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Codes and Standards Enhancement (CASE) Initiative

2019 California Building Energy Efficiency Standards

Quality Insulation Installation (QII) – Final Report

Measure Number: 2019-RES-ENV4-F

Residential Envelope

July 2017

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EXECUTIVE SUMMARY

Introduction

The Codes and Standards Enhancement (CASE) initiative presents recommendations to support California Energy Commission's (Energy Commission) efforts to update California's Building Energy Efficiency Standards (Title 24, Part 6) 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 SoCalGas® – and two Publicly Owned Utilities (POUs) – Los Angeles Department of Water and Power and Sacramento Municipal Utility District– sponsored this effort. The program goal is to prepare and submit proposals that will result in cost-effective enhancements to improve energy efficiency and energy performance in California buildings. This report and the code change proposals presented herein is a part of the effort to develop technical and cost-effectiveness information for proposed requirements on building energy efficient design practices and technologies.

The Statewide CASE Team submits code change proposals to the Energy Commission, the state agency that has authority to adopt revisions to Title 24, Part 6. The Energy Commission will evaluate proposals submitted by the Statewide CASE Team and other stakeholders. The Energy Commission may revise or reject proposals. See the Energy Commission's 2019 Title 24 website for information about the rulemaking schedule and how to participate in the process: http://www.energy.ca.gov/title24/2019standards/.

Measure Description

Under the 2013 and 2016 code, a compliance credit is awarded for installations that perform Quality Insulation Installation (QII). The Standard Design assumes that builders are not performing QII and wall insulation values are modeled at 70 percent of the R-value of the installed insulation, with attic defects assumed as well. If a builder performs QII, the actual insulation values (100 percent) are credited in the modeling. Fiberglass batt insulation is still the most commonly used wall insulation product used in California, while loose-fill fiberglass insulation is commonly used in attic insulation. The proposed 2019 effort will change QII from a compliance credit to a prescriptive requirement for all climate zones, except low-rise multifamily buildings in Climate Zone 7. Verification by a Home Energy Rating System (HERS) rater will be required to ensure proper insulation installation within the entire thermal envelope (including walls, roofs, and floors). QII will remain a compliance credit for multifamily buildings in Climate Zone 7. This prescriptive measure does not apply to alterations.

Making QII part of the prescriptive package will ensure that more insulation installations are properly implemented, increasing the effective U-factor of these envelope assemblies. This measure will modify existing code language, but does not modify the scope of the standards. If QII becomes a prescriptive requirement, it will result in a modification of the prescriptive package, and be removed as a compliance credit in all applicable climate zones. The measure will also require an update to the Joint and Residential Appendices language, and compliance documents, as related to QII requirements. If added to the prescriptive package, QII will be part of the basis for the performance approach for building envelope measures.

Ensuring quality installation of insulation, especially in exterior walls has been problematic for many years. Defects such as gaps, compressed insulation, and insufficient sealing of the building cavities lead to significant reduction in performance of the overall building. Based on information provided by HERS Raters, insulation quality is typically below acceptable standards without thorough independent inspection of insulation installations. To ensure that homes perform as designed and provide the performance and comfort expected by the occupants, third party HERS inspections are needed. Making QII a prescriptive requirement will help achieve ZNE goals by reducing the heating and cooling loads for HVAC systems in residential buildings. Improved insulation installation quality leads to higher overall envelope performance, which reduces the required capacity of the HVAC needed to maintain stable interior temperature while exterior temperatures fluctuate. This will offer benefits to builders as well, since improved envelope integrity, as a component of a ZNE-ready design, will lead to reduced callbacks, improved durability, and increased customer satisfaction.

Scope of Code Change Proposal

Table 1 summarizes the scope of the proposed changes and which sections of the Standards, Reference Appendices, and compliance documents that will be modified as a result of the proposed change.

Table 1: Scope of Code Change Proposal

Measure Name	Type of Requirement	Modified Section(s) of Title 24, Part 6	Modified Title 24, Part 6 Appendices	Will Compliance Software Be Modified	Modified Compliance Document(s)
QII	Prescriptive	150.1	RA3.5, Table RA2-1	Yes	None

Market Analysis and Regulatory Impact Assessment

While QII has been a compliance option in the standards, it is not universal residential industry practice in California but is relatively common as a compliance credit in new construction. An estimated 24 percent of registered single family projects and 13 percent of registered multifamily projects took the QII credit between January 2015 and April 2016.[1] Making this part of the prescriptive package will have a minor impact on builders already using QII as a compliance credit to meet or exceed code, although they would no longer have this measure as a compliance credit tool. Builders that are not currently using QII for code compliance will need additional time and training to ensure cavity insulation is installed per manufacturers' specifications, and to allow time for the HERS Rater to verify the installation. In 2013, QII inspection procedures were significantly revised, which aligned them better with ENERGY STAR's Thermal Bypass Checklist (EPA. 2015). The differences resulted in more stringent inspection procedures for HERS Raters and more compliance challenges for builders.

This proposal is cost-effective over the period of analysis. Overall, this proposal will increase the wealth of the State of California. California consumers and businesses will save more money on energy than they would spend on financing the efficiency measure.

The proposed changes to Title 24, Part 6 Standards have a negligible impact on the complexity of the standards or the cost of enforcement. When developing this code change proposal, the Statewide CASE Team interviewed building officials, Title 24 energy analysts and others involved in the code compliance process to simplify and streamline the compliance and enforcement of this proposal.

Cost-Effectiveness

The proposed code change was found to be cost-effective for all climate zones where it is proposed to be required. The benefit-to-cost (B/C) ratio compares the lifecycle benefits (cost savings) to the lifecycle costs. Measures that have a B/C ratio of 1.0 or greater are cost-effective. The larger the B/C

[1] Based on data provided from HERS registry provided by CalCERTS.

ratio, the faster the measure pays for itself from energy savings. In climate zones where QII was found to be cost-effective, the B/C ratio ranged between 1.02 and 6.52 depending on climate zone. See Section 5 for a detailed description of the cost-effectiveness analysis.

Statewide Energy Impacts

Table 2 shows the estimated energy savings over the first twelve months of implementation of the proposed code change. See Section 6 for more details.

Table 2: Estimated Statewide First-Year[a] Energy and Water Savings

Measure	First-Year Electricity Savings (GWh/yr)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Water Savings (million gallons/yr)	First-Year Natural Gas Savings (million therms/yr)
New Construction	8.7	12.5	N/A	2.7
Additions	0.5	0.7	N/A	0.1
Alterations	N/A	N/A	N/A	N/A

a. First-year savings from all buildings completed statewide in 2020.

Compliance and Enforcement

The Statewide CASE Team worked with stakeholders to develop a recommended compliance and enforcement process and to identify the impacts this process will have on various market actors. The compliance process is described in Section 2.5. The impacts the proposed measure will have on various market actors is described in Section 3.3 and 0. The key issues related to compliance and enforcement are summarized below:

- Training will be necessary to bring the construction industry up to speed on strategies for meeting QII criteria. While cost-effective solutions exist, the industry and many of the trades are already successfully implementing QII practices; most projects in the state are still not taking the QII credit for compliance and may not be familiar or comfortable with the requirements.
- Builders not familiar with QII may need to account for additional time for air sealing and insulation installation. Additionally, they will need to coordinate this with installers and account for time for scheduling a HERS Rater on site several occasions during construction.
- Designers and Title 24 consultants will need to clearly communicate QII requirements to builder and construction team, including when inspections need to occur.
- Insulation contractors will need to ensure their installation crews are properly trained and know how to install insulation to QII standards.

Although a needs analysis has been conducted with the affected market actors while developing the code change proposal, the code requirements may change between the time the final CASE Report is submitted and the time the 2019 Standards are adopted. The recommended compliance process and compliance documentation may also evolve with the code language. To effectively implement the adopted code requirements, a plan should be developed that identifies potential barriers to compliance when rolling-out the code change and approaches that should be deployed to minimize the barriers.

1. INTRODUCTION

The Codes and Standards Enhancement (CASE) initiative presents recommendations to support California Energy Commission's (Energy Commission) efforts to update California's Building Energy Efficiency Standards (Title 24, Part 6) 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 SoCalGas® and two Publicly Owned Utilities (POUs) — Los Angeles Department of Water and Power and Sacramento Municipal Utility District 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 requirements on building energy efficient design practices and technologies.

The Statewide CASE Team submits code change proposals to the Energy Commission, the state agency that has authority to adopt revisions to Title 24, Part 6. The Energy Commission will evaluate proposals submitted by the Statewide CASE Team and other stakeholders. The Energy Commission may revise or reject proposals. See the Energy Commission's 2019 Title 24 website for information about the rulemaking schedule and how to participate in the process: http://www.energy.ca.gov/title24/2019standards/.

The overall goal of this CASE Report is to propose a code change proposal for quality insulation installation (QII). The report contains pertinent information supporting the code change.

When developing the code change proposal and associated technical information presented in this report, the Statewide CASE Team worked with a number of industry stakeholders including building officials, manufacturers, builders, utility incentive program managers, Title 24 energy analysts, and others involved in the code compliance process. The proposal incorporates feedback received during two public stakeholder workshops that the Statewide CASE Team held on September 14, 2016 and March 14, 2017.

Section 2 of this CASE Report provides a description of the measure and its background. This section also presents a detailed description of how this change is accomplished in the various sections and documents that make up the Title 24, Part 6.

Section 3 presents the market analysis, including a review of the current market structure. Section 3.2 describes the feasibility issues associated with the code change, including whether the proposed measure overlaps or conflicts with other portions of the building standards such as fire, seismic, and other safety standards and whether technical, compliance, or enforceability challenges exist.

Section 4 presents the per-unit energy, demand, and energy cost savings associated with the proposed code change. This section also describes the methodology that the Statewide CASE Team used to estimate energy, demand, and energy cost savings.

