.59-0.55~~	~~0.054~~	~~0.041~~	~~0.034~~	~~0.058~~	~~0.053~~
~~0.54-0.50~~	~~0.049~~	~~0.038~~	~~0.032~~	~~0.052~~	~~0.048~~
~~0.49-0.45~~	~~0.047~~	~~0.035~~	~~0.030~~	~~0.047~~	~~0.044~~
~~0.44-0.40~~	~~0.043~~	~~0.033~~	~~0.028~~	~~0.043~~	~~0.040~~
~~0.39-0.35~~	~~0.039~~	~~0.031~~	~~0.027~~	~~0.039~~	~~0.037~~
~~0.34-0.30~~	~~0.035~~	~~0.029~~	~~0.025~~	~~0.037~~	~~0.035~~
~~0.29-0.25~~	~~0.033~~	~~0.027~~	~~0.024~~	~~0.034~~	~~0.032~~

TABLE 140.3 ROOF/CEILING INSULATION TRADEOFF FOR AGED SOLAR REFLECTANCE

Aged Solar Reflectance	Metal Building Climate Zone 1-16 U-factor	Wood-Framed and Other Climate Zone 6 & 7 U-factor	Wood-Framed and Other Climate Zones 1-2, 8-16 U-factor
0.62-0.56	0.041	0.049	0.034
0.55-0.46	0.038	0.045	0.032
0.45-0.36	0.036	0.043	0.031
0.35-0.25	0.035	0.042	0.028

EXCEPTION to Section 140.3(a)1A: Roof area covered by building integrated photovoltaic panels and building integrated solar thermal panels are not required to meet the minimum requirements for solar reflectance, thermal emittance, or SRI.

B. **Roof Insulation.** Roofs shall have an overall assembly U-factor no greater than the applicable value in TABLE 140.3-B, C or D, and where required by Section 110.8(e), insulation shall be placed in direct contact with a continuous roof or drywall ceiling.

2. **Exterior Walls.** Exterior walls shall have an overall assembly U-factor no greater than the applicable value in TABLE 140.3-B, C or D.

3. **Demising Walls.** Demising walls shall meet the requirements of Section 110.8(f).

4. **Exterior Floors and Soffits.** Exterior floors and soffits shall have an overall assembly U-factor no greater than the applicable value in TABLE 140.3-B, C or D.

… {section of code omitted} …

TABLE 140.3-B – PRESCRIPTIVE ENVELOPE CRITERIA FOR NONRESIDENTIAL BUILDINGS (INCLUDING RELOCATABLE PUBLIC SCHOOL BUILDINGS WHERE MANUFACTURER CERTIFIES USE ONLY IN SPECIFIC CLIMATE ZONE; NOT INCLUDING HIGH-RISE RESIDENTIAL BUILDINGS AND GUEST ROOMS OF HOTEL/MOTEL BUILDINGS)

				Climate Zone															
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Envelope	**Maximum U-factor**	**Roofs/ Ceilings**	Metal Building	~~0.065~~ 0.041	~~0.065~~ 0.041	~~0.065~~ 0.041	~~0.065~~ 0.041	~~0.065~~ 0.041	~~0.065~~ 0.041	~~0.065~~ 0.041	~~0.065~~ 0.041	~~0.065~~ 0.041	~~0.065~~ 0.041	~~0.065~~ 0.041	~~0.065~~ 0.041	~~0.065~~ 0.041	~~0.065~~ 0.041	~~0.065~~ 0.041	~~0.065~~ 0.041
			Wood Framed and Other	~~0.049~~ 0.034	~~0.039~~ 0.034	~~0.039~~ 0.034	~~0.039~~ 0.034	~~0.049~~ 0.034	~~0.075~~ 0.049	~~0.067~~ 0.049	0.067	~~0.039~~ 0.034	~~0.039~~ 0.034	~~0.039~~ 0.034	~~0.039~~ 0.034	~~0.039~~ 0.034	~~0.039~~ 0.034	~~0.039~~ 0.034	~~0.039~~ 0.034
		Walls	Metal Building	0.113	0.061	0.113	0.061	0.061	0.113	0.113	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.057	0.061
			Metal-framed	0.098 0.069	0.062	0.082	0.062	0.062	~~0.098~~ 0.069	~~0.098~~ 0.069	0.062	0.062	0.062	0.062	0.062	0.062	0.062	~~0.062~~ 0.057	0.062
			Mass Light[1]	~~0.196~~ 0.170	0.170	~~0.278~~ 0.170	~~0.227~~ 0.170	~~0.440~~ 0.170	~~0.440~~ 0.227	~~0.440~~ 0.227	~~0.440~~ 0.227	0.440	0.170	0.170	0.170	0.170	0.170	0.170	0.170
			Mass Heavy[1]	~~0.253~~ 0.160	~~0.650~~ 0.160	~~0.650~~ 0.160	~~0.650~~ 0.184	~~0.650~~ 0.211	0.690	0.690	0.690	0.690	0.650	0.184	0.253	0.211	0.184	0.184	0.160
			Wood-framed and Other	~~0.102~~ 0.095	0.059	0.110	0.059	0.102	0.110	0.110	0.102	0.059	0.059	~~0.059~~ 0.045	0.059	0.059	0.059	0.042	0.059
		Floors/ Soffits	Mass	0.092	0.092	0.269	0.269	0.269	0.269	0.269	0.269	0.269	0.269	0.092	0.092	0.092	0.092	0.092	0.058
			Other	0.048	0.039	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.039	0.071	0.071	0.039	0.039	0.039
	Roofing Products	**Low-sloped**	Aged Solar Reflectance	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
			Thermal Emittance	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
		Steep-Sloped	Aged Solar Reflectance	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
			Thermal Emittance	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0. 75	0.75	0.75	0.75	0.75	0.75	0.75
	Air Barrier			NR	NR	NR	NR	NR	NR	NR	NR	NR	REQ	REQ	REQ	REQ	REQ	REQ	REQ
	Exterior Doors, Maximum U-factor	Non-Swinging		0.50	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	0.50
		Swinging		0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70

