CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE)

Residential High Performance Walls

Measure Number: 2016-RES-ENV2-F

Residential Envelope

2016 CALIFORNIA BUILDING ENERGY EFFICIENCY STANDARDS

California Utilities Statewide Codes and Standards Team February 6, 2015

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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 proposal for Residential High Performance Walls. 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

Residential High Performance Walls will affect the following code documents listed in Table 1

Table 1: Scope of Code Change Proposal

Standards Requirements (see note below)	Compliance Option	Appendix	Modeling Algorithms	Simulation Engine	Forms
Ps	Yes	JA4	Yes	No	CF1R-NCB-01-E

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

Measure Description

The Residential High Performance Walls measure is intended to increase the performance of the residential envelope, reducing the amount of heat transfer through walls and thus reduce HVAC loads. The Statewide Codes and Standards Enhancement Team (Statewide CASE Team) investigated a change to the Standards for lower prescriptive wall U-factor requirements via increased insulation. This measure requires updating the language contained in row two (2) of Table 150.1-A Component Package A and editing associated footnotes.

For the 2013 Title 24 update, the Statewide CASE Team investigated the feasibility of requiring 2x6 inch studs at 24-inch on-center framing with R-19 cavity insulation as the prescriptive requirement for residential buildings in California. According to market research at the time, most builders were only mildly familiar with this design practice, and the majority preferred 2x4 inch studs at 16 inches on center framing. The 2013 Standards based the prescriptive requirement on 2x4 inch framing with 1” (R-4) continuous exterior insulation, and provided look-up tables for equivalent insulation levels in 2x6 inch framing to meet the requirement. The 2013 Title 24 Standards are not the most stringent values that were found to be cost-effective during analysis for each climate zone. The CEC decided to adopt one value that applies to all climate zones to simplify requirements and encourage compliance.

Detailed lifecycle cost analysis performed by the Statewide CASE Team for the 2016 Standards shows the cost-effectiveness of lowering the effective U-factor of residential walls. Also, recent interviews with the PG&E California Advanced Home Program (CAHP) implementer as part of the 2016 CASE effort reveal that 2x6” studs are now more common in the Central Valley (Climate Zones 11-13) for advanced homes because lower wall U-factors are necessary to be considered an advanced home and eligible for the program.

Section 2 of this report provides detailed information about the code change proposal including: Section 2.2 Summary of Changes to Code Documents (page 5) 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 5: Scope of Code Change Proposal (page 5)
- Table 6: Sections of Standards Impacted by Proposed Code Change (page 5)
- Table 7: Appendices Impacted by Proposed Code Change (page 6)
- Table 8: Sections of Residential ACM Impacted by Proposed Code Change (page 6)

Detailed proposed changes to the text of the building efficiency standards, the reference appendices, and are given in ***Section 6 Proposed Language*** of this report. This section proposes modifications to language with additions identified with <u>underlined</u> text and deletions identified with ~~struck out~~ text.

The following documents will be modified by the proposed change:

- Title 24 Part 6 Sections, 150.1(c)1.B, and Table 150.1-A
- Joint Appendix 4 and Residential Appendix 2
- Residential ACM
- Compliance form CF1R

Market Analysis and Regulatory Impact Assessment

There are several components involved in constructing a high performance wall, and each was investigated for market structure, availability and useful life, persistence and maintenance. The following briefly provides the findings for this measure; further detail is provided in Section 3.

- Exterior rigid and cavity insulations: a variety of insulation types are available that provide varying levels of insulation per unit depth, and can meet the proposed requirement using either 2x4 or 2x6 studs. No additional maintenance is expected for these products if installed properly.
- Framing: The use of 2x6 studs in the California residential market has increased in advanced homes since the 2013 CASE analysis, and is expected to further increase with the 2013 Standards going into effect. A market shift towards greater use of 2x6 studs will only have a minor impact on the timber industry and negligible impact on lumber use due to optimal lumber sawing practices. Framing requirements are expected to have no additional maintenance if installed properly.
- External finish: Stucco is the predominant finishing for California residential new construction. It is expected that there will be labor and material increases when applying stucco over rigid insulation at depths greater than 1" due to the need for longer nails and wider door and window frames.
- Window frames and flashing: Window frames are directly affected by the thickness of the external finish; meaning adjustments must be made in the installation of windows when using thicker rigid exterior insulation.

This proposal of 0.051 U-factor is cost effective in Climate Zones 1-5 and 8-16 over the Lifecycle Cost (LCC) period of analysis of 30 years. Overall this proposal increases the wealth of the State of California. California consumers and businesses save more money on energy than they do for financing the efficiency measure. As a result this leaves more money available for discretionary and investment purposes.

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

- **Impact on builders:** Builders will need to adjust to the lower U-factor requirements by changing one or more 'typical' building practices, including exterior rigid and cavity insulation, or framing size and spacing.
- **Impact on building designers:** The proposed code change is not expected to significantly impact building designers.
- **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:** 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):** Retailers, manufacturers, and distributors will see different lines of products being requested; over time it is expected that the costs of these products will reduce and cost savings will improve.
- **Impact on energy consultants:** The proposed code change is not expected to significantly impact 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.
- **Statewide Employment Impacts:** 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:** The updates to Title 24 as a whole are expected to drive additional business creation in California. This is discussed in greater detail below in Section 3.5.
- **Impacts on the potential advantages or disadvantages to California businesses:** 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.
- **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% Renewable Portfolio Standard (RPS) will increase investment in California by about 3% 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. There are no projected impediments to, or incentives for, innovation that would result from the proposed measures.
- **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:** Building inspection requirements remain the same. Likewise, training or additional time spent on enforcement, which may lead to increased enforcement costs for the state or local government, are very minimal.

- State government already has budgeted 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 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. Although retraining is a cost of the revised standards, Title 24 energy efficiency standards are expected to increase economic growth and income with positive impacts on local revenue.
- These proposed changes would revise an existing measure without significantly affecting the complexity of this measure. 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 the CEC into Title 24, part 6 do not disadvantage or discriminate in regards to race, religion or age group.
- **Impact on Homeowners (including potential first time home owners):** This proposal is cost-effective for the homeowner. As a result the combined mortgage costs and utility bill payment for the homeowner are less if the measure is incorporated into all new homes.
- **Impact on Renters:** This proposal is advantageous to renters as it reduces the cost of utilities which are typically paid by renters. Since the measures adopted were shown to have net negative lifecycle costs, the societal impact will be to save more energy costs than the incremental cost of the adopted measures during construction, resulting in energy cost savings experienced by renters as a whole.
- **Impact on Commuters:** This proposal and all measures adopted by the 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 Residential High Performance Walls. Demand reductions estimates are not available at this time. The statewide TDV savings estimate the energy cost savings over the lifetime of the measure (30 years) for the first year of construction when the new code is in effect.

Table 2: Estimated First Year Energy Savings

	First Year Statewide Savings			Statewide TDV Savings	
	Electricity Savings (GWh)	**Power Demand Reduction (MW)**	**Natural Gas Savings (MMtherms)**	**TDV Energy Savings (Million kBTU)**	**TDV Dollar Savings (Million $)**
U-factor=0.051	6.5	8.6	1.8	675	$109

The savings calculated in Table 2 include all Single Family New Construction the first year the new Standards are in effect. The forecasted new construction is presented in Table 14. The total statewide savings for this measure uses the savings from a model of the proposed U-factor (0.051). Section 4.6.1 discusses the methodology and Section 5.1.1 shows the results for the per unit energy impact analysis.

Cost-effectiveness

Cost-effectiveness Analyses Results are presented in Table 3 below. 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 existing conditions (current minimally compliant construction practice when there are existing Title 24 Standards). 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 1.0 or greater, 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. The CASE Team revised the total incremental measure cost based on discussions with CBIA and ConSol on the cost estimates from the initial docketed draft CASE report. The current total incremental costs are a result of these discussions and reflect a margin of difference between CBIA and ConSol's cost estimate that is significantly smaller than the original estimates.

The Change in Lifecycle Cost values are negative in all climate zones except 6 and 7 (the southern California coast). This means that the proposed code change has a B/C ratio greater than one and is cost effective in climate zones 1-5 and 8-16, and the code change will result in cost savings relative to the existing conditions in those climate zones.

Table 3: Cost-effectiveness Summary for U-factor=0.051

Climate Zone	Benefit: TDV Energy Cost Savings (2016 PV$)	Cost: Total Incremental First Cost and Maintenance Cost (2016 PV$)	Change in Lifecycle Cost (2016 PV$)	Benefit to Cost (B/C) Ratio
Climate Zone 1	$1,148	$517	($631)	2.2
Climate Zone 2	$894	$517	($377)	1.7
Climate Zone 3	$641	$517	($124)	1.2
Climate Zone 4	$821	$517	($304)	1.6
Climate Zone 5	$618	$517	($101)	1.2
Climate Zone 6	$446	$517	$71	0.9
Climate Zone 7	$249	$517	$268	0.5
Climate Zone 8	$529	$517	($12)	1.0
Climate Zone 9	$852	$517	($335)	1.6
Climate Zone 10	$922	$517	($405)	1.8
Climate Zone 11	$1,611	$517	($1,094)	3.1
Climate Zone 12	$1,341	$517	($824)	2.6
Climate Zone 13	$1,633	$517	($1,116)	3.2
Climate Zone 14	$1,530	$517	($1,013)	3.0
Climate Zone 15	$1,715	$517	($1,198)	3.3
Climate Zone 16	$1,524	$517	($1,007)	2.9

Given data regarding the new construction forecast for 2017, the Statewide CASE Team estimates a 30 year lifecycle cost savings of $63 million for all single family houses built in climate zones 1-5 and 8-16 with a U-factor of 0.051 during the first year the 2016 Standards are in effect.

Section 4 discusses the methodology and section 5.2 shows the results of the Cost Effectiveness Analysis.

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 4 presents the estimated avoided greenhouse gas (GHG) emissions of the proposed code change for the first year the standards are in effect. Assumptions used in developing the GHG savings are provided in Section 4.8.1 on page 25 of this report.

The monetary value of avoided GHG emissions is included in TDV cost factors (TDV $) and is thus included in the Cost-effectiveness Analysis prepared for this report.

Table 4: Estimated Statewide Greenhouse Gas Emissions Impacts

	First Year Statewide Avoided GHG Emissions ($MTCO_2e/yr$)
U-factor=0.051	10,993

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.

Field Verification and Diagnostic Testing

The proposed measure will not entail any additional requirements for field verification.

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 lower prescriptive U-factor requirement for residential exterior walls. 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 were 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 year period of analysis.

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

This is a draft version of the CASE Report. The 2016 TDV values were not yet available when this draft report was being developed. The TDV energy and cost savings presented in this draft report were developed using 2013 TDV values. Despite what the table headings indicate, the TDV energy and cost savings presented in this draft report were developed using 2013 TDV values and TDV cost saving are in 2011 dollars. The Statewide CASE Team will be submitting a revised version of this report in fall 2014, which will include the final recommended code change proposal and a updated TDV energy and cost savings results that use the 2016 TDV values.

2. Measure Description

2.1 Measure Overview

2.1.1 Measure Description

The Residential High Performance Walls measure is intended to increase the performance of the residential envelope, reducing the amount of heat transfer through walls and thus reduce HVAC loads. The Statewide Codes and Standards Enhancement Team (Statewide CASE Team) investigated changing the prescriptive wall U-factor requirements in the Standards via increased insulation. This measure requires updating the language contained in Section 150.1(c).B and updating row two (2) of Table 150.1-A Component Package A and associated footnotes.

The list below provides a summary of how each Title 24 document will be modified by the proposed change:

- **Standards:** The proposed language will lower the prescriptive U-factor requirements for walls. The proposed code change will modify the following Sections:
  - 150.1(c).1 Performance and Prescriptive Compliance Approaches for Newly Constructed Residential Buildings - Insulation: Walls.
  - TABLE 150.1-A COMPONENT PACKAGE-A Standard Building Design – row 2.
- **Appendices:** The proposed code change will modify Sections JA4 of the appendices to the Standards.
- **Residential Alternative Calculation Method (ACM) Reference Manual:** The proposed code change will modify sections 2.3 (Building Materials) and 2.5.4.3 (Exterior Walls) of the Residential ACM Reference Manual. The proposal will modify existing language by updating the standard design for exterior walls.

Compliance Forms: The proposed code change will modify the following compliance forms:

- **CF1R-NCB-01-E** – CERTIFICATE OF COMPLIANCE – DATA FIELD DEFINITIONS AND CALCULATIONS.