Section 5 presents the lifecycle cost and cost-effectiveness analysis. This includes a discussion of additional materials and labor required to implement the measure and a quantification of the incremental cost. It also includes estimates of incremental maintenance costs. That is, equipment lifetime and various periodic costs associated with replacement and maintenance during the period of analysis.

Section 6 presents estimates the statewide energy savings and environmental impacts of the proposed code change for the first year after the 2019 Standards take effect. This includes the amount of energy that will be saved by California building owners and tenants, and material impacts (increases or reductions). Statewide water consumption impacts are also considered.

Section 7 concludes the report with specific recommendations with ~~strikeout~~ (deletions) and <u>underlined</u> (additions) language for the Standards, Reference Appendices, Alternate Calculation Manual (ACM) Reference Manual, Compliance Manual, and compliance documents.

2. Measure Description

2.1 Measure Overview

Under the 2013 and 2016 Title 24, Part 6 code, a compliance credit is awarded for installations that perform Quality Insulation Installation (QII). The Standard Design assumes that builders are not performing QII and wall insulation values are modeled at 70 percent of the R-value of the installed insulation, with insulation and draft stopping defects between the attic and the conditioned zone assumed as well. If a builder performs QII, the actual insulation values (100 percent) are credited in the modeling. Fiberglass batt insulation is still the most commonly used wall insulation product used in California, while loose-fill fiberglass insulation is commonly used in attic insulation. The proposed 2019 effort will change QII from a credit to a prescriptive performance requirement for all climate zones, except low-rise multifamily buildings in Climate Zone 7, and require verification by a HERS Rater to ensure proper insulation installation within the entire thermal envelope (including walls, roofs, and floors).

This prescriptive measure will apply to single family and low-rise multifamily buildings, and both new construction and additions greater than 700 square feet. This prescriptive measure does not apply to alterations. Including QII as part of the prescriptive package will ensure that most insulation installations are properly implemented, increasing the effective U-factor of these envelope assemblies. This measure will modify existing code language, but will not modify the scope of the standards. If QII is added to the prescriptive package, it will be part of the basis for the performance approach for building envelope measures and will result in a modification of the prescriptive package as well as be removed as a compliance credit. The measure will also require an update to the Joint and Residential Appendices language and compliance documents, as related to QII requirements. QII procedures will also be expanded to address insulation methods, materials, and techniques not adequately covered under the current QII inspection procedures.

2.2 Measure History

QII is relatively common as a compliance credit in new construction. An estimated 24 percent of registered single family projects and 13 percent of registered multifamily projects took the QII credit between January 2015 and April 2016.[2] Making this part of the prescriptive package will have a minor impact on builders already using QII as a compliance credit to meet or exceed code, although they will no longer have this measure as a compliance credit tool. Builders that are not currently applying QII on projects will need to familiarize themselves with the requirements and procedures. Additional time may be necessary to ensure cavity insulation is installed per manufacturers' specifications, and to allow time for the HERS Rater to verify the installation. However, given that one quarter of all single family projects already use the QII credit, this is evidence it does not appear to impose an undue burden for all builders.

QII is currently a pre-requisite for the 2016 CALGreen Tier 1, Tier 2, and Zero Net Energy Design Credits. Nationally, the ENERGY STAR® Thermal Bypass Checklist (TBC) is required for ENERGY

[2] Based on data provided from HERS registry provided by CalCERTS.

STAR certified homes (EPA 2015), as well as LEED (US Green Building Council 2016) and DOE's Zero Energy Ready Homes programs (Department of Energy 2015). In the 2013 Title 24, Part 6 code, QII procedures were revised to better align with ENERGY STAR's TBC. The differences resulted in more stringent inspection procedures. Significant changes from the 2008 to the 2013 Title 24, Part 6 Standards include:

1. Bottom plate sealing of framed and non-framed assemblies.
2. Tighter restriction on filling all gaps with insulation (2008 Title 24, Part 6 specified gaps larger than 1/8 inch). No gaps are allowed in the current requirements.
3. Installation of air barriers on the inside of exterior walls directly adjacent to tubs/showers.
4. Air-permeable insulation of kneewalls in unconditioned attics must be completely covered with hard insulation or air barrier. Insulation for kneewalls and skylight shafts must be completely enclosed by an air barrier on all six sides, including plates at the top and bottom.
5. Added requirements for homes with conditioned space over the garage.
6. Separated requirements for batt and blanket (RA 3.5.3) from loose fill insulation (RA 3.5.4).
7. Added requirements for rigid board insulation (RA 3.5.5), spray polyurethane foam insulation (RA 3.5.6), structural insulated panels (RA 3.5.7), and insulated concrete foam (RA 3.5.8).
8. Added requirements for several "special situations," including:
    a. Double walls and framed bump-outs.
    b. Structural bracing, tie-downs, and steel structural framing.
    c. Window and door headers.
    d. Attics and cathedral ceilings

Under the 2016 Title 24, Part 6 code cycle, QII was proposed as a mandatory measure. The 2016 Statewide CASE Team evaluated QII and the analysis found that it was cost-effective in all climate zones with the exception of six through eight (California Statewide Utility Codes and Standards Team 2014). Ultimately, QII was removed from the CASE Report and not changed in the 2016 code cycle. The work for the 2019 Title 24, Part 6 code cycle evaluates QII as a prescriptive instead of a mandatory measure. As a prescriptive measure, the builder can trade this measure for other compliance options, like high efficiency HVAC, to meet code.

The 2019 Title 24, Part 6 code cycle is poised to require photovoltaics (PV) in all residential buildings. The "loading order" defined in California's Energy Action Plan prescribes that cost-effective efficiency and conservation measures be prioritized prior to installing new generation (State of California 2003). Considering this, it is important that this process investigate and support cost-effective envelope improvement opportunities prior to requiring PV generation. Given the importance of installing insulation correctly during construction on both building performance and comfort, making QII a prescriptive requirement is an important component energy efficient buildings. A description of current insulation practices in California in provided in Section 3 of this report.

There are no preemption concerns with this measure.

2.3 Summary of Proposed Changes to Code Documents

The sections below provide a summary of how each Title 24, Part 6 document will be modified by the proposed change. See Section 7 of this report for detailed proposed revisions to code language.

2.3.1 Standards Change Summary

This proposal will modify the following sections of the Building Energy Efficiency Standards as shown below. See Section 7.1 of this report for the detailed proposed revisions to the code language.

The proposed change does not change the scope of the standards. Proposed code changes will add/revise prescriptive requirements for building elements already regulated by the standards.

SECTION 150.1 – PERFORMANCE AND PRESCRIPTIVE COMPLIANCE APPROACHES FOR LOW-RISE RESIDENTIAL BUILDINGS

TABLE 150.1-A COMPONENT PACKAGE-A STANDARD BUILDING DESIGN: The proposed requirement will add a row under Building Envelope for "QII Inspection". The existing Table 150.1-A will be expanded to more thoroughly convey differences in and provide improved clarification on the prescriptive envelope requirements between single family and low-rise multifamily buildings. This will reduce the energy use of residential buildings. This requirement cost-effectively will increase the stringency of the standards, thereby minimizing the energy use of residential buildings, which in turn will improve the state's economic and environmental health.

Section 150.1(c)8 Domestic Water-Heating Systems: The proposed requirement will remove or revise the prescriptive option for single gas or propane storage type water heaters with an input of 105,000 Btu per hour or less and rated volume less than or equal to 55 gallons that includes QII as part of the prescriptive requirement. (Section 150.1(c)8A.ii).

2.3.2 Reference Appendices Change Summary

This proposal modifies the following sections of the Standards Appendices as shown below. See Section 7.2 of this report for the detailed proposed revisions to the text of the reference appendices.

RESIDENTIAL APPENDICES

Table RA2-1 - Measures That Require Field Verification and Diagnostic Testing

High Quality Insulation Installation (QII): The proposed requirement makes QII prescriptive in single family homes in Climate Zones 1 through 16 and multifamily buildings in Climate Zones 1 through 6 and 8 through 16. The language here is modified to reflect that change.

RA3.5 – Quality Insulation Installation Procedures: Based on review and discussions with stakeholders, the Statewide CASE Team is proposing modifications to several sections of RA3.5. Language will be modified to provide more clarity where needed, additional definitions, and expand inspection protocols to properly address insulation methods not adequately addressed in the current language.

2.3.3 Alternative Calculation Method (ACM) Reference Manual Change Summary

This proposal modifies the following sections of the Residential Alternative Calculation Method (ACM) Reference Manual as shown below. See Section 7.3 of this report for the detailed proposed revisions to the text of the ACM Reference Manual.

SECTION 2 – The Proposed Design and Standard Design

Section 2.2.6 Insulation Construction Quality: The proposed requirement modifies section 2.2.6 (Insulation Construction Quality) of the Residential Alternative Calculation Method (ACM) Reference Manual by changing the Standard Design assumptions, as well as Table 4: Modeling Rules for Standard Insulation Installation Quality. The description of the Standard Design in the ACM will also be updated to reflect QII in Table 150.1-A.

2.3.4 Compliance Manual Change Summary

The proposed code change modifies the following section of the Title 24, Part 6 Compliance Manual:

- Section 3.6.2: Prescriptive Approach
- Section 3.6.3.4 Quality Insulation Installation (QII): Moved up to Section 3.6.2
- Section 5.4.1 Prescriptive Requirements for Water Heating - Single Dwelling Units: Remove or revise Option two to remove QII as part of the prescriptive requirement for natural gas or

propane storage water heaters with a rated storage volume 55 gallons or less and an input rating of 105,000 Btu per hour or less.