… section of code omitted} …

TABLE 140.3-C – PRESCRIPTIVE ENVELOPE CRITERIA FOR HIGH-RISE RESIDENTIAL BUILDINGS AND GUEST ROOMS OF HOTEL/MOTEL BUILDINGS

				Climate Zone															
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Envelope	**Maximum U-factor**	**Roofs/ Ceilings**	Metal Building	~~0.065~~ 0.041	~~0.065~~ 0.041	~~0.065~~ 0.041	~~0.065~~ 0.041	~~0.065~~ 0.041	~~0.065~~ 0.041	~~0.065~~ 0.041	~~0.065~~ 0.041	~~0.065~~ 0.041	~~0.065~~ 0.041	~~0.065~~ 0.041	~~0.065~~ 0.041	~~0.065~~ 0.041	~~0.065~~ 0.041	~~0.065~~ 0.041	~~0.065~~ 0.041
			Wood Framed and Other	~~0.034~~ 0.028	0.028	~~0.039~~ 0.034	0.028	~~0.039~~ 0.034	~~0.039~~ 0.034	0.039	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028
		Walls	Metal Building	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061
			Metal-framed	~~0.105~~ 0.069	~~0.105~~ 0.069	~~0.105~~ 0.069	~~0.105~~ 0.069	~~0.105~~ 0.069	~~0.105~~ 0.069	0.105	~~0.105~~ 0.069	~~0.105~~ 0.069	~~0.105~~ 0.069	~~0.105~~ 0.069	~~0.105~~ 0.069	~~0.105~~ 0.069	~~0.105~~ 0.069	~~0.105~~ 0.048	~~0.105~~ 0.069
			Mass Light[1]	0.170	0.170	0.170	0.170	0.170	0.227	0.227	0.227	0.196	0.170	0.170	0.170	0.170	0.170	0.170	0.170
			Mass Heavy[1]	0.160	0.160	0.160	0.184	0.211	0.690	0.690	0.690	0.690	0.690	0.184	0.253	0.211	0.184	0.184	0.160
			Wood-framed and Other	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.042	0.059	0.059	0.042	0.042	0.042
		Floors/ Soffits	Mass	0.045	0.045	0.058	0.058	0.058	0.069	0.092	0.092	0.092	0.069	0.058	0.058	0.058	0.045	0.058	0.037
			Other	0.034	0.034	0.039	0.039	0.039	0.039	0.071	0.039	0.039	0.039	0.039	0.039	0.039	0.034	0.039	0.034
	Roofing Products	**Low-sloped**	Aged Solar Reflectance	NR	NR	NR	NR	NR	NR	NR	NR	0.55	0.55	0.55	NR	0.55	0.55	0.55	NR
			Thermal Emittance	NR	NR	NR	NR	NR	NR	NR	NR	0.75	0.75	0.75	NR	0.75	0.75	0.75	NR
		Steep-Sloped	Aged Solar Reflectance	NR	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	NR
			Thermal Emittance	NR	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0. 75	0.75	0.75	0.75	0.75	0.75	NR
	Exterior Doors, Maximum U-factor		Non-Swinging	0.50	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	0.50
			Swinging	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70

6.2 Reference Appendices

There are no proposed changes to the Reference Appendices, other than to add a new construction to the metal building roofs table, Reference Appendix JA4, Table 4.2.7, to accommodate the proposed prescriptive requirement for the filled cavity insulation method for metal building roofs, U-factor of 0.041. This assembly and U-factor is included in ASHRAE 90.1-2013, and the performance level of 0.041 U-factor matches published data from NAIMA for metal building roofs.

6.3 ACM Reference Manual

The Nonresidential ACM Reference Manual will be revised so that the standard design construction assemblies for nonresidential roofs match the recommended U-factors and corresponding assemblies for wood-framed and other roofs. The nonresidential wall U-factors will be updated to match the recommended U-factors for metal-framed walls.