Wall Assembly Strategies

This measure lowers the prescriptive overall wall insulation U-factor requirements for wood framed walls in residential and low-rise multifamily buildings. The Statewide CASE Team investigated the feasibility of lowering U-factor requirements while considering the variety of framing, continuous insulation, and cavity insulation strategies available to reach lower U-factors. These strategies include:

- Increased exterior rigid insulation
- Higher R-value cavity insulation
- 2x6 -inch studs
- Structurally Insulated Panels (SIPs)
- Insulated Concrete Forms (ICFs)

The Statewide CASE Team assessed the use of batt, blown-in, spray foam, flash-and-batt, and continuous (rigid) insulation with these wall types. Currently, all of these approaches are viable to comply with the 2013 Title 24 Standards using the performance approach.

This measure affects the prescriptive requirements and therefore the basis for the performance approach for exterior walls. This measure would modify existing code language, but not modify the scope of the Standards.

2.1.2 Measure History

For the 2013 Title 24 code cycle, the Statewide CASE Team investigated the feasibility of requiring 2x6 inch studs at 24-inch on-center framing with R-19 cavity insulation as the prescriptive requirement for residential buildings in California. According to market research during the 2013 CASE work, most builders were only mildly familiar with this design practice, and most preferred 2x4 inch studs at 16 inches on center framing. The 2013 CASE based the prescriptive standard on 2x4 inch framing with 1" (R-4) continuous exterior insulation, then provided look-up tables for equivalent insulation levels in 2x6 inch framing to meet the new requirements.

The 2013 CASE study Increased Wall Insulation (IOU 2013) found that, based on a very small sample of homes receiving incentives for exceeding 2008 Title 24 Standards by 15% through the California New Homes Program, many builders were using a combination of 2x6 and 2x4 framing. Of the 548 homes[1] in the sample, 67% included some 2x6 exterior wall framing. The 2x6 framed wall area, on average, only accounted for 23% of the total exterior wall area. In no case was 24-inch on center framing specified.

[1] These 548 homes were collectively built by 9 different builders.

During the 2013 code cycle stakeholders raised a concern about the possible increase in wood demand and wood waste resulting from 2x6 studs replacing 2x4 studs. Review of USDA-published literature confirmed that milling 2x6 framing members, alongside other nominal framing sizes results in maximum board foot yield from a standard 9-inch log, and does not require more or larger trees to be cut.[2] Regardless, the wood remnants, not milled into lumber, are never wasted, but used to make composite materials. The milling of 2x6 framing members is therefore not an environmental concern. As an alternative to prescriptively requiring this type of framing, the Statewide CASE Team updated the look-up tables for U-factors which promote 2x6 inch studs and 24-inch on-center framing as compliance options.

The prescriptive U-factor and associated insulation values adopted for wood-framed residential buildings in the 2013 Title 24 Standards are not the most stringent values that were found to be cost-effective for each climate zone. The CEC decided to adopt one value that applies to all climate zones in order simplify requirements and encourage compliance. Although the proposed U-factors were based on insulation levels for 2x4 studs at 16-inches on-center, stakeholders were worried that the lowest U-factors found cost effective would require a learning curve for most contractors. For this reason, not all cost-effective energy savings were captured for all climate zones.

During the 2013 Title 24 code cycle, AWF and ICFs were investigated for integration into the standards for the first time, and were added as compliance options. SIPs were an existing compliance option from the 2008 Standards. The Statewide CASE Team developed tables for the Joint Appendix, including revised values for SIPs in the look up tables to better align with available products and practices, but CEC staff responded that the values would be built into the new modeling software and tables would not be necessary. The 2013 CASE work set the precedence for these framing assemblies to earn proper credit for the energy benefits that they provide.

2.1.3 Existing Standards

Residential walls are currently regulated by 2013 Title 24. The prescriptive requirements are located in Table 150.1-A, and indicate that above grade wood framed walls are required to meet a U-factor of 0.065 or less in all climate zones.

2.1.4 Alignment with Zero Net Energy Goals

The Statewide CASE Team and the CEC are committed to achieving California's zero-net-energy (ZNE) goal. This measure will help achieve ZNE goals by reducing the heating and cooling loads for HVAC systems in residential buildings. Increased insulation and advanced framing practices lead to a higher overall envelope performance, which reduces the required capacity of the HVAC needed to maintain stable interior temperature while exterior temperatures fluctuate. Reduced HVAC operation will lead to reduced electricity demand.

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

This measure will also set the foundation for proposing future code changes that will help ensure ZNE goals are achieved. In particular, this measure could lead directly to the following code changes in the 2019 and 2022 code change cycles:

- Introduction of advanced wall assembly techniques as prescriptive or trade-offs approaches, allowing for greater reductions in prescriptive U-factors
- Introduction of staggered studs or double walls as a prescriptive requirement or compliance option
- Changes in QII requirements.

2.1.5 Relationship to Other Title 24 Measures

Quality Insulation Installation affects all cavity insulation, including that installed in ceilings or floors. Thus, this measure overlaps with the High-Performance Attics and Ducts / Ducts in Conditioned Space 2016 CASE measure (HPA/DCS).

2.2 Summary of Changes to Code Documents

The sections below provide a summary of how each Title 24 document 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 5 identifies the scope of the code change proposal. This measure will impact the following areas (marked by a "Yes").

Table 5: Scope of Code Change Proposal

Mandatory	Prescriptive	Performance	Compliance Option	Trade-Off	Modeling Algorithms	Forms
No	Yes	Yes	Yes	Yes	No	No

Standards

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

Table 6: 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)
150.1(c)1.B	Prescriptive Standards/Component Package – Insulation: Walls	Ps	E
Table 150.1-A	Component Package – A	Ps	E

Appendices

The proposed code change will modify the sections of the indicated appendices presented in Table 7. If an appendix is not listed, then the proposed code change is not expected to have an effect on that appendix.

Table 7: 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

Residential Alternative Calculation Method (ACM) Reference Manual

The proposed code change will modify the sections of the Residential ACM Manual identified in Table 8.

Table 8: Sections of Residential ACM Impacted by Proposed Code Change

Residential Alternative Calculation Method Reference		
Section Number	**Section Title**	**Modify Existing (E) New Section (N)**
2.3	Building Materials	E
2.5.4.3	Exterior Walls	E

CBECC-Res Simulation Engine Adaptations

The proposed code change can be modeled using the current simulation engine (CBECC-Res[3]). Changes to the simulation engine are necessary, specifically, changing the U-factor of the wall assembly in the base case for affected climate zones (1-5 and 8-16).

2.2.2 Standards Change Summary

This proposal would modify the following sections of the Building Energy Efficiency standards as shown below. See ***Section 6.1 Standards*** of this report for the detailed proposed revisions to the standards language.

Changes in Scope

- The proposed code change does not change the scope of the Standards. Proposed code changes add/revise mandatory and prescriptive requirements for building elements already regulated by the Standards.

Changes in Prescriptive Requirements

- The proposed code change will modify Section 150.1(c).B Performance and Prescriptive Compliance Approaches for Newly Constructed Residential Buildings - Insulation: Walls

[3] More information available at: http://cbecc-res.com/

of the Standards by changing the prescriptive U-factors required in Table 150.1-A to U-0.051 for climates zones 1-5 and 8-16.

SECTION 150.1 – – PERFORMANCE AND PRESCRIPTIVE COMPLIANCE APPROACHES FOR NEWLY CONSTRUCTED RESIDENTIAL BUILDINGS

TABLE 150.1-A COMPONENT PACKAGE-A Standard Building Design: The proposed regulations change the row heading for “2x4 Framed” above grade walls to “Wood Framed” and modify the associated U-factors in Climate Zones 1-5 and 8-16.

2.2.3 Standards Reference Appendices Change Summary

This proposal will modify JA4 of the reference appendices of the Standards. See ***Section 6.2 Reference Appendices*** of this report for the detailed proposed revisions to the text of the reference appendices.

JOINT APPENDICES

JA4.3 Walls

Table 4.3.1 – U-factors of Wood Framed Walls: The proposed regulations add data for the rated R-value of continuous insulation up to R-10 to reflect the updated Standards language.

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

The proposed code change will modify sections 2.3 (Building Materials) and 2.5.6.3 (Exterior Walls) of the Residential ACM Reference Manual. The proposal will modify existing language by updating the standard design for exterior walls.

2.2.5 Compliance Forms Change Summary

The proposed code change will modify the following compliance forms listed below. Examples of the revised forms are presented in ***Section 6.5 Compliance Forms***.

- **CF1R** – B. OPAQUE SURFACE DETAILS – Framed

2.2.6 Simulation Engine Adaptations

Change the standard design for exterior walls to include revised U-factors.

2.2.7 Other Areas Affected

No other areas affected.

2.3 Code Implementation

2.3.1 Verifying Code Compliance

The increased R-value of the wall would require visual inspection by a building inspector to ensure that the wall assembly constructed, including framing spacing, wall cavity insulation value, and external insulation value is in compliance, or matches the performance specified in the compliance software. Because visual inspections are standard practice prior to installation of drywall (for cavity insulation) and again at final inspection (for external insulation), there is no added burden for inspections for this measure.

2.3.2 Code Implementation

The U-factor of wall assemblies is already regulated by Title 24, this proposal strengthens those requirements. The strategies required to achieve the proposed U-factors are common practice for a small number of high-performance builders throughout the state, but will require a significant step forward in common practice for the majority of builders. The incremental cost of the compliance will vary with the strategy chosen by the builder, but should be less than $1,000 regardless of the strategy chosen, and could be less than $600. There may be some resistance from the building industry on the grounds of moisture issues resulting from the increased use and thickness of rigid exterior insulation, but technical solutions exist to address those concerns[4,5,6,7]. There may be a learning curve associated with the initial implementation of these new strategies, but over time this too will become standard practice.

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 Statewide CASE Team followed up with window manufacturers, insulation installers and architects, and determined that best practices can provide the structural support and framing necessary to keep moisture out of the walls using current window sizes and accommodate up to 2 inches of rigid exterior insulation, but it is not yet standard practice. Leading window manufacturers are currently working on a best practices guide for installing windows in residential walls with up to 2 inches of rigid exterior insulation. This guide is expected to be published and available to the public later this year (2014). To mitigate the issues associated

4 http://www.buildingscience.com/documents/insights/bsi-038-mind-the-gap-eh/?searchterm=mind%20the%20gap

5 http://www.buildingscience.com/documents/digests/bsd-012-moisture-control-for-new-residential-buildings/?searchterm=Moisture%20Control%20for%20New%20Residential%20Buildings

6 http://www.milgard.com/_doc/products/installation/pdf/aama-2400-02.pdf

7 http://www.milgard.com/_doc/products/installation/pdf/aama-2400-10.pdf

with rigid exterior insulation 2 inches and thicker, the CASE Team is proposing a prescriptive requirement using rigid exterior insulation that is 1 to 1 ½ inches thick.

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 held in May 2014.

3.1 Market Structure

There are many components to a high performance wall, and the market implication of each component was explored. The Statewide CASE Team investigated the implications of the following components:

- Cavity insulation – A variety of insulation types are available to place in wall cavities, including low-density batt, high-density batt, spray foam, and loose-fill. High density batt (or mineral wool batt) and loose-fill insulation products are capable of achieving R-23 in 2x6 framing construction and R-15 in 2x4 framing, and are less expensive than spray foam insulation. Open-cell spray foam at R-4 per inch can achieve R-14 in a 4" cavity and R-22 in a 6" cavity. Closed-cell spray foam (more expensive than open-cell) at R-7 per inch can achieve R-24 in a 4" cavity and R-38 in a 6" cavity.
- Rigid continuous insulation- The Statewide CASE Team found manufacturers of extruded polystyrene (XPS) and expanded polystyrene (EPS) rigid insulation covering R-values from R-2 to R-10, including products that are R-3.8, R-4, R-5, and R-6 per inch.
- Framing – The Statewide CASE Team investigated the effects of lumber usage when changing from predominantly 2x4" studs to 2x6" studs. The expected impact on the timber industry is minor. Framing crews will need to account for the additional weight of 2x6 studs as compared to 2x4 when constructing exterior walls.
- External finish – The Statewide CASE Team reached out to stucco contractors, building supply distributors, and window manufacturers to gain an understanding of the differences of external finishing over 1" versus 2" of exterior continuous insulation. Longer fasteners are required as the thickness of the rigid exterior insulation increases. Most framing nailers can accommodate nails from 2" to 3.5" in length. The minimum required penetration varies by weight of the external finish, but is generally in the range of 1" to 1.5". This means that in most scenarios, a 3.5" nail should be of sufficient length to achieve the required minimum penetration. However, insulation thicker than 2" could potentially require builders to use a nail gun that can accommodate longer nails (if one

exists), switch to screws instead of nails, or hammer longer nails manually, all of which can add to the time and/or cost of affixing the external finish to the studs through the exterior insulation.