2.3.5 Compliance Documents Change Summary

The proposed code change modifies the following compliance documents listed below. Examples of the revised forms are presented in Section 7.5

- CF3R-ENV-21-H: Field Verification and Diagnostic Testing: Air Infiltration Sealing – Framing Stage For Batt, Loose Fill, And SPF
- CF3R-ENV-22-H: Field Verification and Diagnostic Testing: Air Infiltration Sealing – Ceiling/Roof Deck
- CF3R-ENV-23-H: Field Verification and Diagnostic Testing: Insulation Stage

2.4 Regulatory Context

2.4.1 Existing Title 24, Part 6 Standards

Currently a compliance credit is awarded for projects that include QII HERS inspections. There are three components associated with this measure which give credit for verified quality insulation installation in ceilings/attics, knee walls, exterior walls and exterior floors. The Standard Design assumes that builders are not performing QII and the buildings are modeled with lower performing cavity insulation in framed walls, ceilings, and floors; and with added winter heat flow between the conditioned zone and attic to represent construction cavities open to the attic. The assumptions for standard insulation installation quality are summarized in Table 4 of the 2016 Residential ACM Reference Manual (see Figure 1). If a builder performs QII, the actual insulation values (100 percent) are credited and added winter heat flow assumptions are removed in the modeling. See Appendix C for further details on the degradation assumptions.

Modeling Rules for Standard Insulation Installation Quality

Component	Modification
Walls, Floors, Attic Roofs, Cathedral Ceilings	Multiply the cavity insulation R-value/inch by 0.7
Ceilings below attic	Multiply the blown and batt insulation R-value/inch by 0.96-0.00347*R
Ceilings below attic	Add a heat flow from the conditioned zone to the attic of 0.015 times the area of the ceiling below attic times (the conditioned zone temperature - attic temperature) whenever the attic is colder than the conditioned space

Figure 1: Table 4 of 2016 Residential ACM Reference Manual – modeling rules for standard insulation installation quality

QII is currently a pre-requisite for the 2016 CALGreen Tier 1, Tier 2, and Zero Net Energy Design Credits. There are local ordinances that have in past code cycles required QII as part of CALGreen (Title 24, Part 11) Tier 1.

2.4.2 Relationship to Other Title 24 Requirements

QII affects all cavity insulation, including that installed in walls, ceilings and floors. Thus, this measure overlaps with the performance and prescriptive requirements for these building elements. Any savings associated with QII for wall, floor, and ceiling/attic insulation are also affected by any prescriptive or mandatory changes to these components.

QII is currently part of the prescriptive water heating option for gas storage water heaters 55 gallons or less (§150.1(c)8A ii). As QII becomes prescriptive in all cases, this prescriptive option will have to be revised or removed.

2.4.3 Relationship to State or Federal Laws

There are no federal regulatory requirements that address the same topic as this proposed change

2.4.4 Relationship to Industry Standards

While QII is unique to California, it closely aligns with ENERGY STAR's TBC, which is a prerequisite for ENERGY STAR Certified Homes, LEED-Homes, and DOE Zero Energy Ready Homes programs. The requirements and inspection procedures for the TBC are similar to QII but follow the RESNET guidelines for insulation quality (RESNET 2013) which differ from the QII guidelines.

2012 International Energy Conservation Code (IECC) requires that components of the building thermal envelope as listed in Table R402.4.1.1 shall be installed in accordance with the manufacturer's instructions and the criteria listed in Table R402.4.1.1, as applicable to the method of construction (International Code Council 2011). Requirements in IECC Table R402.4.1.1 that are also in QII, include:

- Continuous air barrier
- Exterior thermal envelope insulation for framed walls shall be installed in substantial contact and continuous alignment with the air barrier.
- Where required by the code official, an approved third party shall inspect all components and verify compliance.

2.5 Compliance and Enforcement

The Statewide CASE Team collected input during the stakeholder outreach process on what compliance and enforcement issues may be associated with this measure. This section summarizes how the proposed code change will modify the code compliance process. 0 presents a detailed description of how the proposed code changes could impact various market actors. When developing this proposal, the Statewide CASE Team considered methods to streamline the compliance and enforcement process and how negative impacts on market actors who are involved in the process could be mitigated or reduced.

This code change proposal will affect new construction buildings and additions greater than 700 square feet that use either the prescriptive or performance approach to compliance. QII already exists as a compliance credit in new construction. QII is going from being a compliance option credit to a prescriptive requirement. Buildings using the prescriptive method for compliance will be required to have a third party HERS Rater inspect and sign off QII. Buildings using the performance method are not required to do QII but the performance of the building will be compared against the performance of a building with QII.

The key steps and changes to the compliance process are summarized below:

- **Design Phase**: Title 24 consultants will need to coordinate with architects and the design team to ensure that the QII requirements are understood and that the requirements are clearly articulated in the building specifications and plans. Including when QII inspections are required should be communicated to the building team.

- **Permit Application Phase**: There are no changes to the existing permit application phase process. The plans examiner will review the Compliance Documents and identify HERS measures used for compliance that need to be included as part of the final permitting process.
- **Bidding Phase**: When obtaining bids from subcontractors, it should be clear in the bid documents that QII is included and subs are responsible for meeting the QII criteria.
- **Construction Phase**: The builder will continue to provide coordination between the subcontractors. Additional time should be scheduled for HERS Rater inspections for an air sealing inspection prior to insulating the walls, an insulation inspection prior to sheetrock, and a final inspection. Additional inspections should be scheduled if necessary to inspect areas around inset tubs and cathedral ceilings.
- **Inspection Phase**: There are no changes to the existing QII inspection phase process.

There will be no significant challenges to compliance and enforcement in any of the phases identified above. There will not be a significant burden placed on any market actor as it relates to compliance and enforcement. Including QII as a prescriptive requirement will have no impact on builders already taking advantage of QII, other than not allowing them to use QII credit as a trade-off in performance compliance, and builders currently using QII as part of the prescriptive option for gas storage water heating. For builders that are not currently using the QII compliance credit in their projects, there may be additional time required to ensure cavity insulation is installed per manufacturer's specifications, and to allow time for the HERS Rater to verify the installation.

If this code change proposal is adopted, the Statewide CASE Team recommends that information presented in this section, Section 3 and 0 be used to develop a plan that identifies a process to develop compliance documentation and how to minimize barriers to compliance.

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 actor. 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 stakeholders including utility program staff, Energy Commission staff, and a wide range of industry players who were invited to participate in utility-sponsored stakeholder meetings held on September 14, 2016 and March 14, 2017. Additional literature reviews and background beyond what is presented below is included in Appendix E.

3.1 Market Structure

Insulation contractors are the key players in QII and ensuring quality installation of insulation. Insulation installers must install insulation products to meet manufacturers specifications and according to QII criteria. It is primarily their work that is being inspected by the HERS Rater; however, work by many of the other trades can impact a successful QII job. QII procedures can be applied with various types of insulation products, including batt, blown-in, spray foam, and rigid board insulation. The procedures apply recognized best practices for installation of insulation and air barriers and therefore represent a process that is already embedded in the market place, regardless of the fact that it is not currently used in the majority of homes. The primary challenge will be with industry training and familiarization.

Following is a summary of the principal manufacturers of wall insulation products.

3.1.1 Cavity Insulation

Batt insulation is the predominant insulation type applied in residential California walls (see Section 3.2). Owens Corning, Johns Manville, Knauf Insulation, and CertainTeed are four major manufacturers of fiberglass batt insulation. Other insulation materials include mineral wool batts, blown-in cellulose or fiberglass, and open and closed cell spray polyurethane foam (SPF). These options offer some benefits over traditional batt fiberglass insulation but are currently more expensive on a per R-value basis. Reference Appendix section RA3.5 include quality installation procedures specific to batt, blown-in, and SPF insulation in cavities.

3.1.2 Rigid Board Insulation

QII Section RA3.5.5 includes quality installation procedures for rigid board insulation. There are currently three major types of rigid continuous board insulation that are typically applied in residential wall construction. These are expanded polystyrene (EPS), extruded polystyrene (XPS), and polyisocyanurate (polyiso). EPS manufacturers include Insulfoam and Atlas EPS, among others. XPS is produced by multiple manufacturers including Dow, Owens Corning, and Knauf Insulation. Polyiso is made by Dow, Rmax, and Johns Manville. In addition, there is a variation on EPS that is a graphite-enhanced expanded polystyrene, or GPS, that is now becoming increasingly available.

3.1.3 SIPS, ICF

Less common construction assemblies include structural insulation panels (SIPs), and insulated concrete forms (ICF), covered in RA3.5.8. There are QII inspection procedures specific to SIPs and ICF building construction assemblies in Sections RA3.5.7, and 3.5.8, respectively.

3.2 Technical Feasibility, Market Availability, and Current Practices

QII has been included as a compliance credit in the Title 24, Part 6 Standards since 2005. Implementation is not widespread, but it is commonly taken as a compliance credit in new construction. According to CalCERTS registry data between January 2015 and April 2016, an estimated 24 percent of registered single family projects and 13 percent of registered multifamily projects took the QII credit. Data provided by TRC from the single and multifamily statewide incentive programs for the 2013 code cycle show that approximately 80 percent of single family lots and 74 percent of multifamily buildings participating in the statewide incentive programs included QII.

A 2016 Energy Commission funded report assessed the market for high performance walls by reviewing single family homes from 50 subdivisions across California (ConSol 2016). Collectively, the sampled projects were represented by builders that produced 39.6 percent of all California single family construction in 2014. The study found that batt insulation was the predominant insulation type in 94 percent of projects. High density batt insulation (R-15 for 2x4 framing and R-21+ for 2x6 framing) was not found to be common. While batt insulation is the predominant choice for residential wall cavities, there are other builders experimenting with alternative systems. A merchant builder has been applying open cell spray foam in wall cavities and attics for years, providing both insulating and air sealing benefits. This is their standard construction practice in certain subdivisions.