6.4 Compliance Manuals

Chapter 3 of the Nonresidential Compliance Manual will need to be revised. New compliance forms are not required for this measure.

6.5 Compliance Forms

No significant changes are expected to compliance forms for 2016, due to this measure.

7. REFERENCES AND OTHER RESEARCH

The primary references for the research used to determine proposed code changes includes 2013 Title 24 Standards documents, RS Means Costworks, distributor surveys and product literature from the North American Insulation Manufacturers Association (NAIMA).

[ASHRAE] American Society of Heating, Refrigerating and Air Conditioning Engineers Energy Standard for Buildings except Low-Rise Residential Buildings (ASHRAE 90.1-2013), February 2014.

[CARB] California Air Resources Board. 2010. "Proposed Regulation for a California Renewable Electricity Standard Staff Report: Initial Statement of Reasons Appendix D." http://www.arb.ca.gov/regact/2010/res2010/res10d.pdf. Accessed November 12, 2013.

__. 2011a. California Air Resources Board. "Appendix C: Cost Effectiveness Calculation Methodology." March 10. http://www.arb.ca.gov/msprog/moyer/guidelines/2011gl/appc_3_10_11.pdf.

__. 2011b. "Emission Reduction Offsets Transaction Cost Summary Report for 2011." http://www.arb.ca.gov/nsr/erco/erco.htm.

__. 2012. "Emission Reduction Offsets Transaction Cost Summary Report for 2012." http://www.arb.ca.gov/nsr/erco/erco.htm.

__. 2013a. "Mail-Out #MSC 13-09." March 25. http://www.arb.ca.gov/msprog/mailouts/msc1309/msc1309.pdf.

__. 2013b. "California Air Resources Board Quarterly Auction 3, May 2013 – Summary Results Report." http://www.arb.ca.gov/cc/capandtrade/auction/may-2013/results.pdf.

[CEC] California Energy Commission. 2011. "Life-Cycle Cost Methodology: 2013 California Building Energy Efficiency Standards. July 2011. http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/general_cec_documents/2011-01-14_LCC_Methodology_2013.pdf. Accessed August 2014.

___. 2014. "Time Dependent Valuation of Energy for Developing Building Efficiency Standards: 2016 Time Dependent Valuation (TDV) Data Sources and Inputs." July 2014. http://www.energy.ca.gov/title24/2016standards/prerulemaking/documents/2014-07-09_workshop/2017_TDV_Documents/Title24_2016_TDV_Methodology_Report%20v3.docx. Accessed July 2014.

RS Means, Costworks. Building Construction and Cost Data. 2014.

Pacific Gas & Electric, 2007. Final Report, Insulation Requirements, Codes and Standards Enhancement Initiative for the 2008 Title 24 Building Energy Efficiency Standards, March 2007.

Appendix A: Environmental Impacts Methodology

Greenhouse Gas Emissions Impacts Methodology

Greenhouse Gas Emissions Impacts Methodology

The avoided GHG emissions were calculated assuming an emission factor of 353 metric tons of carbon dioxide equivalents ($MTCO_2e$) per GWh of electricity savings. The Statewide CASE Team calculated air quality impacts associated with the electricity savings from the proposed measure using emission factors that indicate emissions per GWh of electricity generated.[1] When evaluating the impact of increasing the Renewable Portfolio Standard (RPS) from 20 percent renewables by 2020 to 33 percent renewables by 2020, California Air Resources Board (CARB) published data on expected air pollution emissions for various future electricity generation scenarios (CARB 2010). The Statewide CASE Team used data from CARB's analysis to inform the air quality analysis presented in this report.

The GHG emissions factor is a projection for 2020 assuming the state will meet the 33 percent RPS goal. CARB calculated the emissions for two scenarios: (1) a high load scenario in which load continues at the same rate; and (2) a low load rate that assumes the state will successfully implement energy efficiency strategies outlined in the AB32 scoping plan thereby reducing overall electricity load in the state.

To be conservative, the Statewide CASE Team calculated the emissions factors of the incremental electricity between the low and high load scenarios. These emission factors are intended to provide a benchmark of emission reductions attributable to energy efficiency measures that could help achieve the low load scenario. The incremental emissions were calculated by dividing the difference between California emissions in the high and low generation forecasts by the difference between total electricity generated in those two scenarios. While emission rates may change over time, 2020 was considered a representative year for this measure.

Avoided GHG emissions from natural gas savings were calculated using an emission factor of 5,303 $MTCO_2e$/million therms (U.S. EPA 2011).

Water Use and Water Quality Impacts Methodology

There are no water impacts associated with this measure.

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[1] California power plants are subject to a GHG cap and trade program and linked offset programs until 2020 and potentially beyond.