- Window framing – Window framing attaches the window to the exterior wall. This is directly affected by the thickness of the external finish. Thicker rigid exterior insulation may require picture framing around each rough opening to provide structural support for the window and allow the frame to sit flush with the rigid insulation. Alternatively, a new cast could be developed to produce window frames that accommodate the new thickness.

3.2 Market Availability and Current Practices

Current California Advanced Homes Program (CAHP) information indicates that new residential construction along coastal California continues to utilize 2x4 studs, while builders in central California have transitioned to building with 2x6 studs for houses that are built to above-code efficiencies. The 2013 CASE Report Increased Wall Insulation (IOU 2013) found that, based on a very small sample of homes receiving incentives for exceeding 2008 Title 24 Standards by 15% through the California New Homes Program, many builders are using a combination of 2x6 and 2x4 framing. Of the 548 homes[8] in the sample, 67% included some 2x6 exterior wall framing. The 2x6 framed wall area, on average, accounted for 23% of the total exterior wall area.

Interviews with the PG&E CAHP implementer reveal that 2x6" studs are becoming more common in the Central Valley (Climate Zones 11-13). These climates require walls with lower U-factors in order to qualify as an advanced home (15% below the Title 24 energy budget). The Statewide CASE Team also collaborated with PG&E and SCE Emerging Technology (ET) studies on high performance houses. The houses in these studies commonly incorporated 2x6" studs with cavity insulation ranging from R-19 batts to R-23 spray foam or loose-fill cellulose. Most of the houses in CAHP and the ET studies used R-4 continuous exterior insulation.

The Statewide CASE Team found that products necessary to meet the proposed prescriptive requirements are readily available in California:

- Cavity insulation – The Statewide CASE Team found that major manufacturers including John Manville, Owens Corning, Certainteed, and Knauf, have products capable of achieving R-15 in 2x4 framing and R-23 in 2x6 framing, and that these products are commercially available in California. According to interviews with insulation contractors in Northern California, open-cell spray foam at R-4 per inch can achieve R-14 in 2x4 framing and R-22 in 2x6, while closed-cell spray foam at R-7 per inch can achieve R-24 in 2x4 framing and R-38 in 2x6.
- Rigid continuous insulation – R-4 per inch is fairly common. Manufacturers that provide R-5 per inch rigid insulation include Rmax, Dow and Owens Corning. Rmax also sells an R-6 per inch product. All of these manufacturers sell a variety of rigid insulation

[8] These 548 homes were collectively built by 9 different builders.

products, ranging in performance from R-2 to R-10 and ranging in thickness from ½ inch to 2 inches. Cost estimates for EPS, XPS, and Polyisocyanurate (polyiso) products were obtained from builders and distributors in California as well as from large home improvement retailers such as Home Depot and Lowes.

- Window frame profile – A representative from Royal Building Products asserted that window frame manufacturers may need to develop new extrusion dyes to account for different thicknesses of rigid exterior insulation. Each product would require a new dye, which was estimated to cost approximately $50,000 each. A representative from Jeld-Wen asserted that the window manufacturers are in the process of developing a guide for how to install more than 1” of rigid exterior insulation using existing window frames. One architect described an alternative solution where window moldings are placed on the plywood sheathing layer of the wall, under back-grooved rigid insulation. Another solution is to frame the rough in window opening to bring the wood framing to the level of the wall plus rigid foam insulation.
- Wall Framing – The Statewide CASE Team spoke with representatives from the APA-The Engineered Wood Association and the American Wood Council regarding the impacts of lumber use when going from 2x4 exterior wall framing to 2x6 framing. These conversations confirmed that the lumber use impact of 2x6 framing is negligible due to the prevalence of optimal lumber sawing practices in the industry. In other words, for any given tree size, the optimal amount of cut lumber is extracted. Furthermore, 2x4s are often used in glue-laminated and other engineered products, so these smaller cuts of wood would not be wasted if California construction practices shifted to 2x6 framing. This finding confirmed similar analysis completed for the 2013 CASE Report on Increased Wall Insulation[9].

3.3 Useful Life, Persistence, and Maintenance

The rigid insulation, cavity insulation, and framing requirements of the proposed requirements are similar to the current components, and have no maintenance if installed properly. The energy savings related to the insulation installation will persist for the lifetime of the building, assumed to be 30 years.

The methodology the Statewide CASE Team used to determine the costs associated with incremental maintenance costs (if any), relative to existing conditions, is presented in Section 4.7.1, and the analysis of those costs are presented in Section 5.2.1.

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[9] From the 2013 CASE Report on Increased Wall Insulation: “A shift to 2x6, 24-inch on center framing was shown to have a very small environmental impact, with regard to lumber consumption. Review of USDA-published literature confirmed that milling 2x6 framing members, alongside other nominal framing sizes results in maximum board foot yield from a standard 9-inch log, and does not require more or larger trees to be cut (Steele 1984). Regardless, the wood remnants, not milled into lumber, are never wasted, but used to make composite materials. The milling of 2x6 framing members is therefore not an environmental concern.”

3.4 Market Impacts and Economic Assessments

3.4.1 Impact on Builders

As the analysis in Section 5 shows, there are multiple wall assemblies that can meet the new prescriptive requirements. Nonetheless, builders will need to adjust to the lower U-factor requirements by changing one or more ‘typical’ building practices. Builders can comply by changing rigid insulation thickness, cavity insulation type, or framing size and spacing. In some cases the most cost effective solution will be achieved by modifying several components.

3.4.2 Impact on Building Designers

Building designers and modelers will not be significantly impacted by the measure. They will be able to design walls by using U-factor calculations in modeling software, or by referencing the U-factor tables in Joint Appendices 4. This step will be unchanged from the 2013 Standards.

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

Builders incurring higher initial costs of construction for higher performing building materials may be pass off costs onto consumers. However, as shown in section 5.2, the new requirements result in cost savings to the building owner over the lifetime of the measure.

3.4.5 Impact on Retailers (including manufacturers and distributors)

Retailers, manufacturers, and distributors will see different lines of products being requested, including cavity and rigid insulations with higher R-values. The Statewide CASE Team expects that over time the cost of providing these products will decrease and cost savings estimates will improve beyond those presented in this report.

3.4.6 Impact on Energy Consultants

No significant impact is expected for energy consultants.

3.4.7 Impact on Building Inspectors

No significant impact is expected for building inspectors, as building products and practices will generally stay the same.

3.4.8 Impact on Statewide Employment

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.[10] For instance, the statewide lifecycle net present value of this measure is $254 million over the 30 year period of analysis. That is money that utility customers will be able to spend elsewhere in the economy.

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)[11], 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).

Macro-economic 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).

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

[10] Energy efficiency measures may result in reduced power plant construction, both in-state and out-of-state. These plants tend to be highly capital-intensive and often rely on equipment produced out of state, thus we expect that displaced power plant spending will be more than off-set from job growth in other sectors in California.

[11] GSP is the sum of all value added by industries within the state plus taxes on production and imports.

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

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.

Table 9 below shows California industries that are expected to receive the economic benefit of the proposed Title 24 code changes. It is anticipated that these industries will expand due to an increase in funding as a result of energy efficiency improvements. The list of industries is based on the industries that the University of California, Berkeley identified as being impacted by energy efficiency programs (UC Berkeley 2011 Table 3.8).[12] This list provided below is not specific to one individual code change proposal; rather it is an approximation of the industries that may receive benefit from the 2016 Title 24 code changes. A table listing total expected job creation by industry that is expected in 2015 and 2020 from all investments in California energy efficiency and renewable energy is presented in the Appendix B: Job Creation by Industry of this CASE Report.

Table 9: Industries Receiving Energy Efficiency Related Investment, by North American Industry Classification System (NAICS) Code

Industry	NAICS Code
Residential Building Construction	2361
Nonresidential Building Construction	2362
Roofing Contractors	238160
Electrical Contractors	23821
Plumbing, Heating, and Air-Conditioning Contractors	23822
Boiler and Pipe Insulation Installation	23829
Insulation Contractors	23831
Window and Door Installation	23835

[12] Table 3.8 of the UC Berkeley report includes industries that will receive benefits of a wide variety of efficiency interventions, including Title 24 standards and efficiency programs. The authors of the UC Berkeley report did not know in 2011 which Title 24 measures would be considered for the 2016 adoption cycle, so the UC Berkeley report was likely conservative in their approximations of industries impacted by Title 24. Statewide CASE Team believes that industries impacted by utilities efficiency programs is a more realistic and reasonable proxy for industries potentially affected by upcoming Title 24 standards. Therefore, the table provided in this CASE Report includes the industries that are listed as benefiting from Title 24 and utility energy efficiency programs.

Asphalt Paving, Roofing, and Saturated Materials	32412
Manufacturing	32412
Other Nonmetallic Mineral Product Manufacturing	3279
Industrial Machinery Manufacturing	3332
Ventilation, Heating, Air-Conditioning, & Commercial Refrigeration Equip. Manf.	3334
Computer and Peripheral Equipment Manufacturing	3341
Communications Equipment Manufacturing	3342
Electric Lighting Equipment Manufacturing	3351
Household Appliance Manufacturing	3352
Other Major Household Appliance Manufacturing	335228
Used Household and Office Goods Moving	484210
Engineering Services	541330
Building Inspection Services	541350
Environmental Consulting Services	541620
Other Scientific and Technical Consulting Services	541690
Advertising and Related Services	5418
Corporate, Subsidiary, and Regional Managing Offices	551114
Office Administrative Services	5611
Commercial & Industrial Machinery & Equip. (exc. Auto. & Electronic) Repair & Maint.	811310

3.5.3 Competitive Advantages or Disadvantages for Businesses within 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.

3.5.4 Increase or Decrease of Investments in the State of California

CARB's economic analysis indicate that higher levels of energy efficiency and 33% RPS will increase investment in California by about 3% in 2020 compared to 20% RPS and lower levels of energy efficiency (CARB 2010b Figures 7a and 10a).

3.5.5 Incentives for Innovation 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.

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

The Statewide CASE Team expects positive overall impacts on state and local government revenues due to higher GSP and personal income resulting in higher tax revenues, as noted earlier. Higher property valuations due to energy efficiency enhancements may also result in positive local property tax revenues. The Statewide CASE Team has not obtained specific data to quantify potential revenue benefits for this measure.

3.5.6.1 Cost of Enforcement

There are no projected impediments to, or incentives for, innovation that would result from the proposed measures. Building inspection requirements remain the same. Likewise, training or additional time spent on enforcement, which may lead to increased enforcement costs for the state or local government, are very minimal.

Cost to the State

State government already has budgeted 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.

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. For example, utilities offer compliance training such as “Decoding” talks to provide training and materials to local permitting departments. As noted earlier, although retraining is a cost of the revised standards, Title 24 energy efficiency standards are expected to increase economic growth and income with positive impacts on local revenue.

These proposed changes would revise an existing measure without significantly affecting the complexity of this measure. Therefore, on-going costs are not expected to change significantly.

3.5.6.2 Impacts on Specific 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

We expect that the proposed code changes for the 2016 Title 24 code change cycle would reduce energy costs and could put potential first-time homeowners in a better position to afford mortgage payments. On the other hand, homeowners may experience higher first costs to the extent that builders pass the increased costs of Title 24 compliance through to home buyers. Some financial institutions have progressive policies that recognize that home buyers can better afford energy efficiency homes (even with a higher first cost) due to lower energy costs.[13]

Renters will typically benefit from lower energy bills if they pay energy bills directly. These savings should more than offset any capital costs passed-through from landlords. Renters who do not pay directly for energy costs may see more of less of the net savings based on how much landlords pass the energy cost savings on to renters.

On average, low-income families spend less on energy than higher income families, however lower income families spend a much larger portion of their incomes on energy (Roland-Holst 2008). Thus it seems reasonable that low-income families would disproportionately benefit from Title 24 standards that reduce residential energy costs.

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, simulation 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. The baseline condition assumes that a building complies with the 2013 Title 24 Standards for residential walls. The existing standard is covered in Table 150.1-A of the 2013 Standards. Residential buildings built in all climate zones must meet the prescriptive U-factor requirement of 0.065 or less for above grade walls. U-factor requirements for interior, mass, and below grade walls are not being altered.

Table 150.1-A also provides examples of wall assemblies that meet the prescriptive requirements, including 2x4 framing with R13+5 and R15+4 insulation. The Statewide CASE Team assumes the lowest cost wall design meeting the 2013 CASE prescriptive requirements as the basis for all cost and savings calculations: 2x4 studs at 16” on-center, R-15 cavity insulation, plus 1” of R-4 continuous insulation.

[13] For example, see US EPA’s Energy Star website for examples: http://www.energystar.gov/index.cfm?fuseaction=new_homes_partners.showStateResults&s_code=CA.