There are no required technological advances necessary to meet QII criteria. The challenges are with proper installation practices. While some builders have been including QII in their projects for a long time, there are still many builders who are unfamiliar with the QII or the requirements to achieve the credit. Many insulation contractors are familiar with QII but due to competitive pricing for installation costs, will only install to QII standards if required and inspected by a HERS Rater. Based on feedback from the HERS Rater survey completed in 2016, current practices show that insulation is not installed correctly unless the QII credit is enforced (see Appendix F).

Feedback from a HERS Rater survey completed in 2016 indicates lack of installer training and knowledge of QII requirements as a big issue. Historically the IOUs have provided builder and contractor QII trainings through utility training centers. Enrollment in these classes have been challenging because it is hard to get installers out of the field and into a classroom for training. High turnover rates among installation crews also results in installers with little or no training in QII procedures. HERS Raters experience inspection challenges as a result of the lack of knowledge and training. For additional feedback from the interviews, refer to Appendix F.

Builders and insulation contractors continue to have challenges meeting QII standards, leading to frequent inspection failures at the start of projects. Changes in inspection procedures in the 2013 code have made QII inspections more difficult to pass. Making QII a prescriptive requirement could increase the market penetration of QII practices amongst California builders but additional on-site trades training will be useful to help transform the market. Builders will also need to coordinate with insulation contractors and other trades to ensure job is completed to QII standards.

3.3 Market Impacts and Economic Assessments

3.3.1 Impact on Builders

It is expected that builders will not be impacted significantly by any one proposed code change or the collective effect of all proposed changes to Title 24, Part 6. Builders could be impacted by change in demand for new buildings and by construction costs. Demand for new buildings is driven more by factors such as the overall health of the economy and population growth than the cost of construction. The cost of complying with Title 24, Part 6 requirements represents a very small portion of the total building value. Increasing the building cost by a fraction of a percent is not expected to have a significant impact on demand for new buildings or the builders' profits. Even as shown in Figure 2. California home prices have increased by about $300,000 in the last 20 years. In the six years between the peak of the market bubble in 2006 and the bottom of the crashing in 2012, the median home price dropped by $250,000. The current median price is about $500,000 per single family home. The combination of all single family measures for the 2016 Title 24, Part 6 Standards was around $2,700 (California Energy Commission 2015b). This is a cost impact of approximately half of one percent of the home value. The cost impact is negligible as compared to other variables that impact the home value.

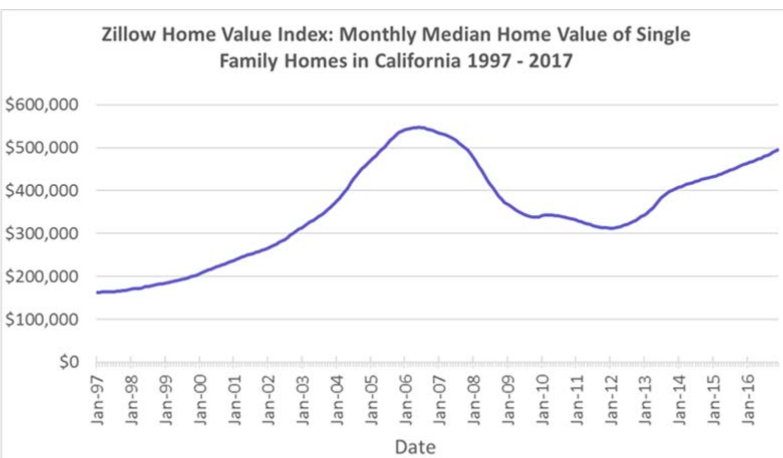

Figure 2: California median home values 1997 to 2017

Source: (Zilllow 2017)

Market actors will need to invest in training and education to ensure the workforce, including those working in construction trades, know how to comply with the proposed requirements. Workforce training is not unique to the building industry, and is common in many fields associated with the production of goods and services. Costs associated with workforce training are typically accounted for in long-term financial planning and spread out across the unit price of many units as to avoid price spikes when changes in designs and/or processes are implemented.

Builders will need to become more familiar with QII requirements for air sealing and insulation quality and adjust their expectations from the insulation contractors accordingly to comply. Builders will also need to verify that the bid specifications clearly identify QII requirements, that the bids from insulation contractors include meeting QII criteria, and that subcontractors are aware of the HERS inspections related to their work scope. They should become advocates along with the HERS Raters to ensure that QII standards are met by installers. Job superintendents will need to schedule HERS Rater for inspections and work with HERS Rater to understand QII requirements and ensure that all subcontractors are complying with QII. For builders with little or no prior experience with QII, there are limited QII training opportunities through the IOUs and on line videos available, but it is probably best to work directly with the HERS Rater on the project to become more familiar with QII requirements and criteria. Most HERS Raters offer on-site trainings as an additional service. It may take a few jobs (or additional training time up front) for the insulation subcontractor and crew to learn how to meet QII, after which it becomes standard practice.

Refer to Appendix B for a description of how the compliance process will impact builders.

3.3.2 Impact on Building Designers and Energy Consultants

Adjusting design practices to comply with changing building codes practices is within the normal practices of building designers. Building codes (including the California Building code and model national building codes published by the International Code Council, the International Association of Plumbing and Mechanical Officials, and ASHRAE) are typically updated on three-year cycles. As discussed in Section 3.3.1, all market actors, including building designers and energy consultants, should (and do) plan for training and education that may be required to adjusting design practices to accommodate compliance with new building codes. The measures the Statewide CASE Team is proposing for the 2019 code cycle aim to provide designers and energy consultants with opportunities to comply with code requirements in multiple ways, thereby providing flexibility in how requirements can be met.

Architects and designers will not be significantly impacted by this measure. They are responsible for developing building details and specifications. While designers may not be familiar with QII, if QII is included in the project, they should work with the energy consultant to ensure that the specifications explicitly call out QII requirements and that insulation quality and air sealing practices will need to be signed off by a third party HERS Rater.

Energy consultants, accustomed to using QII as a compliance trade off with other design features to meet compliance, may need to work with the design team to develop other strategies for compliance. Energy consultants will continue to serve as the primary resource for designers and builders for Title 24, Part 6 compliance information. If QII is included in the performance calculations, the energy consultant will need to communicate with the design team and the builder to ensure that all parties are aware that QII is required for demonstrating compliance with code. The consultant may need to spend more time educating clients on the project specific requirements related to QII. Energy Code Ace is an important resource for the energy consultant.[3]

[3] http://energycodeace.com/

Refer to 0 for a description of how the compliance process will impact building designers and energy consultants.

3.3.3 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 Division of Occupational Safety and Health. All existing health and safety rules will remain in place. Complying with the proposed code change is not anticipated to have adverse impacts on the safety or health of occupants, or those involved with the construction, commissioning, and maintenance of the building.

3.3.4 Impact on Building Owners and Occupants (Including Homeowners and Potential First-Time Homeowners)

Building owners and occupants will benefit from lower energy bills. For example, the Energy Commission estimates that on average the 2016 Title 24, Part 6 Standards will increase the construction cost by $2,700 per single family home, but the standards will also result in a savings of $7,400 in energy and maintenance cost savings over 30 years. This is roughly equivalent to a $11 per month increase in payments for a 30-year mortgage and a monthly energy cost savings of $31 per month. Overall, the 2016 Title 24, Part 6 Standards are expected to save homeowners about $240 per year relative to homeowners whose single family homes are minimally compliant with the 2013 Title 24, Part 6 requirements (California Energy Commission 2015b). As discussed in Section 3.4.1, when homeowners or building occupants save on energy bills, they tend to spend it elsewhere in the economy thereby creating jobs and economic growth for the California economy. Energy cost savings can be particularly beneficial to low income homeowners who typically spend a higher portion of their income on energy bills, often have trouble paying energy bills, and sometimes go without food or medical care to save money for energy bills (Association, National Energy Assistance Directors 2011).

Additional benefits to the builder owner and occupants include increased interior comfort for the occupant, improved durability, and reduced risk of moisture intrusion through the building envelope due to good thermal envelope integrity.

3.3.5 Impact on Building Component Retailers (Including Manufacturers and Distributors)

This proposed measure is not expected to have significant impact on manufacturers, distributors, and retailers of insulation products. QII only verifies that insulation and air sealing are installed according to manufacturers' recommendations and do not change the components used in construction. There is a potential that market share of certain insulation products may change as QII adoption increases, and certain products may be seen as more favorable to successful QII installations. There may be more demand from the building industry to provide support and guidance on how to meet QII standards using their product.

Refer to Appendix B for a description of how the compliance process will impact building designers and energy consultants.

3.3.6 Impact on Building Inspectors and HERS Raters

Building inspectors will not be significantly impacted by this measure. As the party responsible for inspecting and signing off on QII, HERS Raters are affected by compliance challenges with QII. It is anticipated that making QII prescriptive will increase the number of projects using QII for compliance and HERS Raters should expect to increase the frequency that QII verification is requested as a result of this measure becoming prescriptive. Building officials have commented that their insulation inspections consume less time when QII verification is completed by HERS inspectors.

3.3.7 Impact on Statewide Employment

Section 3.4.1 discusses statewide job creation from the energy efficiency sector in general, including updates to Title 24, Part 6.

3.4 Economic Impacts

The estimated impacts that the proposed code change will have on California's economy are discussed below.

3.4.1 Creation or Elimination of Jobs

In 2015, California's building energy efficiency industry employed more than 321,000 workers who worked at least part time or a fraction of their time on activities related to building efficiency. Employment in the building energy efficiency industry grew six percent between 2014 and 2015 while the overall statewide employment grew three percent (BW Research Partnership 2016). Lawrence Berkeley National Laboratory's report *Energy Efficiency Services Sector Workforce Size and Expectations for Growth* (2010) provides a detail on the types of jobs in the energy efficiency sector that are likely to be supported by revisions to building codes.