APPENDIX B: SIMULATION RESULTS DETAILS

Table 42: Medium Retail Wall Parametric Results

Filename	Weather Station	Roof U	Wall U	Comp Total	Slope	Constant
RetlMed-WallTest-CZ1a	ARCATA_725945	0.065	0.098	116.03	72.0833	108.9952
RetlMed-WallTest-CZ1b	ARCATA_725945	0.065	0.062	113.536		
RetlMed-WallTest-CZ1c	ARCATA_725945	0.065	0.037	111.62		
RetlMed-WallTest-CZ2a	SANTA-ROSA_724957	0.065	0.098	196.493	81.67901	188.5034
RetlMed-WallTest-CZ2b	SANTA-ROSA_724957	0.065	0.062	193.604		
RetlMed-WallTest-CZ2c	SANTA-ROSA_724957	0.065	0.037	191.504		
RetlMed-WallTest-CZ3a	OAKLAND_724930	0.065	0.098	146.972	58.63772	141.2485
RetlMed-WallTest-CZ3b	OAKLAND_724930	0.065	0.062	144.94		
RetlMed-WallTest-CZ3c	OAKLAND_724930	0.065	0.037	143.385		
RetlMed-WallTest-CZ4a	SAN-JOSE-REID_724946	0.065	0.098	192.427	71.23148	185.4551
RetlMed-WallTest-CZ4b	SAN-JOSE-REID_724946	0.065	0.062	189.893		
RetlMed-WallTest-CZ4c	SAN-JOSE-REID_724946	0.065	0.037	188.078		
RetlMed-WallTest-CZ5a	SANTA-MARIA_723940	0.065	0.098	141.827	54.83605	136.4644
RetlMed-WallTest-CZ5b	SANTA-MARIA_723940	0.065	0.062	139.892		
RetlMed-WallTest-CZ5c	SANTA-MARIA_723940	0.065	0.037	138.477		
RetlMed-WallTest-CZ6a	TORRANCE_722955	0.065	0.098	180.539	57.27065	174.9412
RetlMed-WallTest-CZ6b	TORRANCE_722955	0.065	0.062	178.528		
RetlMed-WallTest-CZ6c	TORRANCE_722955	0.065	0.037	177.039		
RetlMed-WallTest-CZ7a	SAN-DIEGO-LINDBERGH_722900	0.065	0.098	168.036	46.19302	163.5073
RetlMed-WallTest-CZ7b	SAN-DIEGO-LINDBERGH_722900	0.065	0.062	166.367		
RetlMed-WallTest-CZ7c	SAN-DIEGO-LINDBERGH_722900	0.065	0.037	165.219		
RetlMed-WallTest-CZ8a	FULLERTON_722976	0.065	0.098	204.407	68.03527	197.746
RetlMed-WallTest-CZ8b	FULLERTON_722976	0.065	0.062	201.98		
RetlMed-WallTest-CZ8c	FULLERTON_722976	0.065	0.037	200.254		
RetlMed-WallTest-CZ9a	BURBANK-GLENDALE_722880	0.065	0.098	231.422	88.19089	222.7915
RetlMed-WallTest-CZ9b	BURBANK-GLENDALE_722880	0.065	0.062	228.289		

RetlMed-WallTest-CZ9c	BURBANK-GLENDALE_722880	0.065	0.037	226.037		
RetlMed-WallTest-CZ10a	RIVERSIDE_722869	0.065	0.098	237.041	93.65509	227.872
RetlMed-WallTest-CZ10b	RIVERSIDE_722869	0.065	0.062	233.701		
RetlMed-WallTest-CZ10c	RIVERSIDE_722869	0.065	0.037	231.324		
RetlMed-WallTest-CZ11a	RED-BLUFF_725910	0.065	0.098	249.877	127.2597	237.4173
RetlMed-WallTest-CZ11b	RED-BLUFF_725910	0.065	0.062	245.336		
RetlMed-WallTest-CZ11c	RED-BLUFF_725910	0.065	0.037	242.109		
RetlMed-WallTest-CZ12a	SACRAMENTO-METRO_724839	0.065	0.098	232.125	65.12513	225.3231
RetlMed-WallTest-CZ12b	SACRAMENTO-METRO_724839	0.065	0.062	228.337		
RetlMed-WallTest-CZ12c	SACRAMENTO-METRO_724839	0.065	0.037	225.225		
RetlMed-WallTest-CZ13a	FRESNO_723890	0.065	0.098	254.669	126.7013	242.2709
RetlMed-WallTest-CZ13b	FRESNO_723890	0.065	0.062	250.172		
RetlMed-WallTest-CZ13c	FRESNO_723890	0.065	0.037	246.932		
RetlMed-WallTest-CZ14a	PALMDALE_723820	0.065	0.098	247.382	130.4275	234.5749
RetlMed-WallTest-CZ14b	PALMDALE_723820	0.065	0.062	242.6		
RetlMed-WallTest-CZ14c	PALMDALE_723820	0.065	0.037	239.437		
RetlMed-WallTest-CZ15a	PALM-SPRINGS-INTL_722868	0.065	0.098	322.8	166.1425	306.5346
RetlMed-WallTest-CZ15b	PALM-SPRINGS-INTL_722868	0.065	0.062	316.876		
RetlMed-WallTest-CZ15c	PALM-SPRINGS-INTL_722868	0.065	0.037	312.658		
RetlMed-WallTest-CZ16a	BLUE-CANYON_725845	0.065	0.098	190.573	148.394	175.9871
RetlMed-WallTest-CZ16b	BLUE-CANYON_725845	0.065	0.062	185.082		
RetlMed-WallTest-CZ16c	BLUE-CANYON_725845	0.065	0.037	181.54		