4.2 Proposed Conditions

The proposed code change will require a wall assembly U-factor of 0.051. Table 10 shows the various assemblies and U-factors that were considered by the Statewide CASE Team. Projected energy savings from increased U-factor requirements for residential walls in each climate zone were calculated using the CBECC-Res energy simulation software for a variety of scenarios with U-factors between 0.051 and 0.043. The boxes highlighted in green indicate the wall assemblies and U-factors that were modeled and vetted by the Statewide CASE Team. The U-factor highlighted in red is the 2013 Standards prescriptive baseline. Wall assemblies with U-factors lower than the proposed U-factor of 0.051 are assumed to provide additional energy savings.

Table 10: Overall wall assembly U-factors for various interior and exterior insulation levels

Framing	Spacing (on center)	Cavity Insulation	Exterior insulation					
			none	R4	R5	R6	R8	R10
2x4	16"	R15	0.095	**0.065**	0.061	0.057	0.050	**0.045**
2x6	16"	R19	0.074	0.054	**0.051**	**0.048**	**0.043**	0.040
2x6	16"	R21	0.069	**0.051**	**0.048**	**0.046**	0.042	0.038
2x6	16"	R23	0.067	**0.049**	**0.047**	**0.044**	0.040	0.037
2x6	24"	R19	0.071	0.052	0.049	0.047	0.042	0.039
2x6	24"	R21	0.066	0.050	0.047	0.045	0.040	0.037
2x6	24"	R23	0.064	0.048	0.045	0.043	0.039	0.036

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4.3 Simulation Prototype Buildings

CBECC-Res is the modeling software used for energy simulation. According to CEC guidelines, the prototype buildings for this analysis are both the 2,100 and the 2,700 square foot prototypes defined in the Residential ACM Manual (Section 4.2) with 20% fenestration equally distributed across the four wall orientations and tile roofs. The framing area accounts for the surface area of all exterior walls, including sections with windows and doors. The cavity area is the total wall area minus the wood framing, windows and doors, and is used to calculate the square footage of insulation required for the house. Table 11 shows the summary characteristics and relevant components of the two prototypes, along with the relevant weighting used to represent the statewide average for costs and savings results.

Table 11: Prototype Buildings used for Energy, Demand, Cost, and Environmental Impacts Analysis

	Occupancy Type	Floor Area (Square Feet)	Number of Stories	Framing Area (Square Feet)	Cavity Area (Square Feet)	Relative Weighting for Statewide Estimates
Prototype 1	Residential	2,100	1	1,288	848	45%
Prototype 2	Residential	2,700	2	2,172	1,612	55%

4.4 Climate Dependent

The proposed measures have been modeled in each of California's 16 climate zones, as the impacts of envelope insulation are highly climate dependent. U-factors that proved cost-effective for individual climate zones have been proposed accordingly.

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.

TDV energy estimates are based on present-valued cost savings but are presented 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 the TDV[14] values that were used in the analyses for this report (CEC 2014a). 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 during the first year buildings complying with the 2016 Title 24 Standards are in operation. The Statewide CASE Team used the reference method, modeling using CBECC-Res without enhancements, to perform the energy analysis.

[14] As of July 3, 2014, TDV from the 2013 code cycle update was used as the 2016 TDV was not yet available.

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 building basis, weighted between the prototypes according to Table 11.

Analysis Tools

Parametric modeling (e.g., running batches of models) in CBECC-Res was used to complete over 10,000 simulations to cover the ranges of climate zones and assembly types possible. The results were exported and organized in a spreadsheet for analysis.

Key Assumptions

As mentioned, the CEC provided a number of key assumptions to be used in the energy impacts analysis (CEC 2014b). 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 12.

Table 12: Key assumptions for per unit Energy Impacts Analysis

Parameter	Assumption	Source	Notes
TDV Values	2016	CEC	-
Base Case Wall Assembly	U-factor: 0.065 2x4 16" O.C. R-15 + R-4 CI	2013 Title 24 Table 150.1-A Prescriptive Requirement for wood framed walls.	Wall assembly that is minimally compliant with 2013 Title 24 prescriptive requirements.
Weighting of results	55% 2,700 sf prototype, 45% 2,100 sf prototype	CEC	CEC assumes this 55/45 ratio is representative of typical construction statewide.

4.6.2 Statewide Energy Impacts Methodology

First Year Statewide Impacts

The CEC Demand Analysis office provided the projected annual residential dwelling starts for the single family and multifamily sectors. CEC provided three projections: low, mid and high estimates with each cases broken out by 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 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 14.

The Statewide CASE Team estimated statewide impacts for the first year that new houses comply with the 2016 Title 24 Standards by multiplying per unit savings estimates by statewide construction forecasts.

Table 13: Translation from FCZ to BCZ

		Building Standards Climate Zones (BCZ)																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Grand Total
Forecast Climate Zones (FCZ)	1	22.51%	20.62%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	9.80%	33.14%	0.16%	0.00%	0.00%	13.77%	100.00%
	2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	22.00%	75.70%	0.00%	0.00%	0.00%	2.30%	100.00%
	3	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	20.95%	22.76%	54.50%	0.00%	0.00%	1.79%	100.00%
	4	0.15%	13.73%	8.36%	46.03%	8.94%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	22.81%	0.00%	0.00%	0.00%	0.00%	100.02%
	5	0.00%	4.23%	89.13%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	6.64%	0.00%	0.00%	0.00%	0.00%	100.00%
	6	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	100.00%
	7	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	75.80%	7.08%	0.00%	17.12%	100.00%
	8	0.00%	0.00%	0.00%	0.00%	0.00%	40.37%	0.00%	51.08%	8.09%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.46%	100.00%
	9	0.00%	0.00%	0.00%	0.00%	0.00%	6.97%	0.00%	24.54%	57.85%	0.00%	0.00%	0.00%	0.00%	6.68%	0.00%	3.95%	99.99%
	10	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	74.90%	0.00%	0.00%	0.00%	12.27%	7.90%	4.93%	100.00%
	11	0.00%	0.00%	0.00%	0.00%	0.00%	33.04%	0.00%	24.75%	42.21%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
	12	0.00%	0.00%	0.00%	0.00%	0.00%	0.92%	0.00%	20.20%	75.19%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	3.69%	100.00%
	13	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	69.55%	0.00%	0.00%	28.77%	0.00%	0.00%	0.00%	1.56%	0.09%	0.00%	99.97%
	14	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
	15	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.12%	99.88%	0.00%	100.00%
	16	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
	17	2.95%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	97.05%	100.00%

Table 14: CEC Residential New Construction Forecast Households Mid Case

Source: CEC Demand Analysis Office

Building Climate Zone	Single Family Starts	Multifamily Starts
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.

The proposed code change will apply to all low-rise residential new construction of above grade wood-framed walls. As shown in Section 5.2, the proposed measure is cost effective in Climate Zones 1-5 and 8-16, therefore the statewide energy impacts do not include any impacts in climate zones 6 or 7.

The total statewide savings are based on a model of the proposed U-factor (0.051).

4.7 Cost-effectiveness Methodology

This measure proposes a mandatory and prescriptive requirement. As such, a lifecycle cost analysis is required to demonstrate that the measure is cost-effective over the 30 year period of analysis. The two proposed measures have been proven cost-effective independently of one another, and in tandem.

CEC's procedures for calculating lifecycle cost-effectiveness are documented in LCC Methodology (CEC 2014b). 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 equipment 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.

4.7.1 Incremental Cost Methodology

Cost estimates were primarily derived from online data from Big-Box retailers and interviews with builders, contractors, manufacturers, and residential energy efficiency program implementers. When cost information was limited or unavailable from these sources, the Statewide CASE Team relied upon RSMeans Online (RSMeans 2014). The majority of RSMeans cost estimates are higher than those received from builders and contractors, and may have led to higher incremental cost estimates. Thus, the Statewide CASE Team has a high degree of confidence that the lifecycle cost savings presented in this report are conservative – i.e. measures may be more cost-effective in practice than we assume for this analysis.

The Statewide CASE Team and CEC met with CBIA and ConSol to discuss cost assumptions from the initial docketed draft CASE report. Based on these discussions, the CASE team revised the cost assumptions. Although the two parties have not eliminated the cost differences between their respective estimates, the margin of difference is significantly smaller than the original and both parties agree that the cost differences are minor and within reasonable error bounds.

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.

Key assumptions used to derive costs are presented in Table 15.

Table 15: Key Assumptions for per unit Incremental Construction Cost

Parameter	Assumption	Source	Notes
Baseline wall assembly	2x4" studs, 16" on center, R-15 cavity insulation, R-4 exterior insulation	2013 Title 24 Table 150.1-A Prescriptive Requirement for wood framed walls.	The Statewide CASE Team assumes the lowest cost wall design meeting the 2013 CASE prescriptive requirements as the basis for all cost and savings calculations
Rigid insulation average costs	\$0.55 ft^2 - \$1.73/ft^2	Builder survey, distributors, manufacturers, retailers	Range from R-4 to R-10, and include EPS, XPS and polyiso boards
Oriented strand board average costs	\$0.81 - \$1.85/ft^2	RSMeans Online, retailers	Average of 7/16", 1/2", and 5/8" thicknesses
Wall framing average costs	\$1.01/ft^2 - \$1.13/ ft^2	RSMeans Online	Average costs for 2x4 @ 16 o.c. and 2x6 @ 16 o.c. exterior wall framing
Batt insulation average costs	\$0.41/ft^2 - \$1.05/ ft^2	Online, builder survey, manufacturers, retailers	Range from R-13 low-density to R-23 high-density
Additional Framing / Rough Opening Extension Support Element	15 minutes per window plus lumber	Interview with window manufacturer	Rough Opening Extension Support Element (picture frame with 1x2 or 2x2) built out and protruding from the sheathing around each rough opening such that the window aligns with the exterior insulation in order to facilitate proper integration and alignment with exterior cladding
Prototype wall areas	1,774 ft^2 wall areas 506 ft^2 window areas 1,268 ft^2 for wall insulation areas	2013 Title 24 Reference ACM	Areas includes 45/55 weighting of 2,100 ft^2 and 2,700 ft^2 prototypes

According to the LCC Methodology (CEC 2014b), 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 Cost Savings Methodology

Energy Cost Savings Methodology

The Present Value (PV) of the energy savings were calculated using the method described in the LCC Methodology (CEC 2014b). In short, the hourly energy savings estimates for the first year of building operation were multiplied by the TDV cost values to arrive at the PV of the cost savings over the period of analysis.

This measure does not have any non-energy cost savings.

4.7.3 Cost-effectiveness Methodology

The Statewide CASE Team calculated the cost-effectiveness using the LCC Methodology (CEC 2014b). 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 1.0 or greater (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 assuming that 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).

Greenhouse Gas Emissions Monetization Methodology

The 2016 TDV cost values include the monetary value of avoided GHG emissions, so the Cost-effectiveness Analysis presented in Section 5.2 of this report does include the cost savings from avoided GHG emissions. The monetization for the TDV values includes permit (retail) cost of avoided GHG emissions, but it does not include the social costs of avoided emissions. As evident in the results of the Cost-effectiveness Analysis, the value of avoided GHG emissions is aggregated into the total TDV cost savings and the contribution of GHG emissions is not easily discernible.

4.8.2 Material Impacts Methodology

Conversations with the APA-The Engineered Wood Association and the American Wood Council determined that increased usage of 2x6 studs would have a minimal impact on lumber usage. Smaller wood comes from federally leased land, where the forests are thinned to let the larger trees grow. Those logs account for approximately 2% of the demand. Replacing 2x4 studs with 2x6 results in the smaller pieces being used for other products such as glulams (glue laminated wood). The algorithms for how boards are cut from timber are proprietary, but the capacity for lumber production has increased over time. Overall, the U.S. is adding forests, not deforesting.

The 2013 CASE Report on Increased Wall Insulation (IOU 2013) performed extensive lumber usage estimates determining that lumber usage will not be significantly affected if the building industry moves from the status quo (2x4) to more 2x6 construction:

“*The proposed measure does not have substantial adverse impacts on the environment. The proposed measure will result in less lumber consumption, for homes in climates zones 1 and 11-16, where 2x6 16-inch on center framing is the assumed baseline. However, the use of 2x6 framing in place of 2x4 framing will increase the board feet of lumber for framing in homes in climate zones 2 through 10, where 2x4 framing is the baseline.*”

*“Results, shown in [*Figure 1*], estimate a 1.7% increase in total lumber use per home in climate zones 2 through 10, and a 3% decrease in climate zones 1 and 11 through 16. If 35% of all lumber consumed is for residential new construction, using new construction estimates as outlined in detail in section 7.3, the measure will reduce total lumber consumption in California by 2.12%*”

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

Figure 1: Change in board feet from base case framing to proposed framing (2013 CASE report)

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

As explained in section 2.1.2, the 2013 CASE report estimated that some 2x6 wall framing (23%) is used in exterior wall framing projects, so an increase in lumber usage of 3.7% is a conservative estimate.