Building codes that reduce energy consumption provide jobs through *direct employment*, *indirect employment*, and *induced employment*.[4] Title 24, Part 6 creates jobs in all three categories with a significant amount attributed to induced employment, which accounts for the expenditure-induced effects in the general economy due to the economic activity and spending of direct and indirect employees (e.g., non-industry jobs created such as teachers, grocery store clerks, and postal workers). A large portion of the induced jobs from energy efficiency are the jobs created by the energy cost savings due to the energy efficiency measures. For example, as mentioned in Section 3.3.4, the 2016 Standards are expected to save single family homeowners about $240 per year. Money saved from hundreds of thousands of homeowners over the entire life of the building will be reinvested in local businesses. Wei, Patadia, and Kammen (2010) estimate that energy efficiency creates 0.17 to 0.59 net job-years per GWh saved.[5] By comparison, they estimate that the coal and natural gas industries create 0.11 net job-years per GWh produced. Using the mid-point for the energy efficiency range (0.38 net job-years per GWh saved) and estimates that this proposed code change will result in a statewide first-year savings of 6.6 GWh, this measure will result in approximately 3.3 jobs created in the first year. See Section 6.1 for statewide savings estimates.

An alternative analysis of the potential for job creation within the installer industry was also conducted. The proposed measure results in an expected increase in labor hours of 2.0 hours per "typical" single family home and 1.0 hours per multifamily dwelling unit (based on the prototype buildings applied in this analysis). HERS Rater labor hours are estimated at four hours per single family home and 0.75 hours per multifamily dwelling unit. On a statewide basis, assuming 100 percent of new projects use QII for compliance and accounting for the current percentage of projects already building with QII, this

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[4] The definitions of direct, indirect, and induced jobs vary widely by study. Wei et al (2010) describes the definitions and usage of these categories as follows: "*Direct employment* includes those jobs created in the design, manufacturing, delivery, construction/installation, project management and operation and maintenance of the different components of the technology, or power plant, under consideration. *Indirect employment* refers to the ''supplier effect'' of upstream and downstream suppliers. For example, the task of installing wind turbines is a direct job, whereas manufacturing the steel that is used to build the wind turbine is an indirect job. *Induced employment* accounts for the expenditure-induced effects in the general economy due to the economic activity and spending of direct and indirect employees, e.g., non-industry jobs created such as teachers, grocery store clerks, and postal workers."

[5] One job-year (or ''full-time equivalent'' FTE job) is full time employment for one person for a duration of 1 year.

corresponds to an increase in construction employment by 107 full time employees and an increase in HERS Rater employment of 216 full time employees.

3.4.2 Creation or Elimination of Businesses in California

There are approximately 43,000 businesses that play a role in California's advanced energy economy (BW Research Partnership 2016). California's clean economy grew ten times more than the total state economy between 2002 and 2012 (20 percent compared to two percent). The energy efficiency industry, which is driven in part by recurrent updates to the building code, is the largest component of the core clean economy (Ettenson and Heavey 2015). Adopting cost-effective code changes for the 2019 Title 24, Part 6 code cycle will help maintain the energy efficiency industry.

Table 3 lists industries that will likely benefit from the proposed code change by North American Industry Classification System (NAICS) Code. Builders, insulation contractors, and manufacturers will all be impacted, primary as it relates to the new construction residential industry. All of the insulation manufacturers mentioned in Section 3.1 conduct business within California and have the opportunity to increase sales revenue. The proposed code change is not expected to have a significant impact on the retrofit market.

Table 3: Industries Receiving Energy Efficiency Related Investment, by North American Industry Classification System (NAICS) Code

Industry	NAICS Code
Residential Building Construction	2361
Insulation Contractors	23831
Manufacturing	32412
Building Inspection Services	541350

3.4.3 Competitive Advantages or Disadvantages for Businesses in California

In 2014, California's electricity statewide costs were 1.7 percent of the state's gross domestic product (GPD) while electricity costs in the rest of the United States were 2.4 percent of GDP (Thornberg, Chong and Fowler 2016). As a result of spending a smaller portion of overall GDP on electricity relative to other states, Californians and California businesses save billions of dollars in energy costs per year relative to businesses located elsewhere. Money saved on energy costs can be otherwise invested, which provides California businesses with an advantage that will only be strengthened by the adoption of the proposed code changes that impact nonresidential buildings.

3.4.4 Increase or Decrease of Investments in the State of California

The proposed changes to the building code are not expected to impact investments in California on a macroeconomic scale, nor are they expected to affect investments by individual firms. The allocation of resources for the production of goods in California is not expected to change as a result of this code change proposal.

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

The proposed code changes are not expected to have a significant impact on the California's General Fund, any state special funds, or local government funds. Revenue to these funds comes from taxes levied. The most relevant taxes to consider for this proposed code change are: personal income taxes, corporation taxes, sales and use taxes, and property taxes. The proposed changes for the 2019 Title 24, Part 6 Standards are not expected to result in noteworthy changes to personal or corporate income, so the revenue from personal income taxes or corporate taxes is not expected to change. As discussed, reductions in energy expenditures are expected to increase discretionary income. State and local sales tax revenues may increase if homeowners spend their additional discretionary income on taxable items. Although logic indicates there may be changes to sales tax revenue, the impacts that are directly related to revisions to Title 24, Part 6 have not been quantified. Finally, revenue generated from property taxes is directly linked to the value of the property, which is usually linked to the purchase price of the property. The proposed changes will increase construction costs. As discussed in Section 3.3.1, however, there is no statistical evidence that Title 24, Part 6 drives construction costs or that construction costs have a significant impact on home price. Since compliance with Title 24, Part 6 does not have a clear impact on purchase price, it can follow that Title 24, Part 6 cannot be shown to impact revenues from property taxes.

3.4.5.1 Cost of Enforcement

Cost to the State

State government already has budget for code development, education, and compliance enforcement. While state government will be allocating resources to update the Title 24, Part 6 Standards, including updating education and compliance materials and responding to questions about the revised requirements, 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 proposed residential changes will not impact state buildings.

Cost to Local Governments

All revisions to Title 24, Part 6 will result in changes to compliance determinations. Local governments will need to train building department staff on the revised Title 2, Part 6 Standards. While this re-training is an expense to local governments, it is not a new cost associated with the 2019 code change cycle. The building code is updated on a triennial basis, and local governments plan and budget for retraining. There are numerous resources available to local governments to support compliance training that can help mitigate the cost of retraining, including tools, training and resources provided by the IOU Codes and Standards program (such as EnergyCode Ace). As noted in Section 2.5 and 0, the Statewide CASE Team considered how the proposed code change might impact various market actors involved in the compliance and enforcement process and aimed to minimize negative impacts on local governments.

3.4.6 Impacts on Specific Persons

The proposed changes to Title 24, Part 6 are not expected to have a differential impact on any groups relative to the state population as a whole, including migrant workers, commuters, or persons by age, race, or religion. Given construction costs are not well correlated with home prices, the proposed code changes are not expected to have an impact on financing costs for business or home-buyers. Some financial institutions have progressive policies that recognize the financial implications associated with occupants of energy efficient homes saving on energy bills and therefore have more discretionary income.[6]

Renters 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 some of the net savings depending on if and how landlords account for energy cost when determining rent prices.

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 (Association, National Energy Assistance Directors 2011). Thus, low-income families are likely to disproportionately benefit from Title 24, Part 6 Standards that reduce residential energy costs.

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[6] For example, see U.S. EPA's ENERGY STAR website for examples: http://www.energystar.gov/index.cfm?fuseaction=new_homes_partners.showStateResults&s_code=CA.

4. ENERGY SAVINGS

4.1 Key Assumptions for Energy Savings Analysis

The energy savings analysis relied on the CBECC-Res software to estimate energy use for single family and multifamily prototype buildings. QII was evaluated and compared to a building that minimally complies with the 2016 Title 24, Part 6 Standards. All climates zones were evaluated.

4.2 Energy Savings Methodology

To assess the energy, demand, and energy cost impacts, the Statewide CASE Team compared current design practices to design practices that will comply with the proposed requirements. There is an existing Title 24, Part 6 Standard that covers QII, and applies to both new construction and additions where energy compliance is demonstrated for the "addition alone" (§150.2(a)2A). Existing conditions assume a building minimally complies with the 2016 Title 24, Part 6 Standards. The 2016 Title 24 Part 6 prescriptive Standards do not require QII verification, therefore the baseline condition is a building without QII. See Section 5.1 for further details on the simulation assumptions.

The proposed conditions are defined as the design conditions that will comply with the proposed code change. Specifically, the proposed code change applies QII as a prescriptive requirement in all climate zones for new construction and additions greater than 700 square feet (ft^2), except low-rise multifamily buildings in Climate Zone 7.

The Energy Commission provided guidance on the type of prototype buildings that must be modeled. Residential single family energy savings are calculated using two prototypes (a 2,100 ft^2 single story building and a 2,700 ft^2 two-story building) available in CBECC-Res. Residential results are weighted 45 percent for the 2,100 ft^2 and 55 percent for the 2,700 ft^2. Multifamily savings are calculated based on a multifamily prototype (an eight-unit, 6,960 ft^2 two-story building) available in CBECC-Res. Details on the prototypes are available in the ACM Approval Manual (California Energy Commission 2015a).

Table 4 presents the details of the prototype buildings used in the analysis. Additional prototype details can be found in Appendix C.