Table 43: Medium Retail Roof Parametric Results

Filename	Weather Station	Wall U	Roof U	Comp Total	Slope	Const
RetlMed-RoofTest-CZ1a	ARCATA_725945	0.098	0.097	119.992	133.9827	107.0417
RetlMed-RoofTest-CZ1b	ARCATA_725945	0.098	0.060	115.18		
RetlMed-RoofTest-CZ1c	ARCATA_725945	0.098	0.028	110.74		
RetlMed-RoofTest-CZ2a	SANTA-ROSA_724957	0.062	0.097	199.917	211.8980	179.408
RetlMed-RoofTest-CZ2b	SANTA-ROSA_724957	0.062	0.060	192.219		
RetlMed-RoofTest-CZ2c	SANTA-ROSA_724957	0.062	0.028	185.289		
RetlMed-RoofTest-CZ3a	OAKLAND_724930	0.082	0.097	150.213	138.2193	136.8305
RetlMed-RoofTest-CZ3b	OAKLAND_724930	0.082	0.060	145.177		
RetlMed-RoofTest-CZ3c	OAKLAND_724930	0.082	0.028	140.672		
RetlMed-RoofTest-CZ4a	SAN JOSE	0.062	0.097	195.696	193.2938	176.9895
RetlMed-RoofTest-CZ4b	SAN JOSE	0.062	0.060	188.68		
RetlMed-RoofTest-CZ4c	SAN JOSE	0.062	0.028	182.352		
RetlMed-RoofTest-CZ5a	SANTA-MARIA_723940	0.062	0.097	143.625	126.7189	131.355
RetlMed-RoofTest-CZ5b	SANTA-MARIA_723940	0.062	0.060	139.005		
RetlMed-RoofTest-CZ5c	SANTA-MARIA_723940	0.062	0.028	134.878		
RetlMed-RoofTest-CZ6a	TORRANCE_722955	0.098	0.097	185.843	173.5173	169.0138
RetlMed-RoofTest-CZ6b	TORRANCE_722955	0.098	0.060	179.429		
RetlMed-RoofTest-CZ6c	TORRANCE_722955	0.098	0.028	173.87		
RetlMed-RoofTest-CZ7a	SAN-DIEGO-LINDBERGH_722900	0.098	0.097	172.644	150.4894	158.0288

RetlMed-RoofTest-CZ7b	SAN-DIEGO-LINDBERGH_722900	0.098	0.060	167.02		
RetlMed-RoofTest-CZ7c	SAN-DIEGO-LINDBERGH_722900	0.098	0.028	162.263		
RetlMed-RoofTest-CZ8a	FULLERTON_722976	0.062	0.097	208.353	208.4831	188.1472
RetlMed-RoofTest-CZ8b	FULLERTON_722976	0.062	0.060	200.693		
RetlMed-RoofTest-CZ8c	FULLERTON_722976	0.062	0.028	193.965		
RetlMed-RoofTest-CZ9a	BURBANK-GLENDALE_722880	0.062	0.097	235.999	249.8683	211.7751
RetlMed-RoofTest-CZ9b	BURBANK-GLENDALE_722880	0.062	0.060	226.796		
RetlMed-RoofTest-CZ9c	BURBANK-GLENDALE_722880	0.062	0.028	218.756		
RetlMed-RoofTest-CZ10a	RIVERSIDE_722869	0.062	0.097	241.544	250.8070	217.1986
RetlMed-RoofTest-CZ10b	RIVERSIDE_722869	0.062	0.060	232.21		
RetlMed-RoofTest-CZ10c	RIVERSIDE_722869	0.062	0.028	224.241		
RetlMed-RoofTest-CZ11a	RED-BLUFF_725910	0.062	0.097	255.051	310.71778	224.9144
RetlMed-RoofTest-CZ11b	RED-BLUFF_725910	0.062	0.060	243.564		
RetlMed-RoofTest-CZ11c	RED-BLUFF_725910	0.062	0.028	233.611		
RetlMed-RoofTest-CZ12a	SACRAMENTO-METRO_724839	0.062	0.097	236.529	269.2898	210.4591
RetlMed-RoofTest-CZ12b	SACRAMENTO-METRO_724839	0.062	0.060	226.727		
RetlMed-RoofTest-CZ12c	SACRAMENTO-METRO_724839	0.062	0.028	217.94		
RetlMed-RoofTest-CZ13a	FRESNO_723890	0.062	0.097	260.589	334.8982	228.1296
RetlMed-RoofTest-CZ13b	FRESNO_723890	0.062	0.060	248.279		
RetlMed-RoofTest-CZ13c	FRESNO_723890	0.062	0.028	237.477		
RetlMed-RoofTest-	PALMDALE_723820	0.062	0.097	253.123	326.2677	221.3888