5. Analysis and Results

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

Residential walls in climate zones 1-6 and 9-16 (all but the Southern California coast) can cost effectively achieve a U-factor of 0.051 or less using 2x6 framing spaced at 16" on center with R-19 unfaced fiberglass batt insulation in the cavities and R-5 continuous insulation (expanded polystyrene insulated sheet (EPS) or polyisocyanurate (polyiso) rigid foam insulation). Spacing the studs at 24" on center instead of 16" has the potential to use less wood, reducing the framing cost and framing factor of the wall assembly, thus increasing the cost-effectiveness of the energy savings. If a builder strongly prefers to use 2x4" studs, R-15 unfaced fiberglass batt cavity insulation in combination with 2" (R-8) continuous insulation (extruded polystyrene (XPS) or polyiso rigid foam board) will meet the proposed U-factor.

There are several other methods available for achieving a U-factor of 0.051 or less, including Structurally Insulated Panels (SIPs), Insulated Concrete Forms (ICF), staggered studs, double walls, and flash and batt insulation[15]. The Statewide CASE Team did not analyze these strategies for cost-effectiveness, but these options are available using the performance approach. At the CEC's request, the Statewide CASE Team has provided results from additional assemblies, specifically with a U-factor=0.049, in Appendix C: CBECC-Res Simulation Results .

Adding exterior insulation to a wall assembly increases the importance and complexity of flashing around the windows to improve moisture control within that wall. To account for the added cost and complexity of flashing around each window in the presence of exterior insulation greater than 1-1/4 inches, we included a cost estimate to frame around each rough opening. In consultation with a leading window manufacturer, we estimated this effort should take approximately 15 minutes per window once the installer is familiar with the technique.

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[15] "Flash and batt" refers to the use of spray foam and fiberglass batts together in a single cavity. Usually this entails at least two inches of closed cell foam in a six-inch cavity, with open faced batt insulation filling the remainder of the cavity. This technique usually provides improved air sealing, as the foam acts as an air barrier, however there are increased moisture concerns, particularly in colder climates.

5.1 Energy Impacts Results

5.1.1 Per Unit Energy Impacts Results

The Statewide CASE Team modeled the whole building energy impacts for a variety of wall assemblies at various U-factors. Based on direction from the CEC all results presented in this report are weighted as described in Section 4.3 and shown again below in Table 16.

Table 16: Prototype Buildings used for Energy, Demand, Cost, and Environmental Impacts Analysis

	Occupancy Type	Floor Area (Square Feet)	Number of Stories	Framing Area (Square Feet)	Cavity Area (Square Feet)	Relative Weight to Statewide Estimates
Prototype 1	Residential	2,100	1	1,288	848	45%
Prototype 2	Residential	2,700	2	2,172	1,612	55%
Weighted Prototype	Residential	2,430	2	1,774	1,268	100%

The U-factors of the wall assemblies modeled are listed in Table 17. The results of the energy simulations per weighted prototype are presented in Table 18.

Table 17: U-factors of wall assemblies modeled

U-factor	Framing	Spacing (o.c.)	Cavity Insulation	Exterior Insulation
U=0.051	2x6	16”	R-21	R-4
U=0.051	2x6	16”	R-19	R-5
U=0.049	2x6 2x6	16” 16”	R-23 R-19	R-4 R-6
U=0.046	2x6	16”	R-21	R-6
U=0.044	2x6	16”	R-23	R-6
U=0.050	2x4	16”	R-15	R-8
U=0.045	2x4	16”	R-15	R-10

Table 18: Energy savings per weighted prototype for various wall assembly U-factors

Energy Savings	U=0.051		U=0.050		U=0.049		U=0.046		U=0.045	
	kWh	Therms	kWh	Therms	kWh	Therms	kWh	Therms	kWh	Therms
Climate Zone 1	31	36	31	36	35	41	41	48	41	48
Climate Zone 2	27	22	26	22	31	25	36	30	34	30
Climate Zone 3	17	18	16	18	19	21	22	24	22	24
Climate Zone 4	28	19	25	19	31	22	36	26	33	25
Climate Zone 5	16	19	15	18	18	21	21	25	20	24
Climate Zone 6	13	10	12	10	15	12	17	14	16	13
Climate Zone 7	7	5	6	5	8	5	9	6	8	6
Climate Zone 8	23	8	19	8	26	9	30	11	26	11
Climate Zone 9	43	11	39	11	49	12	56	14	51	14
Climate Zone 10	55	12	50	12	62	14	72	16	66	16
Climate Zone 11	101	22	99	23	115	25	135	30	132	30
Climate Zone 12	60	22	55	22	67	25	79	30	73	30
Climate Zone 13	107	20	104	20	121	22	142	27	139	27
Climate Zone 14	95	23	93	23	108	26	127	31	124	30
Climate Zone 15	234	4	235	4	264	4	314	5	312	5
Climate Zone 16	43	42	41	43	48	48	57	57	55	57

It is estimated that the total TDV energy savings over the 30 year period of analysis will range from 1,439 kBTU in climate zone 7 to 9,913 kBTU in climate zone 15 for U-factor=0.051. The TDV methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods.

Table 19: Energy Impacts per Weighted Prototype with Exterior Walls, U-factor=0.051[1]

Climate Zone	Per Unit First Year Savings[2]			
	Electricity Savings[4] (kWh/yr)	Demand Savings (kW)	Natural Gas Savings (Therms/yr)	Total TDV Savings[5] (kBTU)
Climate Zone 1	31	0.00	36	6,636
Climate Zone 2	27	0.01	22	5,167
Climate Zone 3	17	0.00	18	3,707
Climate Zone 4	28	0.03	19	4,747
Climate Zone 5	16	0.00	19	3,571
Climate Zone 6	13	0.02	10	2,576
Climate Zone 7	7	0.01	5	1,439
Climate Zone 8	23	0.05	8	3,056
Climate Zone 9	43	0.09	11	4,927
Climate Zone 10	55	0.09	12	5,331
Climate Zone 11	101	0.11	22	9,313
Climate Zone 12	60	0.09	22	7,753
Climate Zone 13	107	0.14	20	9,437
Climate Zone 14	95	0.12	23	8,846
Climate Zone 15	234	0.19	4	9,913
Climate Zone 16	43	0.03	42	8,809

1. Each unit refers to one house, using the weighting of prototypes representing average new construction as described in Section 4.3, with a wall assembly U-factor=0.051.
2. Savings from one unit (weighted prototype building), for the first year the building is in operation.
3. TDV energy savings for one unit (weighted prototype building) for the first year the building is in operation.
4. Site electricity savings. Does not include TDV of electricity savings.
5. Calculated using CEC's 2016 TDV factors and methodology. Includes savings from electricity and natural gas.

5.1.2 Statewide Energy Impacts Results

First Year Statewide Energy Impacts

The individual statewide energy impacts of high performance walls (U-factor=0.051) are presented in Table 20. As shown in Section 5.2, the proposed measure is cost effective in Climate Zones 1-5 and 8-16, therefore the statewide energy impacts do not include climate zones 6 or 7.

Table 20: Statewide Energy Impacts of Exterior Walls, U-factor=0.051

Climate Zone	First Year Statewide Savings[1]			
	Electricity Savings[3] (GWh)	Power Demand Reduction (MW)	Natural Gas Savings (MMtherms)	Total TDV Savings[4] (Million kBTU)
Climate Zone 1	0.02	0.00	0.02	5
Climate Zone 2	0.07	0.04	0.06	13
Climate Zone 3	0.09	0.03	0.09	19
Climate Zone 4	0.17	0.20	0.11	28
Climate Zone 5	0.02	0.00	0.02	4
Climate Zone 6	n/a	n/a	n/a	n/a
Climate Zone 7	n/a	n/a	n/a	n/a
Climate Zone 8	0.16	0.35	0.06	22
Climate Zone 9	0.36	0.75	0.09	41
Climate Zone 10	0.91	1.55	0.20	89
Climate Zone 11	0.60	0.65	0.13	56
Climate Zone 12	1.17	1.67	0.42	151
Climate Zone 13	1.48	1.99	0.27	131
Climate Zone 14	0.32	0.39	0.08	30
Climate Zone 15	0.91	0.74	0.02	39
Climate Zone 16	0.13	0.08	0.13	28
TOTAL	**6.4**	**8.4**	**1.7**	**654**

1. First year savings from all buildings built statewide during the first year the 2016 Standards are in effect.
2. First year TDV savings from all buildings built statewide during the first year the 2016 Standards are in effect.
3. Site electricity savings.
4. Calculated using CEC's 2016 TDV factors and methodology.

As shown in Table 20, during the first year buildings complying with the 2016 Title 24 Standards are in operation, the proposed measures are expected to reduce annual statewide electricity use by 6.4 GWh and electricity demand by 8.4 MW. Natural gas use is expected to be reduced by 1.70 MMtherms. All assumptions and calculations used to derive per unit and statewide energy and demand savings are presented in Section 4.6.2 of this report.

5.2 Cost-effectiveness Results

5.2.1 Incremental Cost Results

The incremental cost of the proposed measure, relative to existing conditions, is presented in Table 21. 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. Upon review, the Statewide CASE Team determined that there is no incremental maintenance costs associated with the proposed code change.

Table 21: Incremental Cost of Proposed Measure 2016 Present Value Dollars[1]

Condition	Initial Construction Cost		Incremental Present Value of Maintenance Cost[4]	Total Incremental Cost[5]
	Current[2]	Post Adoption[3]		
Existing Conditions	$18,614	$18,614	n/a	n/a
Proposed Conditions	$19,118	$19,118	n/a	$504
Incremental[1]	$504	$504	n/a	-

1. Incremental costs equal the difference between existing conditions and proposed conditions. Negative values indicate the Proposed Conditions are less expensive than Existing Conditions.
2. Initial construction cost using current prices; ΔCI_C
3. Initial construction cost using estimated prices after adoption; ΔCI_{PA}
4. Present value of maintenance costs over 30 year period of analysis; ΔCM.
5. Total costs equals incremental cost (post adoption) plus present value of maintenance costs; $\Delta CI_{PA} + \Delta CM$

The incremental cost presented in Table 21 is based on the costs presented in Table 22 for the scenario with U-factor = 0.051. Although the CASE Team analysis arrived at a total incremental cost of $504 for the proposed wall assembly, the CASE Team has elected to use a value of $517, which was derived during discussions with CEC, CBIA and ConSol.

Table 22: Incremental Cost per weighted prototype for various wall assemblies and U-factors

Stud	O.C.	Cavity Insulation	Exterior (rigid) insulation	Wall Assembly U-Value	Incremental Cost
2x4	**16**	**R-15**	**R-4 (1")**	**0.065**	**-**
2x6	16	R-19	R-5 (1")	0.051	$517
2x6	16	R-21	R-4 (1")	0.051	$718
2x6	16	R-15	R-8 (2")	0.050	$782
2x6	16	R-23	R-4 (1")	0.049	$785
2x6	16	R-19	R-6 (1.5")	0.049	$684
2x6	16	R-23	R-5 (1")	0.047	$1,029
2x6	16	R-21	R-6 (1.5")	0.046	$783
2x4	16	R-15	R-10 (2")	0.045	$1,253
2x6	16	R-23	R-6 (1.5")	0.044	$1,209
2x6	16	R-19	R-8 (2")	0.043	$1,042

The incremental cost of changing from R-4 continuous insulation to R-5 is approximately $226 per weighted prototype, including the cost of the materials, labor and additional window framing required. Changing from 2x4 studs to 2x6 studs increases the lumber costs by approximately $628. Changing from a high density cavity insulation (R-15) to a low density batt (R-19) results in a cost savings of approximately $337. The breakdown of the incremental costs by building component is detailed in Figure 2 in the next section, Incremental Construction Cost Results.

Incremental Construction Cost Results

As described in Section 4.7.1, cost data was collected from interviews with builders, manufacturers, retailers and distributors, retailer on-line data, and supplemented with RSMeans cost data points as appropriate (RSMeans 2014). For situations when only product costs were available, the Statewide CASE Team added the estimated labor component as estimated by RSMeans. The team calculated incremental construction costs for several scenarios covering a variety of wall assemblies and U-factors. This calculation is based on the costs presented in Table 23.