Table 4: Prototype Buildings used for Energy, Demand, Cost, and Environmental Impacts Analysis

Prototype ID	Occupancy Type	Area (ft^2)	Number of Stories	Statewide Area (million ft^2)
New Construction Prototype 1	Residential single family	2,100	1	110.6
New Construction Prototype 2	Residential single family	2,700	2	173.8
New Construction Prototype 3	Residential low-rise multifamily	6,960	2	45.7

The energy savings from this measure varies by climate zone. As a result, the energy impacts and cost-effectiveness were evaluated by climate zone.

Energy savings, energy cost savings, and peak demand reductions were calculated using a TDV (Time Dependent Valuation) methodology. The 2019 TDV multipliers were applied.

4.3 Per-Unit Energy Impacts Results

All result tables in Sections 4 and 5 present results for both a single family dwelling unit (weighted by one-story, two-story ratio) and for the eight-unit multifamily prototype. Energy impacts for each of the three prototypes are presented in Appendix G.

Energy savings and peak demand reductions per unit for the blended single family prototype (45 percent one-story, 55 percent two-story) and the multifamily eight-unit prototype (new construction) are presented in Table 5 and Table 6 respectively. See Section 6.1 of this report for estimated statewide savings from additions and alterations. The per-unit energy savings estimates do not take naturally occurring market adoption or compliance rates into account.

Blended single family "per-unit" first-year savings are projected to range from a high of 306 kilowatt-hours per year (kWh/yr) and 54 therms/year to a low of 10 kWh/yr and five therms/yr, depending upon climate zone. Demand reductions are expected to range between zero kilowatts (kW) and 0.24 kW depending on climate zone. The proposed measure does have expected demand reductions in most climates, however the impact is marginal and the impact on demand response potential is negligible.

Table 5: First-Year Energy Impacts per Single Family Dwelling Unit (Averaged over One and Two-Story Prototypes) - New Construction

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	46.0	0.00	54.4	12,641
2	32.6	0.03	31.0	9,056
3	23.0	0.00	27.4	6,705
4	29.5	0.05	22.8	7,937
5	22.5	0.00	27.9	6,626
6	18.7	0.02	16.8	4,967
7	9.7	0.02	9.9	2,736
8	37.1	0.10	10.2	6,368
9	65.1	0.13	13.1	7,993
10	76.2	0.12	15.3	8,311
11	142.8	0.13	29.5	13,508
12	72.9	0.15	27.7	12,602
13	157.8	0.16	24.6	13,923
14	132.7	0.15	29.7	14,006
15	306.3	0.24	5.3	14,923
16	58.5	0.04	51.2	13,042

Multifamily "per 8-unit building" first-year savings are projected to range from a high of 518 kilowatt-hours per year (kWh/yr) and 107 therms/year to a low of -36 kWh/yr and 2 therms/year depending upon climate zone. Demand reductions are expected to range between -0.08 kilowatts (kW) and 0.42 kW depending on climate zone. The proposed measure does have expected demand reductions in most climates, however the impact is marginal and the impact on demand response potential is negligible. Some mild climates show slight increases in cooling energy use and demand from internal heat gains, but net TDV savings are positive in all climates.

Table 6: First-Year Energy Impacts per Multifamily Building Type (Eight-Unit Prototype) - New Construction

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	48.3	-0.02	91.8	21,228
2	57.8	0.05	57.9	16,495
3	-3.5	0.00	36.9	8,422
4	80.8	0.15	40.2	14,686
5	-36.1	-0.08	32.2	5,150
6	5.0	0.03	17.7	5,359
7	-15.5	0.03	1.9	1,114
8	81.5	0.14	8.7	8,770
9	126.2	0.24	15.5	13,363
10	124.1	0.20	19.9	13,015
11	250.4	0.26	54.0	26,239
12	159.0	0.21	52.4	22,411
13	276.8	0.29	46.2	25,404
14	231.9	0.24	54.3	24,778
15	518.3	0.42	2.4	24,778
16	130.3	0.08	107.4	27,840

5. Lifecycle Cost and Cost-Effectiveness

5.1 Energy Cost Savings Methodology

Time Dependent Valuation (TDV) energy is a normalized format for comparing electricity and natural gas cost savings that takes into account the cost of electricity and natural gas consumed during each hour of the year. The TDV values are based on long-term discounted costs (30 years for all residential measures and nonresidential envelope measures and 15 years for all other nonresidential measures). In this case, the period of analysis used is 30 years. The TDV cost impacts are presented in 2020 present value (PV) dollars. The TDV energy estimates are based on present-valued cost savings but are normalized in terms of “TDV kBtu.” Peak demand reductions are presented in peak power reductions (kW). The Energy Commission derived the 2020 TDV values that were used in the analyses for this report (Energy + Environmental Economics 2016).

The 2016 CBECC-Res software was used to quantify energy savings and peak electricity demand reductions resulting from the proposed measure. Simulations were conducted using the 2016.2.0+ (864) version of the software and the 2016.2.0+ (626) version of the BEM Compliance Manager with minor updates described below to the Standard Design to better reflect existing conditions.

1. The Energy Commission expects to adopt the ANSI/ASHRAE Standard 62.2-2016 (ASHRAE 2016) which requires higher mechanical ventilation airflows for single family homes than the 2010 version of the standard (the 2010 standard is the current requirement in California). The proposed 2016 airflows have been included in both the Standard Design and the Proposed Design for the single family analysis. There is no change in ventilation requirements for multifamily; therefore no adjustments were made for ventilation rates in the multifamily prototype.
2. The 2016 California Plumbing Code includes requirements that all hot water pipes be insulated (CA BSC (Building Standards Commission) 2016). The next release of CBECC-Res is expected

to incorporate this requirement, but the current release does not. The Standard Design and the Proposed Design have been adjusted to include pipe insulation for both the single family and the multifamily analyses.

3. The next release of CBECC-Res is expected to automatically degrade all R-19 insulation to an installed value of R-18, due to compression of the batt in a 2x6 wall cavity. This affects the Standard Design because the 0.051 U-factor requirement is modeled as a wall with R-19 cavity insulation. This was applied to the Standard Design for the single family and multifamily analyses.

The proposed code change applies to new construction and additions greater than 700 square feet only and does not apply to alterations. The energy savings per square foot are assumed to be the same for additions as for new construction.

5.2 Energy Cost Savings Results

The per-unit TDV energy cost savings for newly-constructed buildings over the 30-year period of analysis are presented in Table 7 and Table 8 for single family and multifamily new construction, respectively. These are presented as the discounted present value of the energy cost savings over the analysis period.

Single family per-unit savings for the 2,430 ft^2 blended prototype over the 30-year analysis period are expected to range from a high of $2,582 to a low of $473 depending upon climate zone. Multifamily per-building (8 units) savings over the 30-year period of analysis are expected to range from a high of $4,816 to a low of $193 depending upon climate zone. The TDV methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods. Energy cost savings results for each prototype are presented in Appendix G.

Table 7: TDV Energy Cost Savings Over 30-Year Period of Analysis – per Single-Family Dwelling Unit (Averaged Across One and Two-Story Prototypes) – New Construction

Climate Zone	30-Year TDV Electricity Cost Savings (2020PV $)	30-Year TDV Natural Gas Cost Savings (2020PV $)	Total 30-Year TDV Energy Cost Savings (2020PV $)
1	$226	$1,961	$2,187
2	$398	$1,169	$1,567
3	$121	$1,039	$1,160
4	$505	$868	$1,373
5	$108	$1,038	$1,146
6	$218	$641	$859
7	$105	$368	$473
8	$708	$394	$1,102
9	$879	$504	$1,383
10	$848	$589	$1,438
11	$1,220	$1,117	$2,337
12	$1,128	$1,053	$2,180
13	$1,470	$939	$2,409
14	$1,285	$1,138	$2,423
15	$2,375	$207	$2,582
16	$349	$1,907	$2,256

Table 8: TDV Energy Cost Savings Over 30-Year Period of Analysis – per Multifamily Building Type (Eight-Unit Prototype) – New Construction

Climate Zone	30-Year TDV Electricity Cost Savings (2020PV $)	30-Year TDV Natural Gas Cost Savings (2020PV $)	Total 30-Year TDV Energy Cost Savings (2020PV $)
1	$301	$3,371	$3,672
2	$650	$2,203	$2,854
3	$48	$1,409	$1,457
4	$1,011	$1,529	$2,541
5	-$325	$1,216	$891
6	$241	$686	$927
7	$132	$60	$193
8	$1,180	$337	$1,517
9	$1,722	$590	$2,312
10	$1,481	$771	$2,252
11	$2,480	$2,059	$4,539
12	$1,878	$1,999	$3,877
13	$2,613	$1,782	$4,395
14	$2,203	$2,083	$4,287
15	$4,190	$96	$4,287
16	$807	$4,010	$4,816

5.3 Incremental First Cost

Incremental first costs were estimated from detailed interviews with HERS Raters and builders as well as previous research (California Statewide Utility Codes and Standards Team 2014, TRC Energy Services 2016). During this process the Statewide CASE Team endeavored to consider all aspects of the proposed measure that may result in additional cost. Additionally, where costs were uncertain or the data provided spanned a broad range, the Statewide CASE Team attempted to estimate conservatively so as not to underestimate the first-cost impact. Cost estimates were made to reflect costs expected in the year 2020 when the 2019 Title 24, Part 6 code will be implemented.

Incremental costs for QII include additional labor costs install and air seal to QII standards and HERS Rater inspection costs. All incremental costs are based on labor only. No incremental material costs are assumed. HERS Rater costs include assumptions for sampling for both single and multifamily buildings. HERS procedures allow for a sampling rate of testing one out of seven units. HERS sampling rates used for this report were obtained from CalCERTS. The sampled and tested homes in the registry sample were broken out into single family and multifamily products as well as by 2008 and 2013 code cycles. The results, summarized in Table 9, show approximately 50 percent of units are tested for single family homes in both code cycles and multifamily units in 2008, with the number of tested multifamily units in the 2013 code cycle dropping to one-in-four.