CZ14a						
RetlMed-RoofTest-CZ14b	PALMDALE_723820	0.062	0.060	240.779		
RetlMed-RoofTest-CZ14c	PALMDALE_723820	0.062	0.028	230.624		
RetlMed-RoofTest-CZ15a	PALM-SPRINGS-INTL_722868	0.062	0.097	329.596	401.3113	290.6401
RetlMed-RoofTest-CZ15b	PALM-SPRINGS-INTL_722868	0.062	0.060	314.657		
RetlMed-RoofTest-CZ15c	PALM-SPRINGS-INTL_722868	0.062	0.028	301.91		
RetlMed-RoofTest-CZ16a	BLUE-CANYON_725845	0.062	0.097	194.743	311.1893	164.5317
RetlMed-RoofTest-CZ16b	BLUE-CANYON_725845	0.062	0.060	183.147		
RetlMed-RoofTest-CZ16c	BLUE-CANYON_725845	0.062	0.028	173.275		

The energy costs and total lifecycle costs are calculated by:

$$\text{LCCtotal} = \text{LCCfirst} + \text{LCCmaint} + \text{LCCenergy}$$

The energy cost is estimated from the regressions by:

$$\text{TDVenergy} = \text{slope x U-factor} + \text{const}$$

The TDV energy is then converted to present value dollars by:

$$\text{LCCenergy} = \text{TDVenergy (kTDV/SF floor area) x floor area / wall-or-roof area x PV\_TDV}$$

The PV_TDV conversion factor converts TDV to present value dollars. The lifecycle costs, in dollars per square foot of component area, is then calculated as the sum of the three terms above. For this analysis, maintenance costs are unlikely to be significant.

Appendix C: Prototype Summary for Energy Savings Estimates

The primary prototype for the nonresidential analysis is a medium retail building, a prototype building originally developed by DOE, and adjusted so that all inputs for building envelope, lighting and HVAC exactly match the minimum prescriptive requirements of Title 24-2013. As an alternative to the retail building, a sensitivity test was performed by adjusting both the internal gains of a building to that of a Title 24-compliant office building, and by adjusting the occupant schedules to reflect an office schedule.

The hotel building, a four-story building with guestrooms and a variety of common spaces, is served by a four-pipe fan coil system. The details of these systems are shown in the table below.

Table 44: Summary of Prototype Building

Geometry	Medium Retail Building	Hotel Building
Total Floor Area (square feet)	24,692 SF (178.05 ft X 138.68 ft)	43,200 (180 ft x 60 ft)
Conditioned Floor Area	24,563 SF	42.554 SF
Aspect Ratio	1.29	3
Number of Floors	1	4
Azimuth	0	0
Thermal Zoning	Five zones: Back Space, Core Retail, Front Entry, Front Retail, Point of Sale	Ground Floor: 19 zones including guest rooms, lobby, office space, meeting room, laundry room, employee lounge, restrooms, exercise room, mechanical room, corridor, stairs, storage; 2nd-4th Floor: 16 zones per floor, including guest rooms, corridor, stairs and storage;
Floor to floor height (feet)	20	Ground floor: 11 ft, Upper floors: 9 ft
Floor to ceiling height (feet)	20	Ground floor: 11 ft, Upper floors: 9 ft
Roof Dimensions	Based on floor area and aspect ratio	Based on floor area and aspect ratio
Roof Tilt and Orientation	horizontal	horizontal
Window Fraction (Window to Wall Ratio)	Average total – 7.4% 25.4% WWR for street-facing façade	Average total - 10.9% South - 3.1% East - 11.4% West - 15.2% North - 4%
Window Dimensions	82.14 ft x 4.98 ft on the long side of 'Front Retail' and 'Point of Sale' spaces	based on window fraction, location, glazing sill height, floor area and aspect ratio
Glazing Sill Height (feet)	3.74 ft	3 ft in ground floor, 2 ft. in upper floors
Window Location	long side of 'Front Retail' and 'Point of Sale' spaces	one per guestroom (4' x 5')
Skylight Fraction (Skylight to Roof Ratio)	2.97%	NA
Skylight Dimensions	Core_Retail- 17227.4 SF (32 skylights @16SF)	NA

APPENDIX D: MEASURE COST ESTIMATE SURVEY FORM

Appropriate cost estimates that are consistent with current costs are important for evaluating cost effectiveness. For this measure, as a starting point, RS Means Costworks (2014) was consulted to gather cost estimates (both material costs and total installed costs, including markup for overhead and profit), for a variety of batt and continuous insulation products. Then, distributors were contacted to obtain written cost estimates for a number of products, focusing primarily on roof deck insulation, batt insulation for framed wood roofs, and batt and continuous insulation for steel-framed and wood-framed walls. Cost estimates were obtained from distributors in the San Francisco Bay Area, Los Angeles area and Sacramento area.