Table 23: Cost basis for incremental cost calculation

Product Type	R-Value	Description	$/Unit	Unit/home	Unit	$/home [16]
Concrete Stucco	-	Stucco, 3 coats, float finish, with mesh, on wood frame, 1" thick	$4.89	1268	ft²	$6,200
	-	One-coat stucco	$3.86			$4,896
Batt Insulation	13	Fiberglass, foil faced and unfaced, 3.5"	$0.70	1268	ft²	$883
	15	Blanket, mineral wool, 3.5"	$0.98			$1,244
	19	Fiberglass kraft faced, foil faced, and unfaced, 6"	$0.79			$998
	21	Fiberglass unfaced batt insulation, 6"	$1.03			$1,304
	23	Blanket, mineral wool, 5.5"	$1.06			$1,349
Rigid Insulation	2	EPS (Expanded Polystyrene Foam Board)	$0.73	1268	ft²	$931
	4	EPS, and molded bead board	$0.83			$1,050
	5	XPS (Extruded Polystyrene), polyiso and molded bead board	$0.98			$1,429
	6	EPS, polyiso	$1.02			$1,300
	8	EPS, and molded bead board	$1.21			$1,538
	10	XPS, polyiso	$1.50			$1,904
Spray foam	R4/in	open cell spray foam	$0.38	2x4 – 4,439	board foot	$1,665
				2x6 – 6,975		$2,616
	R7/in	closed cell spray foam	$1.00	2x4 – 4,439	board foot	$4,439
				2x6 – 6,975		$6,975
Loose fill	21	Poured insulation, cellulose fiber, R3.8 per inch, 6" thick	$0.90	1268	ft²	$1,143
Gypsum board	-	Standard and fire resistant	$0.74	1268	ft²	$938
OSB	-	7/16", 1/2", 5/8"	$1.36	1774	ft²	$2,414
Weather Barrier	-	Asphalt felt, polyproylene, and polyethylene	$0.25	1774	ft²	$447
Wood Framing	-	2x4 16"OC	$1.01	1774	ft²	$1,793
	-	2x6 16"OC	$1.13			$2,005
	-	2x6 24"OC	$0.99			$1,765
Metal Flashing	-	Sheet Metal Cladding, aluminum, window casing, up to 6 bends, .024" thick	$4.84	118	ft²	$571
Additional sill flashing with exterior insulation	R4/5 (1")	Picture framing around rough opening (each window) to account for 1" of exterior insulation	$14.31	32	window	$458
	R6 (1.5")	Picture framing around rough opening (each window) to account for 1.5" of exterior insulation	$16.47			$527
	R8/10 (2")	Picture framing around rough opening (each window) to account for 2" of exterior insulation	$18.45			$591

The CASE Team and CEC staff discussed the measure costs in the docketed draft CASE report with CBIA and ConSol who had developed their own cost estimates. The purpose of the meetings were to understand and resolve differences and reduce the discrepancy in total measure cost estimates between CBIA and the CASE Team's estimates. Table 24 below provides the updated cost estimates discussed during the CEC and CASE Team's meetings with CBIA and ConSol. As a result of these conversations, the CASE Team continued data

[16] Each home described here is the representative prototype described in Section 4.3, which weighted as 45% the 2,100 sf CEC residential prototype and 55% the 2.700 sf CEC residential prototype.

collection and discussions with industry members to develop revised cost estimates. Although the two parties have not eliminated the cost differences between their respective estimates, the margin of difference is significantly smaller than the original and both parties agree that the cost differences are minor and within reasonable error bounds.

The costs in **Error! Reference source not found.** are each an average among the 2,100 square foot and 2,700 square foot prototypes, using CBIA building area assumptions for consistency, which differ from the CEC prototype. Costs derived from RS Means already include a markup, which is consistent with CBIA methodology. The CBIA assumes a 50%/50% split between the two prototypes; whereas, the CASE Team assumes a 45%/55% split based on CEC forecast. The CASE Team estimates are based on the per unit incremental costs in Table 23; the difference between the whole house costs below and those in Table 21 is the area assumptions for each prototype.

Table 24: CBIA and CASE Team Cost Assumption Comparison

Parameter	CBIA Cost Estimate[1]	CASE Cost Estimate[2]
Framing/Lumber to 2x6 at 16” O.C. construction	$589	$628
Cavity Insulation (R-19)	($269)	($337)
Insulating Sheathing (R-5)	$287	$226
TOTAL COST (weighted)	**$608**	**$517**

[1]CBIA assumes a 50/50 split between the two single family prototypes.

[2]CASE Team assumes a 45/55 split between the two single family prototypes.

Figure 2 below details the cost premium for the components of each wall assembly compared to two different baselines: 1) 2x4 framed 16” o.c. with R-15 cavity and R-4 exterior insulation; and 2) 2x6 framed 16” o.c. with R-19 cavity and R-2 exterior insulation. The second baseline provides the estimated cost premium for builders already constructing walls using 2x6 studs to meet the 2013 prescriptive U-factor of 0.065.

Figure 2 shows that the two different baselines account for a price difference of less than ten dollars for any of the modeled scenarios. The color coding in the chart shows the tradeoff between the cost for framing and cost for insulation. The cost for 2x4 framing is cheaper than 2x6, but R-15 cavity insulation is more expensive than R-19 cavity insulation. Additionally rigid exterior insulation generally gets more expensive as the R-value increases. The rightmost scenario shows the cost savings potential from spacing 2x6 studs at 24 inches on center instead of at 16 inches.

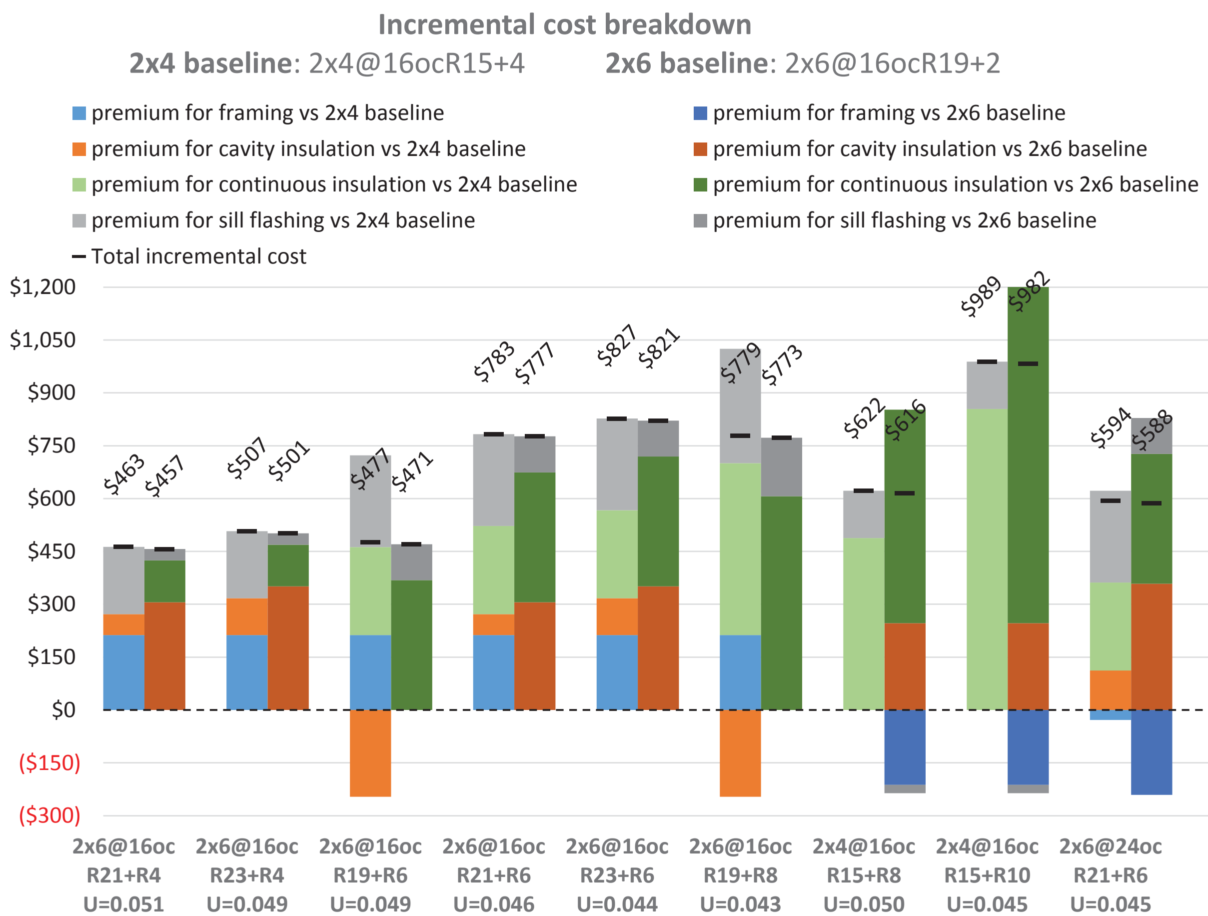

Figure 2: Incremental Cost Breakdown for various assemblies, U-factors 0.051 to 0.043

Incremental Maintenance Cost Results

As described in Section 3.3, there are assumed to be zero incremental maintenance costs associated with the code change proposal, relative to existing conditions. The higher R-value rigid insulation, cavity insulation, and deeper framing needed to meet the proposed requirements are similar to the current components, and are low maintenance if installed properly and no changes are made to the wall.

5.2.2 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. These are the present dollar value of the energy savings resulting from building a wall with a U-factor of 0.051, and separately, the present dollar value of the energy savings resulting from constructing a wall with a U-factor of 0.065 (the 2013 Standards prescriptive U-factor).

Table 25: TDV Energy Cost Savings Over 30 Year Period of Analysis - Per Weighted prototype, 2016 PV $

Climate Zone	U-factor=0.051
Climate Zone 1	$1,148
Climate Zone 2	$894
Climate Zone 3	$641
Climate Zone 4	$821
Climate Zone 5	$618
Climate Zone 6	$446
Climate Zone 7	$249
Climate Zone 8	$529
Climate Zone 9	$852
Climate Zone 10	$922
Climate Zone 11	$1,611
Climate Zone 12	$1,341
Climate Zone 13	$1,633
Climate Zone 14	$1,530
Climate Zone 15	$1,715
Climate Zone 16	$1,524

Given data regarding the new construction forecast for 2017, the Statewide CASE Team estimates TDV energy cost savings (30 year) of $237 million for all single family houses built in climate zones 1-5 and 8-16 with a wall assembly U-factor of 0.051 during the first year the 2016 Standards are in effect.

Other Cost Savings Results

This measure does not have any non-energy cost savings.

5.2.3 Cost-effectiveness Results

The results of the lifecycle Cost-effectiveness Analyses per house for a U-factor=0.051 is presented in Table 26. The proposed measure saves money over the 30 year period of analysis relative to the existing conditions in the climate zones for which the new requirements are proposed; climate zones 1-5 and 8-16. The proposed U-factor is not cost effective in climate zones 6 or 7 (the southern California coast).

Table 26: Cost-effectiveness Summary for Exterior Walls, U-factor=0.051[1]

Climate Zone	Benefit: TDV Energy Cost Savings [2] (2016 PV$)	Cost: Total Incremental Cost[3] (2016 PV$)	Change in Lifecycle Cost[4] (2016 PV$)	Benefit to Cost Ratio[5]
Climate Zone 1	$1,148	$517	($631)	2.2
Climate Zone 2	$894	$517	($377)	1.7
Climate Zone 3	$641	$517	($124)	1.2
Climate Zone 4	$821	$517	($304)	1.6
Climate Zone 5	$618	$517	($101)	1.2
Climate Zone 6	$446	$517	$71	0.9
Climate Zone 7	$249	$517	$268	0.5
Climate Zone 8	$529	$517	($12)	1.0
Climate Zone 9	$852	$517	($335)	1.6
Climate Zone 10	$922	$517	($405)	1.8
Climate Zone 11	$1,611	$517	($1,094)	3.1
Climate Zone 12	$1,341	$517	($824)	2.6
Climate Zone 13	$1,633	$517	($1,116)	3.2
Climate Zone 14	$1,530	$517	($1,013)	3.0
Climate Zone 15	$1,715	$517	($1,198)	3.3
Climate Zone 16	$1,524	$517	($1,007)	2.9

1. Relative to existing conditions. All cost values presented in 2016 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 cost 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 1.0 or greater.

Given data regarding the new construction forecast for 2017, the Statewide CASE Team estimates a 30 year lifecycle cost savings of $63 million for all single family houses built in climate zones 1-5 and 9-16 with a wall assembly U-factor of 0.051 during the first year the 2016 Standards are in effect.

There are various strategies available to achieve the proposed prescriptive U-factor of 0.051 or less in climate zones 1-5 and 8-16. The cost-effectiveness of three such scenarios are presented below in Figure 3. The scenario with a U-factor of 0.051 constructed with 2x6 framing spaced 16” on center with R-5 rigid exterior (continuous) insulation provides the basis for energy savings and cost-effectiveness calculations supporting this code change proposal. Some builders may choose an alternative compliant assembly in some climate zones, such as R-21 cavity insulation in place of R-19, to allow them to continue using R-4 exterior insulation, which is the current common practice. There may be reasons other than energy performance that would prompt a builder to want to meet the code requirements while still using 2x4 framing at 16” on center with R-8 continuous insulation. Regardless of the assembly chosen, there are multiple options available to meet the proposed requirements in a cost effective manner.