A 50 percent testing rate (1-in-2) for single family and a 25 percent testing rate (1-in-4) for multifamily is applied for the cost-effectiveness analysis.

Table 9: QII HERS Sampling Data

Categories	**2008 Code Single Family**	**2013 Code Single Family**	**2008 Code Multifamily**	**2013 Code Multifamily**
% Tested	49.8%	50.9%	54.3%	25.0%

Additional labor costs to install and air seal to QII standards are based on two additional hours per single family home and one additional hour per multifamily dwelling unit. Labor costs were based on a fully loaded labor rate from RSMeans of $44/hour after applying an average California regional multiplier of 1.1.

HERS verifications costs were obtained from interviews with raters and builders. Raters reported that they typically conduct two to four HERS inspections on each project and total costs per project ranged from $160 to $1,200. Assumptions for this report assume three QII inspections per tested single family building with the third inspection completed at the time of other final HERS inspections and tests, and an average cost of $433 ($142 per inspection). Costs for sampled units are based on the average cost for a single inspection of $183. Multifamily costs assume four site visits per building and a per-visit cost for the 8-unit prototype building of $225 ($225 x 4 = $900). The assumption includes inspection of all tested units during same visit. For additional feedback from the interviews refer to Appendix F.

Table 10 presents the incremental costs for QII broken down by component. Total costs are presented as costs to the builder. The higher “per-building” cost for multifamily is due to inspection of the whole eight-unit building.

Table 10: Summary of Incremental Costs Applied in the Analysis

Component	**Single Family (2,100 ft² & 2,700 ft² Prototypes)**	**Multifamily (6,960 ft², eight-unit Prototype)**
Additional Installation Labor	$88	$352
HERS Verification (Tested)	$433	$900
HERS Verification (Sampled)	$183	$400
HERS Testing Rate	1-in-2	1-in-4
Avg. Cost per Building	($433 + $183)/2 + $88 **= $396**	($900*1 + $400*3)/4 + $352 **= $877**

Incremental costs for additions are expected to be somewhat higher than those estimated for new construction. The economies of scale and opportunity to use HERS sampling (available in new construction) are not present for doing additions. HERS inspection visits will still need to be scheduled at various times during construction, independent of the size of the addition.

Per the Energy Commission's guidance, design costs are not included in the incremental first cost.

5.4 Lifetime Incremental Maintenance Costs

QII verification ensures that insulation and air barriers are installed properly, which can minimize the likelihood of envelope assembly degradation over time. The useful life of the proposed measure is expected to be the lifetime of the home. There are no maintenance requirements or net increase in the maintenance cost for the proposed measures relative to existing conditions.

5.5 Lifecycle Cost-Effectiveness

This measure proposes a 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 Energy Commission establishes the procedures for calculating lifecycle cost-effectiveness. The Statewide CASE Team collaborated with Energy Commission staff to confirm that the methodology in this report is consistent with their guidelines, including which costs were included in the analysis. In this case, incremental first cost and incremental maintenance costs over the 30-year period of analysis were included. The TDV energy cost savings from electricity and natural gas savings were also included in the evaluation.

Design costs were not included nor was the incremental cost of code compliance verification. It is not anticipated that costs in either of these categories will be affected by this measure.

According to the Energy Commission's definitions, a measure is cost-effective if the benefit-to-cost (B/C) ratio is greater than one. The B/C ratio is calculated by dividing the total present lifecycle cost benefits by the present value of the total incremental costs.

Results of the per-unit lifecycle cost-effectiveness analyses are presented in Table 11 and Table 12 for single family and multifamily new construction, respectively. If B/C ratios are less than one, they are highlighted in a red font.

For the 2,430 ft^2 blended single family prototype case, the proposed measure demonstrates a favorable B/C ratio over the 30-year period of analysis relative to the existing conditions in all climate zones. For the multifamily prototype, cost-effectiveness is slightly less favorable, but is cost-effective in all Climate Zones except 7.

Table 11: Lifecycle Cost-Effectiveness Summary per Single-Family Dwelling Unit (Averaged Across One and Two-Story Prototypes) – New Construction

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2020PV $) (from Table 7)	Costs Total Incremental Present Valued (PV) Costs[b] (2020PV $)	Benefit-to-Cost Ratio
1	$2,187	$396	5.52
2	$1,567	$396	3.96
3	$1,160	$396	2.93
4	$1,373	$396	3.47
5	$1,146	$396	2.89
6	$859	$396	2.17
7	$473	$396	1.20
8	$1,102	$396	2.78
9	$1,383	$396	3.49
10	$1,438	$396	3.63
11	$2,337	$396	5.90
12	$2,180	$396	5.50
13	$2,409	$396	6.08
14	$2,423	$396	6.12
15	$2,582	$396	6.52
16	$2,256	$396	5.70

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes present value maintenance cost savings if PV of proposed maintenance costs is less than the PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation adjusted) three percent rate. Includes incremental first cost if proposed first cost is greater than current first cost. Includes present value of maintenance incremental cost if PV of proposed maintenance costs is greater than the PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

Table 12: Lifecycle Cost-Effectiveness Summary per Multifamily Building Type (Eight-Unit Prototype) – New Construction

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2020PV $) (from Table 8)	Costs Total Incremental Present Valued (PV) Costs[b] (2020PV $)	Benefit-to-Cost Ratio
1	$3,672	$877	4.19
2	$2,854	$877	3.25
3	$1,457	$877	1.66
4	$2,541	$877	2.90
5	$891	$877	1.02
6	$927	$877	1.06
7	$193	$877	0.22
8	$1,517	$877	1.73
9	$2,312	$877	2.64
10	$2,252	$877	2.57
11	$4,539	$877	5.18
12	$3,877	$877	4.42
13	$4,395	$877	5.01
14	$4,287	$877	4.89
15	$4,287	$877	4.89
16	$4,816	$877	5.49

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes present value maintenance cost savings if PV of proposed maintenance costs is less than the PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation adjusted) three percent rate. Includes incremental first cost if proposed first cost is greater than current first cost. Includes present value of maintenance incremental cost if PV of proposed maintenance costs is greater than the PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

Lifecycle cost-effectiveness will differ for additions relative to new construction. While incremental costs are expected to be similar to new construction, HERS sampling would not be available to additions. Without the cost savings benefits of HERS sampling, QII was still found to be cost-effective for single family additions greater than 700 square feet in all climates except Climate Zone 7. With a goal of striving for simplicity in the standards, the Statewide CASE Team is proposing that since the measure is cost-effective on a statewide basis for additions, it should be applied to all climate zones.

6. First-Year Statewide Impacts

6.1 Statewide Energy Savings and Lifecycle Energy Cost Savings

The Statewide CASE Team calculated the first-year statewide savings for new construction by multiplying the per-unit savings, which are presented in Section 4.3, by the statewide new construction forecast for 2020 or expected alterations in 2020, which is presented in more detail in Appendix A.

The approach to estimate energy savings for additions and alterations is based on the methodology applied in the impact analysis report for the 2016 Title 24, Part 6 updates (Noresco and Nittler 2015). In the impact analysis, the projected savings for new construction buildings were increased by 43 percent to account for additions and alterations. The 43 percent factor was based on the dollars spent on new construction compared to that spent on additions and alterations according to 2011 data from the Construction Industry Research Board. For this proposal, the 43 percent is revised to reflect that the proposed code change does not apply to alterations, nor does it apply to additions less than or equal to 700 square feet. In the absence of better information, it is assumed that additions represent half of the total dollars spent on additions and alterations. It is also assumed that 25 percent of additions, by floor area, are greater than 700 square feet and subject to the new proposed prescriptive requirements. Taking all of this into account, the projected savings for new construction have been increased by 5.4 percent to account for additions greater than 700 square feet.[7] Note that this approach does not consider differences in incremental costs or energy savings for additions relative to new construction.

The first-year energy impacts represent the first-year annual savings from all buildings that were completed in 2020, for the climate zones and building types where the measure is cost-effective. The lifecycle energy cost savings represents the energy cost savings over the entire 30-year analysis period. Results are presented in Table 13. The statewide savings estimates do not take naturally-occurring market adoption or compliance rates into account.

Results from new construction by climate zone are presented in Table 13. Table 14 presents first-year statewide energy savings from new construction, additions and alterations. Given data regarding the new construction forecast and expected additions in 2020, the Statewide CASE Team estimates that the proposed code change will reduce annual statewide electricity use by 8.7 GWh/yr with an associated demand reduction of 13.2 MW. Natural gas use is expected to be reduced by 2.8 million therms/yr. The energy savings for buildings constructed in 2020 are associated with a (discounted) present valued energy cost savings of approximately PV $201 million in (discounted) energy costs over the 30-year period of analysis.

[7] 43% * 50% * 25% = 5.4%

Table 13: Statewide Energy and Energy Cost Impacts (Combined Single Family & Multifamily) – New Construction

Climate Zone	Statewide New Construction in 2020 (units)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (million therms)	Lifecycle[b] Present Value Energy Cost Savings (PV $ million)
1	576	0.022	0.000	0.027	$1.1
2	4,672	0.112	0.108	0.107	$5.4
3	19,928	0.260	0.037	0.354	$14.9
4	11,283	0.259	0.461	0.189	$11.4
5	2,191	0.029	-0.007	0.043	$1.7
6	9,829	0.123	0.136	0.116	$5.9
7	9,718	0.056	0.095	0.057	$2.7
8	15,101	0.421	1.106	0.107	$11.9
9	22,643	0.964	1.899	0.181	$20.0
10	22,590	1.467	2.363	0.292	$27.6
11	4,694	0.587	0.539	0.121	$9.6
12	25,437	1.535	3.113	0.578	$45.2
13	8,409	1.158	1.197	0.181	$17.7
14	4,240	0.484	0.540	0.109	$8.8
15	3,657	1.011	0.793	0.017	$8.5
16	4,629	0.210	0.150	0.182	$8.1
TOTAL	**169,597**	**8.7**	**12.5**	**2.7**	**$201**

a. First-year savings from all new buildings completed statewide in 2020.

b. Energy cost savings from all new buildings completed statewide in 2020 accrued during 30-year period of analysis.