A sample cost estimate form is shown below.

Table 45: Metal Building Roofs Material Costs

Roof Type	Details	Insulation	Costs /SF		
			Insulation Costs	**Fastener Costs**	**Thermal Block**
Screw Down Roof	no thermal block	R-11 batt			n/a
		R-13 batt			n/a
		R-19 batt			n/a
Standing Seam Roof	Single Layer of Insulation draped over purlins and	R-11 batt			
	compressed. Thermal	R-13 batt			
	blocks at supports (R-5)	R-19 batt			
Standing Seam Roof	Double layer of insulation. Thermal	R-11 + R-11			
	blocks at supports (R-5)	R-13 + R-13			
		R-11 + R-19			
		R-13 + R-19			
		R-19 + R-19			
Filled Cavity with Thermal Blocks	Long Tab Banded - see Roof Detail	R-19 + R-10			
Roof Deck Rigid Insulation	1" rigid extruded polystyrene, 25psi*	R-5			n/a
	2" rigid extruded polystyrene, 25psi	R-10			n/a
	3" rigid extruded polystyrene, 25psi	R-15			n/a
	4" rigid extruded polystyrene, 25psi	R-20			n/a
	1" rigid polyisocyranurate, 20psi or typical	R-5.6			n/a
	2" rigid polyisocyranurate, 20psi or typical	R-11.2			n/a

	3" rigid polyisocyranurate, 20psi or typical	R-16.8			n/a
	4" rigid polyisocyranurate, 20psi or typical	R-22.4			n/a

* Note: If you find that expanded polystyrene (EPS) is more common than extruded, you can provide an estimate for that if you have one available.

Table 46: Wood-Framed Rafter Roofs

Roof Type	Detail		Insulation Cost
2x6	24" o.c.	R-11 batt	
		R-13 batt	
		R-15 batt	
		R-21 batt	
2x8	24" o.c.	R-19 batt	
		R-21 batt	
2x10		R-22	
		R-25	
		R-30	
2x12	24" o.c.	R-30	
		R-38	

Table 47: Steel-Framed Wall Insulation

Wall Type	Details		Insulation Costs	Fastener Costs
2 x 4 steel framed, 24" o.c.	batt insulation	R-11		
	batt insulation	R-13		
	batt insulation	R-15		
	rigid polystyrene insulation, 1"	R-5		
	rigid polystyrene insulation, 2"	R-10		
	rigid polystyrene insulation, 3"	R-15		
	rigid polystyrene insulation, 4"	R-20		
	rigid polyiso insulation, 1"	R-5.6		
	rigid polyiso insulation, 2"	R-11.2		
	rigid polyiso insulation, 3"	R-16.8		
2 x 6 steel framed, 24" o.c.	batt insulation	R-19		
	batt insulation	R-21		
	rigid polystyrene insulation, 1"	R-5	if	
	rigid polystyrene insulation, 2"	R-10	different	
	rigid polystyrene insulation, 3"	R-15	than	
	rigid polystyrene insulation, 4"	R-20	above	
	rigid polyiso insulation, 1"	R-5.6	for 2x4	
	rigid polyiso insulation, 2"	R-11.2		
	rigid polyiso insulation, 3"	R-16.8		

APPENDIX E: ADDENDUM FOR RELOCATABLE CLASSROOMS

Justification for Revisions to Prescriptive Envelope Requirements for Relocatable Classrooms

Relocatable classroom buildings are a subset of nonresidential buildings, and they must comply with all nonresidential prescriptive requirements of the Title 24 Standards in Section 140, including the building opaque envelope requirements. By definition, the location of a relocatable classroom is not fixed in one climate zone; relocatable classrooms could be moved throughout the state to any climate zone. The prescriptive envelope requirements in Table 140.3-B, for which proposed revisions are presented above, apply to “relocatable public school buildings where the manufacturer certifies use only in specific climate zone”. If a manufacturer of a relocatable classroom does not certify the relocatable classroom for use in a specific climate zone, the relocatable classroom must comply with the requirements in *Table 140.3-D Prescriptive Envelope Criteria for Relocatable Public School Buildings for Use in All Climate Zones*.

The requirements in Table 140.3-D are established in such a way that relocatable classrooms will comply with the prescriptive requirements in most climate zones. Table 48 summarizes the proposed standards for relocatable classrooms presented in Table 140.3-D of the Standards compared to the requirement for other nonresidential buildings presented in Table 140.3-B of the Standards. The 2013 Standards and the proposed 2016 Standards for relocatable classrooms roofs are at least as stringent as the maximum U-factor requirements in all 16 climate zones. That is, reloadable classrooms must meet the prescriptive roof insulation requirements for every climate zone and every assembly. In some climate zones (namely, climates zones 11 and 15), the insulation requirements for some relocatable classroom wall assemblies are less stringent than requirements for other nonresidential buildings. For example, the requirements for walls of wood framed nonresidential buildings in climate zone 15 are more stringent than the U-factor requirements for reloadable classrooms.