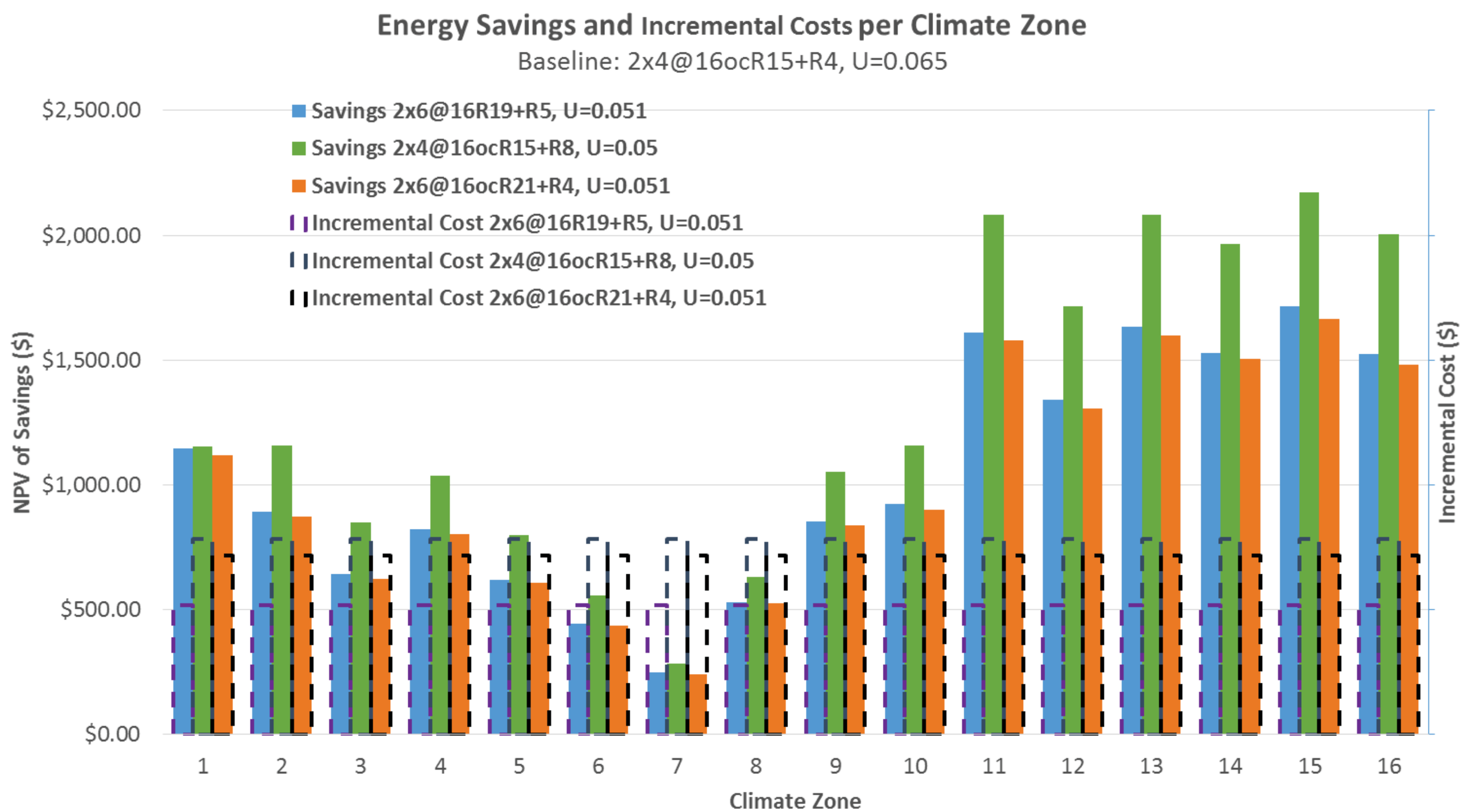

Figure 3: Energy Savings and Incremental Costs of Assemblies with U-factors 0.051 or less

5.3 Environmental Impacts Results

5.3.1 Greenhouse Gas Emissions Results

Table 27 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. 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 27: Statewide Greenhouse Gas Emissions Impacts for Exterior Walls, U-factor=0.051

Climate Zone	First Year Statewide Avoided GHG Emissions[1] ($MTCO_2e/yr$)
Climate Zone 1	139
Climate Zone 2	331
Climate Zone 3	533
Climate Zone 4	660
Climate Zone 5	121
Climate Zones 6, 7, 8	n/a
Climate Zone 9	593
Climate Zone 10	1393
Climate Zone 11	920
Climate Zone 12	2666
Climate Zone 13	1978
Climate Zone 14	512
Climate Zone 15	403
Climate Zone 16	744
TOTAL	10,993

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 28.

Table 28: 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)	NC	NC	NC	NC	NC	NC
Per Unit Impacts[3]	n/a	n/a	n/a	n/a	n/a	n/a
Statewide Impacts (first year)	n/a	n/a	n/a	n/a	n/a	n/a
Comment on reasons for your impact assessment	n/a	n/a	n/a	n/a	n/a	n/a

1. Does not include water savings at power plant
2. Assumes embedded energy factor of 10,045 kWh per million gallons of water.
3. Unit means per prototype building. For description of prototype buildings refer to section 4.3.

5.3.3 Material Impacts Results

The proposed requirements recommend, but do not require changing standard practice from 2x4 studs to 2x6 studs. The material impacts below conservatively estimate the increase in lumber of all wall construction previously used 2x4 studs and as a result of this code change will use 2x6 studs. A weight of 33lbs per cubic foot of wood framing material is assumed.

Table 29: Impacts of Material Use

	Impact on Material Use Material Increase (I), Decrease (D), or No Change (NC) compared to base case (lbs/year)					
	Mercury	Lead	Copper	Steel	Plastic	Wood (lumber)
Impact (I, D, or NC)	NC	NC	NC	NC	NC	I
Per Unit Impacts	n/a	n/a	n/a	n/a	n/a	21
Statewide Impacts (first year)	n/a	n/a	n/a	n/a	n/a	2,287,428

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).

This measure is modifying the prescriptive U-factor requirements for residential wood-framed walls from 0.065 to 0.051 in all climate zones that were proven cost effective (1-5 and 9-16).

6.1 Standards

This measure requires updating the language contained in row two (2) of Table 150.1-A Component Package A with the values in Table 22, below, and editing associated footnotes.

SECTION 150.1 – PERFORMANCE AND PRESCRIPTIVE COMPLIANCE APPROACHES FOR NEWLY CONSTRUCTED RESIDENTIAL BUILDINGS

Table 150.1-A

Table 30: Proposed changes to the 2013 Standards Table 150.1-A Component Package A

Climate Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Building Envelope, Insulation, Walls, Above Grade, ~~2x4~~ Wood Framed[1]	~~U-0.065~~ ~~R 15+4 or R13+5~~ U-0.051 or R-19+5	~~U-0.065~~ ~~R 15+4 or R13+5~~ U-0.051 or R-19+5	~~U-0.065~~ ~~R 15+4 or R13+5~~ U-0.051 or R-19+5	~~U-0.065~~ ~~R 15+4 or R13+5~~ U-0.051 or R-19+5	~~U-0.065~~ ~~R 15+4 or R13+5~~ U-0.051 or R-19+5	U-0.065 R 15+4 or R13+5	U-0.065 R 15+4 or R13+5	~~U-0.065~~ ~~R 15+4 or R13+5~~ U-0.051 or R-19+5	~~U-0.065~~ ~~R 15+4 or R13+5~~ U-0.051 or R-19+5	~~U-0.065~~ ~~R 15+4 or R13+5~~ U-0.051 or R-19+5	~~U-0.065~~ ~~R 15+4 or R13+5~~ U-0.051 or R-19+5	~~U-0.065~~ ~~R 15+4 or R13+5~~ U-0.051 or R-19+5	~~U-0.065~~ ~~R 15+4 or R13+5~~ U-0.051 or R-19+5	~~U-0.065~~ ~~R 15+4 or R13+5~~ U-0.051 or R-19+5	~~U-0.065~~ ~~R 15+4 or R13+5~~ U-0.051 or R-19+5	~~U-0.065~~ ~~R 15+4 or R13+5~~ U-0.051 or R-19+5

[1] U-factors can be met by cavity insulation alone or with continuous insulation alone, or with both cavity and continuous insulation that results in a U-factor equal to or less than the U-factor shown. "~~R-15+4~~ R-19+5" means ~~R-15~~ R-19 cavity insulation plus ~~R-4~~ R-5 continuous insulation sheathing. Any combination of cavity insulation and/or continuous insulation that results in a U-factor equal to or less than ~~0.065~~ 0.051 is allowed.

6.2 Reference Appendices

No proposed changes.

6.3 ACM Reference Manual

No proposed changes.

6.4 Compliance Manuals

The following sections of the Residential Compliance Manual will need to be revised:

1.6.3 – Prescriptive Package A – 150.1(c)
3.6 – Envelope Features.

Specific edits to the manual will be determined at the conclusion of the CEC rulemaking process.

6.5 Compliance Forms

The proposed code change will modify the following compliance forms listed below.

- **CF1R-NCB-01-E** – CERTIFICATE OF COMPLIANCE – DATA FIELD DEFINITIONS AND CALCULATIONS.

6.5.1 B. OPAQUE SURFACE DETAILS – Framed

1. Tag/ID: A label (if any) from the plans, such as A1.4 or wall.
2. Assembly Type: Roof, Ceiling, Wall, Floor over crawlspace or floor over exterior.
3. Frame type: Wood or Metal.
4. Frame Depth: Nominal dimensions (in inches) of framing material such as 2x4 or 2x6.
5. Frame Spacing: 16 or 24 (inches on center).
6. Cavity R-value: Cavity R-value: insulation installed between framing members. NOTE: Wall U-factor required for ~~all~~ climate zones 6, 7, and 8 is 0.065. Wall U-factor required for climate zones 1-5 and 9-16 is 0.051.
~~This~~ The U-factor~~s~~ of 0.065 can be met by wood framed 2x4 walls with R-13 cavity + R5 continuous insulation (not interrupted by framing), R-15 cavity plus R-4 continuous insulation, or any combination of cavity and/or continuous insulation that results in a U-factor equal to or less than 0.065. The U-factor of 0.051 can be met by wood framed 2x6 walls with R-19 cavity + R5 continuous insulation (not interrupted by framing), 2x4 walls with R-15 cavity + R8 continuous insulation, or any combination of cavity and/or continuous insulation that results in a U-factor equal to or less than 0.051. Continuous Insulation: R-value of rigid or continuous insulation (not interrupted by framing).
7. U-factor: The U-factor for the proposed assembly. Must be less than or equal to column 10 or have an attached CF1R-ENV-02-E to show that a weighted U-factor for multiple assemblies will meet the maximum value in column 11.
8. Appendix JA4 Table: Table number used to determine the R-value or U-factor (e.g., an ICF wall is 4.3.13).
9. Appendix JA4 Cell: Cell number used to determine the R-value or U-factor (e.g., an 8-inch thick ICF wall with 2 inches of EPS (R-15.4) is A6).

10. Required U-factor: from Package A: Value required based on climate zone and assembly type.

…

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Dave Rivers, Southern California Edison
Mazi Shirakh, California Energy Commission
Tim Sloan, Harris & Sloan Consulting Group, Inc.
Will Vicent, Southern California Edison
Bruce Wilcox
William Zoeller, Consortium for Advanced Residential Buildings (Steven Winter Associates)

Appendix A: Environmental 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.[17] 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).

Greenhouse Gas Emissions Monetization Methodology

The 2016 TDV cost values used in the LCC Methodology includes the monetary value of avoided GHG emissions based on a proxy for permit costs (not social costs) and the Cost-effectiveness Analysis presented in Section 5.2 of this report includes the cost savings from avoided GHG emissions.

Water Use and Water Quality Impacts Methodology

There are no direct water impacts as a result of this proposed measure.

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

APPENDIX B: JOB CREATION BY INDUSTRY

Table 31 shows total job creation by industry that is expected from all investments in California energy efficiency and renewable energy (Source: UC Berkeley 2010b, Appendix D). While it is not specific to codes and standards, this data indicates the industries that generally will receive the greatest job growth from energy efficiency programs.

Table 31: Job Creation by Industry

NAICS	Industry Description	Direct Jobs	
		2015	2020
23822	Plumbing, Heating, and Air-Conditioning Contractors	8,695	13,243
2361	Residential Building Construction	5,072	7,104
2362	Nonresidential Building Construction	5,345	6,922
5611	Office Administrative Services	2,848	4,785
23821	Electrical Contractors	3,375	4,705
551114	Corporate, Subsidiary, and Regional Managing Offices	1,794	3,014
54133	Engineering Services	1,644	2,825
5418	Advertising and Related Services	1,232	2,070
334413	Semiconductor and Related Device Manufacturing	1,598	1,598
541690	Other Scientific and Technical Consulting Services	796	1,382
23831	Drywall and Insulation Contractors	943	1,331
3334	Ventilation, Heating, Air-Conditioning, & Commercial Refrigeration Equip. Manf.	453	792
3351	Electric Lighting Equipment Manufacturing	351	613
926130	Regulation and Administration of Communications, Electric, Gas, Other Utilities	322	319
23816	Roofing Contractors	275	277
54162	Environmental Consulting Services	151	261
484210	Used Household and Office Goods Moving	137	239
23835	Finish Carpentry Contractors	120	120
23829	Other Building Equipment Contractors	119	113
3352	Household Appliance Manufacturing	63	110
other	other	454	547
	Total	**35,788**	**52,369**

APPENDIX C: CBECC-RES SIMULATION RESULTS FOR ADDITIONAL WALL ASSEMBLIES

Energy modeling simulation results for various construction assemblies are provided below.

Table 32: Alternate Assembly U-Values

	U-Value of Assembly						
Assembly	2x6@16ocR 21+R4	2x4@16oc R15+R8	2x6@16ocR 23+R4	2x6@16ocR 19+R6	2x6@16ocR 21+R6	2x4@16ocR 15+R10	2x6@16ocR 23+R6
U-Value	0.051	0.050	0.049	0.049	0.046	0.045	0.044

Table 33: Alternate Assembly TDV Savings

Climate Zone	Savings (Baseline – Proposed) in TDV kBTU/ft2						
	2x6@16ocR 21+R4	2x4@16oc R15+R8	2x6@16ocR 23+R4	2x6@16ocR 19+R6	2x6@16ocR 21+R6	2x4@16ocR 15+R10	2x6@16ocR 23+R6
1	2.7	2.7	3.1	3.2	3.7	3.7	4.1
2	2.1	2.1	2.4	2.5	2.8	2.8	3.1
3	1.5	1.5	1.7	1.8	2.0	2.0	2.3
4	1.9	1.9	2.2	2.3	2.6	2.5	2.9
5	1.4	1.4	1.7	1.7	2.0	1.9	2.2
6	1.0	1.0	1.2	1.2	1.4	1.3	1.6
7	0.6	0.5	0.7	0.7	0.8	0.7	0.8
8	1.3	1.1	1.4	1.5	1.6	1.5	1.8
9	2.0	1.9	2.3	2.4	2.7	2.5	3.0
10	2.1	2.1	2.5	2.6	2.9	2.8	3.2
11	3.8	3.7	4.4	4.5	5.1	5.0	5.7
12	3.1	3.1	3.6	3.8	4.3	4.1	4.7
13	3.8	3.7	4.4	4.5	5.2	5.0	5.7
14	3.6	3.5	4.2	4.3	4.9	4.7	5.4
15	4.0	3.9	4.6	4.7	5.6	5.2	5.9
16	3.5	3.6	4.1	4.3	4.9	4.8	5.4

Table 34: Alternate Assembly First Costs

Wall Assembly	2x6@16ocR 21+R4	2x4@16oc R15+R8	2x6@16ocR 23+R4	2x6@16ocR 19+R6	2x6@16ocR 21+R6	2x4@16ocR 15+R10	2x6@16ocR 23+R6
Measure First Costs ($)	$ 718	$ 782	$ 785	$ 684	$ 783	$ 1,253	$ 1,209

Table 35: Alternate Assembly PV of Energy Cost Savings

Climate Zone	PV of Energy Cost Savings ($)						
	2x6@16ocR 21+R4	2x4@16oc R15+R8	2x6@16ocR 23+R4	2x6@16ocR 19+R6	2x6@16ocR 21+R6	2x4@16ocR 15+R10	2x6@16ocR 23+R6
1	$ 1,117	$ 1,154	$ 1,307	$ 1,363	$ 1,547	$ 1,538	$ 1,711
2	$ 871	$ 869	$ 1,015	$ 1,056	$ 1,195	$ 1,156	$ 1,318
3	$ 623	$ 638	$ 724	$ 760	$ 860	$ 849	$ 948
4	$ 804	$ 779	$ 930	$ 961	$ 1,088	$ 1,036	$ 1,199
5	$ 606	$ 606	$ 704	$ 729	$ 824	$ 798	$ 905
6	$ 436	$ 412	$ 509	$ 521	$ 603	$ 556	$ 662
7	$ 242	$ 217	$ 278	$ 283	$ 317	$ 283	$ 343
8	$ 526	$ 476	$ 609	$ 612	$ 693	$ 631	$ 763
9	$ 838	$ 796	$ 976	$ 996	$ 1,131	$ 1,054	$ 1,243
10	$ 900	$ 873	$ 1,056	$ 1,075	$ 1,222	$ 1,156	$ 1,348
11	$ 1,578	$ 1,564	$ 1,845	$ 1,901	$ 2,161	$ 2,082	$ 2,385
12	$ 1,306	$ 1,284	$ 1,522	$ 1,582	$ 1,792	$ 1,714	$ 1,978
13	$ 1,597	$ 1,561	$ 1,862	$ 1,912	$ 2,173	$ 2,081	$ 2,402
14	$ 1,505	$ 1,475	$ 1,756	$ 1,799	$ 2,047	$ 1,965	$ 2,263
15	$ 1,667	$ 1,622	$ 1,940	$ 1,987	$ 2,351	$ 2,170	$ 2,488
16	$ 1,484	$ 1,504	$ 1,730	$ 1,808	$ 2,047	$ 2,003	$ 2,263

Table 36: Alternate Assembly Life Cycle Cost

Climate Zone	Life Cycle Cost ($)						
	2x6@16ocR 21+R4	2x4@16oc R15+R8	2x6@16ocR 23+R4	2x6@16ocR 19+R6	2x6@16ocR 21+R6	2x4@16ocR 15+R10	2x6@16ocR 23+R6
1	$ (399)	$ (372)	$ (522)	$ (679)	$ (764)	$ (285)	$ (502)
2	$ (153)	$ (87)	$ (230)	$ (372)	$ (412)	$ 97	$ (109)
3	$ 95	$ 144	$ 61	$ (76)	$ (77)	$ 404	$ 261
4	$ (86)	$ 3	$ (145)	$ (277)	$ (305)	$ 217	$ 10
5	$ 112	$ 176	$ 81	$ (45)	$ (41)	$ 455	$ 304
6	$ 282	$ 370	$ 276	$ 163	$ 180	$ 697	$ 547
7	$ 476	$ 565	$ 507	$ 401	$ 466	$ 970	$ 866
8	$ 192	$ 306	$ 176	$ 72	$ 90	$ 622	$ 446
9	$ (120)	$ (14)	$ (191)	$ (312)	$ (348)	$ 199	$ (34)
10	$ (182)	$ (91)	$ (271)	$ (391)	$ (439)	$ 97	$ (139)
11	$ (860)	$ (782)	$ (1,060)	$ (1,217)	$ (1,378)	$ (829)	$ (1,176)
12	$ (588)	$ (502)	$ (737)	$ (898)	$ (1,009)	$ (461)	$ (769)
13	$ (879)	$ (779)	$ (1,077)	$ (1,228)	$ (1,390)	$ (828)	$ (1,193)
14	$ (787)	$ (693)	$ (971)	$ (1,115)	$ (1,264)	$ (712)	$ (1,054)
15	$ (949)	$ (840)	$ (1,155)	$ (1,303)	$ (1,568)	$ (917)	$ (1,279)
16	$ (766)	$ (722)	$ (945)	$ (1,124)	$ (1,264)	$ (750)	$ (1,054)

At the CEC's request, additional details for a U-factor=0.049 are provided below. The energy impacts per weighted prototype (as described in Section 4.3) are presented in Table 37. The extrapolated statewide impact is presented in Table 38, and the Cost-effectiveness summary is contained in Table 39.

Table 37: Energy Impacts per Weighted Prototype with Exterior Walls, U-factor=0.049[1]

Climate Zone	Per Unit First Year Savings[2]			
	Electricity Savings[4] (kWh/yr)	Demand Savings (kW)	Natural Gas Savings (Therms/yr)	Total TDV Savings[5] (kBTU)
Climate Zone 1	35	0.00	41	7,556
Climate Zone 2	31	0.02	25	5,866
Climate Zone 3	19	0.01	21	4,184
Climate Zone 4	31	0.04	22	5,375
Climate Zone 5	18	0.00	21	4,070
Climate Zone 6	15	0.02	12	2,943
Climate Zone 7	8	0.01	5	1,609
Climate Zone 8	26	0.06	9	3,520
Climate Zone 9	49	0.11	12	5,641
Climate Zone 10	62	0.11	14	6,105
Climate Zone 11	115	0.13	25	10,666
Climate Zone 12	67	0.10	25	8,797
Climate Zone 13	121	0.16	22	10,764
Climate Zone 14	108	0.14	26	10,149
Climate Zone 15	264	0.21	4	11,214
Climate Zone 16	48	0.03	48	10,001

1. Each unit refers to one house, using the weighting of prototypes representing average new construction as described in Section 4.3, with a wall assembly U-factor=0.049.
2. Savings from one unit (weighted prototype building), for the first year the building is in operation.
3. TDV energy savings for one unit (weighted prototype building) for the first year the building is in operation.
4. Site electricity savings. Does not include TDV of electricity savings.
5. Calculated using CEC's 2016 TDV factors and methodology. Includes savings from electricity and natural gas.

Table 38: Statewide Energy Impacts of Exterior Walls, U-factor=0.049

Climate Zone	First Year Statewide Savings[1]			
	Electricity Savings[3] (GWh)	**Power Demand Reduction (MW)**	**Natural Gas Savings (MMtherms)**	**Total TDV Energy Savings[4] (Million kBTU)**
Climate Zone 1	0.02	0.00	0.03	5
Climate Zone 2	0.08	0.04	0.07	15
Climate Zone 3	0.10	0.03	0.11	22
Climate Zone 4	0.19	0.23	0.13	32
Climate Zone 5	0.02	0.00	0.02	5
Climate Zone 6	0.06	0.08	0.05	12
Climate Zone 7	0.05	0.09	0.04	10
Climate Zone 8	0.19	0.41	0.07	25
Climate Zone 9	0.40	0.88	0.10	47
Climate Zone 10	1.03	1.81	0.23	101
Climate Zone 11	0.68	0.75	0.15	64
Climate Zone 12	1.31	1.90	0.48	171
Climate Zone 13	1.68	2.29	0.31	150
Climate Zone 14	0.36	0.46	0.09	34
Climate Zone 15	1.03	0.83	0.02	44
Climate Zone 16	0.15	0.08	0.15	31
TOTAL	**7.4**	**9.9**	**2.0**	**769**

1. First year savings from all buildings built statewide during the first year the 2016 Standards are in effect.
2. First year TDV savings from all buildings built statewide during the first year the 2016 Standards are in effect.
3. Site electricity savings.
4. Calculated using CEC's 2016 TDV factors and methodology.

Table 39: Cost-effectiveness Summary for Exterior Walls, U-factor=0.049[1]

Climate Zone	Benefit: TDV Energy Cost Savings [2] (2016 PV$)	Cost: Total Incremental Cost[3] (2016 PV$)	Change in Lifecycle Cost[4] (2016 PV$)	Benefit to Cost Ratio[5]
Climate Zone 1	$1,307	$785	($523)	1.7
Climate Zone 2	$1,015	$785	($230)	1.3
Climate Zone 3	$724	$785	$61	0.9
Climate Zone 4	$930	$785	($145)	1.2
Climate Zone 5	$704	$785	$81	0.9
Climate Zone 6	$509	$785	$276	0.6
Climate Zone 7	$278	$785	$506	0.4
Climate Zone 8	$609	$785	$176	0.8
Climate Zone 9	$976	$785	($191)	1.2
Climate Zone 10	$1,056	$785	($272)	1.3
Climate Zone 11	$1,845	$785	($1,061)	2.4
Climate Zone 12	$1,522	$785	($737)	1.9
Climate Zone 13	$1,862	$785	($1,077)	2.4
Climate Zone 14	$1,756	$785	($971)	2.2
Climate Zone 15	$1,940	$785	($1,155)	2.5
Climate Zone 16	$1,730	$785	($945)	2.2

1. Relative to existing conditions. All cost values presented in 2016 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 cost 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 1.0 or greater.