Table 48: Summary of Envelope Requirements for Relocatable Classrooms, 2013 Standards and Proposed 2016 Standards

		Roofs/Ceilings		Walls				
		Roofs of Metal Buildings	Roofs of all non-Metal Buildings	Walls of Wood Frame Buildings	Walls of Metal Frame Buildings	Walls of Metal Buildings	Walls of Mass/7.0<HC, Any building	All other Walls
2013 Standards	2013 Standard for relocatable classrooms (Maximum U-Factor), Table 140.3-D	0.048	0.039	0.059	0.062	0.057	0.17	0.059
2013 Standards	Climate zones where maximum U-factor requirements in Table 140.3-B are more stringent than requirements for relocatable classrooms in Table 140.3-D	none	none	15	none	none	Mass Light: none Mass Heavy: 16	15
2016 Standards	2016 Standard for relocatable classrooms (Maximum U-Factor), Table 140.3-D	~~0.048~~ 0.041	~~0.039~~ 0.034	0.059	0.062	0.057	0.17	0.059
2016 Standards	Climate zones where maximum U-factor requirements in Table 140.3-B are more stringent than requirements for relocatable classrooms in Table 140.3-D	none	none	11, 15	15	none	Mass Light: none Mass Heavy: 1, 2, 3, 16	11,15

The Statewide CASE Team recommends that the prescriptive roof requirements for relocatable classrooms be updated to provide consistency with the proposed revisions to Table 140.3-B. If the relocatable classroom roof envelope requirements were not updated, then the requirements for relatable classrooms would be less stringent than the U-factor requirements for other nonresidential buildings for most assemblies and climate zones.

The Statewide CASE Team does not recommend that the prescriptive wall requirements for relocatable classrooms be modified. The proposed revisions to the requirements in Table 140.3-B do result in the envelope requirements for nonresidential buildings with certain assemblies in select climate zones to be more stringent than the requirements for relocatable classrooms. Although the requirements for nonresidential buildings will become more stringent, relocatable classrooms will still be compliant with the envelop requirements for most climate zones and assemblies. The Statewide CASE Team is not recommending changes to the wall requirements for relocatable classrooms because nearly all recommended changes do not exceed the stringency of the current 2013 Title 24 relocatable classroom wall insulation requirements. The only recommended modification to the prescriptive requirements that is more stringent than the current relocatable classroom requirements for walls is the wood-frame wall requirement of U=0.045 for climate zone 11 (Fresno) and the metal-framed wall requirement of U=0.057 for Palm Springs (climate zone 15). If the modifications to requirements for nonresidential buildings resulted in relocatable classrooms being out of compliance in most climate zones, the Statewide CASE Team would have recommended revisions to the requirements for relocatable classrooms.

Proposed Code Language: Prescriptive Envelope Requirements for Relocatable Classrooms

The proposed changes to the Standards are provided below. Changes to the 2013 documents are marked with underlining (new language) and ~~strikethroughs~~ (deletions).

TABLE 140.3-D PRESCRIPTIVE ENVELOPE CRITERIA FOR RELOCATABLE PUBLIC SCHOOL BUILDINGS FOR USE IN ALL CLIMATE ZONES

Roofs/Ceilings		
Roofs of Metal Buildings		Maximum U-factor ~~0.048~~ 0.041
Roofs of all non-Metal Buildings		Maximum U-factor ~~0.039~~ 0.034
Roofing Products – Aged Reflectance/Emittance		
Low-sloped	Low-Sloped	0.63/0.75
Steep-Sloped	Steep-Sloped	0.20/0.75
Walls		
Walls of Wood frame buildings		Maximum U-factor 0.059
Walls of Metal frame buildings		Maximum U-factor 0.062
Walls of Metal buildings		Maximum U-factor 0.057
Walls of Mass/7.0≤ HC, any building		Maximum U-factor 0.170
All Other Walls		Maximum U-factor 0.059
Floors and soffits of all buildings		Maximum U-factor 0.048
Windows of all buildings		
U-factor		Maximum U-factor 0.47
RSHGC		Maximum RSHGC 0.26
Glazed Doors, All Buildings		
Max Average Weighted U-factor		0.45
Max Average Weighted RSHGC		0.23
Exterior Doors, all buildings		
Non-Swinging doors		Maximum U-factor 0.50
Swinging doors		Maximum U-factor 0.70
Skylights		
Glass with Curb		Maximum U-factor 0.99
Glass -without Curb		Maximum U-factor 0.57
Plastic with Curb		Maximum U-factor 0.87
Glass Skylights	0-2% SRR	Maximum SHGC 0.46
	2.1-5% SRR	Maximum SHGC 0.36
Plastic Skylights	0-2% SRR	Maximum SHGC 0.69
	2.1-5% SRR	Maximum SHGC 0.57