Table 14: Statewide Energy and Energy Cost Impacts – New Construction, Alterations and Additions

Construction Type	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First -Year Natural Gas Savings (million therms)	Lifecycle[b] Present Valued Energy Cost Savings (PV $ million)
New Construction	8.7	12.5	2.7	$201
Additions	0.5	0.7	0.1	$11
Alterations	N/A	N/A	N/A	N/A
TOTAL	9.2	13.2	2.8	$212

a. First-year savings from all buildings completed statewide in 2020.

b. Energy cost savings from all buildings completed statewide in 2020 accrued during 30-year period

6.2 Statewide Water Use Impacts

The proposed code change will not result in impacts to water use.

6.3 Statewide Material Impacts

The proposed code change will not result in impacts to toxic materials or materials which require significant energy inputs.

6.4 Other Non-Energy Impacts

Non-energy benefits of the proposed measures include improved occupancy comfort and durability of envelope assemblies.

7. PROPOSED REVISIONS TO CODE LANGUAGE

The proposed changes to the Standards, Reference Appendices, and the ACM Reference Manuals are provided below. Changes to the 2016 documents are marked with <u>underlining</u> (new language) and ~~strikethroughs~~ (deletions).

7.1 Standards

The proposed measure will add a new row in the Building Envelope Insulation section of Table 150.1-A Component Package-A as well as add new language regarding this new prescriptive requirement in Section 150.1.

SECTION 150.1 – PERFORMANCE AND PRESCRIPTIVE COMPLIANCE APPROACHES FOR LOW-RISE RESIDENTIAL BUILDINGS

<u>Section 150.1(c)1.E:</u>

<u>All requirements for Quality Insulation Installation (QII) shall be met as specified in Reference Appendix RA3.5.</u>

Remove Section 150.1(c)8.A.ii:

~~ii. A single gas or propane storage type water heater with an input of 105,000 Btu per hour or less, rated volume less than or equal to 55 gallons and that meets the requirements of Sections 110.1 and 110.3. The dwelling unit shall meet all of the requirements for Quality Insulation Installation (QII) as specified in the Reference Appendix RA3.5, and in addition one of the following shall be installed:~~

~~a. A compact hot water distribution system that is field verified as specified in the Reference Appendix RA4.4.16; or~~

~~b. All domestic hot water piping shall be insulated and field verified as specified in the Reference Appendix RA4.4.1, RA4.4.3 and RA4.4.14.~~

Table 150.1-A:

Table 15: Proposed Updates to Table 150.1-A Component Package-A – Single Family

		Climate Zone															
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Building Envelope Insulation	**<u>QII Inspection</u>**	<u>REQ</u>	<u>REQ</u>	<u>REQ</u>	<u>REQ</u>	<u>REQ</u>	<u>REQ</u>	<u>REQ</u>	<u>REQ</u>	<u>REQ</u>	<u>REQ</u>	<u>REQ</u>	<u>REQ</u>	<u>REQ</u>	<u>REQ</u>	<u>REQ</u>	<u>REQ</u>

Table 16: Proposed Updates to Table 150.1-A Component Package-A – Multifamily

		Climate Zone															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Building Envelope Insulation	QII Inspection	REQ	REQ	REQ	REQ	REQ	REQ	NR	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ

Note: This requires separate prescriptive package tables for single family and multifamily.

7.2 Reference Appendices

The proposed measure will modify Sections RA2.2 and RA3.5 of the Residential Appendices, as described below. Proposed changes include expanding inspection protocols to properly address insulation methods not adequately addressed in the current language, revising language to provide more clarity where needed, and deleting sections that are already covered elsewhere in RA3.5.

SECTION RA2.2 – MEASURES THAT REQUIRE FIELD VERIFICATION AND DIAGNOSTIC TESTING

Table RA2-1: *Summary of Measures Requiring Field Verification and Diagnostic Testing*

	Building Envelope Measures	
~~High~~ Quality Insulation Installation (QII)	Compliance Software recognizes standard and improved envelope construction. ~~Compliance credit can be taken for quality installation of insulation.~~ Quality Installation of Insulation is a prescriptive measure in all climate zones for new construction and additions greater than 700 square feet, except low-rise multifamily buildings in Climate Zone 7. Field verification is required.	RA3.5

The Statewide CASE Team is recommending a rewrite of some parts of Section 3.5 of Residential Appendix 3 (RA3.5) to provide more clarity where needed, reduce duplication of language to simplify, and add additional language to describe inspection procedures for insulation methods not adequately addressed in the current version of RA3.5.

SECTION RA3.5 – QUALITY INSULATION INSTALLATION INSPECTION PROCEDURES

SECTION RA3.5.2 – Definitions

Compression	~~Compacting~~ The improper placement of insulation in an assembly that results in ~~elimination of the air pockets trapped in the material that gives the insulation its R-value per inch~~ an installation less than the product's nominal thickness. Batt insulation should be "lofted" and loose-fill and spray foam material properly field applied to the manufacturer specified density to achieve its full R-value. Limited compression is allowed at plumbing, vents, and other obstructions and in cavities of non-standard framing. ~~Compression of insulation in these situations by more than 50% is excessive and shall not be allowed~~ Compression of insulation in these situations is limited to no more than 30% of its' nominal thickness.

Delaminated	Separation of the insulation's full thickness to facilitate its installation around or between obstructions. Batt and blanket insulation are often split or delaminated to fit around electrical wires and plumbing runs through a wall cavity to prevent voids, or compression of the insulation. The delamination must ensure that the full thickness of the insulation is installed between the obstruction and the finish material covering the framing. For example, an electrical wire located one-third of the distance from the front of the cavity should have batt insulation delaminated so that two-thirds of the batt is installed towards the outside wall surface and one-third is installed towards the inside wall surface from the wire.
Inset Stapling	A method of attaching faced batt or blanket insulation to wood framing, where the ~~The~~ flange of the insulation facing is pushed inside the face of the framing member and stapled. This method causes a void between the insulation and the air barrier. ~~as opposed to~~ In windy areas installers often staple the flanges of faced batts to the sides of the stud ~~in order to~~ to assure that the insulation remains in place until covered with drywall, particularly on the wall between the house and the garage where there isn't any exterior sheathing to help keep the insulation in place. The void created by the flange inset shall not extend more than two inches from the stud on each side.
Non-Standard Framing	Standard framing consists of installation of framing members spaced at regular intervals (16” or 24” on center), where batt insulation products can be installed to the full dimensional width of the cavity between framing members. Non-standard framing may include multiple framing members, framing members at unusual spacing, additional blocking within cavity, structural columns or beams, or metal structural connections that alter the cavity depth or width.

SECTION RA3.5.3 – BATT AND BLANKET INSULATION

RA3.5.3.1.1 Requirements for Walls, Roof/Ceilings and Floors

(h) When batt and blanket insulation are cut to fit a non-standard cavity, they shall be snuggly fitted to fill the cavity without ~~excessive~~ compression.

~~(j) For batts and blanket insulation that is taller than the trusses, full-width batts shall be used so that they expand to touch each other over the trusses.~~

~~(k) Hard covers or draft stops shall be placed over all drop ceiling areas and interior wall cavities to keep insulation in place and stop air movement. If hard covers or draft stops are missing or incomplete, they shall be completed before insulation is installed.~~

~~(l) Required eave ventilation shall not be obstructed - the net free-ventilation area of the eave vent shall be maintained.~~

~~(m) Eave vent baffles shall be installed to prevent air movement under or into the batt.~~

~~(n) Insulation shall cover all recessed lighting fixtures. If the fixtures are not rated for insulation cover (IC) and air tight, the fixtures shall be replaced.~~

~~All recessed light fixtures that penetrate the ceiling shall be listed for zero clearance insulation contact (IC), have a label that certifies it as airtight with leakage less than 2.0 cfm @ 75 Pa when tested to ASTM E283, and shall be sealed with a gasket or caulk between the light's housing and the ceiling.~~

RA3.5.3.1.3 Certificates

All provisions of Residential Appendix RA2 shall be met. All ~~An~~ Insulation Certificates of Installation completed and signed by the insulation installer shall be provided ~~that states~~ stating the installation is consistent with the Certificate of Compliance, plans and specifications for which the building permit was issued. ~~The certificate shall also state the installing company name, insulation company and manufacturer's name and material identification, and the installed R-value.~~ The insulation installer shall ~~also~~ complete ~~the~~ all applicable sections of the Certificate of Installation form and attach a product specification or data sheet for every insulation material used.

RA3.5.3.2 Wall Insulation

(e) Batt and blanket insulation shall be installed to fill the cavity and be in contact with the sheathing on the back and the wallboard on the front - no gaps or voids.

i. Exception: Batt insulation with flanges that are inset stapled to the side of the stud must be flush with the face of the cavity (or protrude beyond) except for the portion that is less than two inches from the edge of the stud.

~~(f) Batts with flanges that are inset stapled to the side of the stud must be flush with the face of the cavity (or protrude beyond) except for the portion that is less than two inches from the edge of the stud.~~

~~(g) Non-standard-width cavities shall be filled with insulation fitted into the space without excessive compression.~~

~~(h) Batt insulation shall be cut to butt-fit around wiring and plumbing, or be split (delaminated) so that one layer can fit behind the wiring or plumbing, and one layer fit in front.~~

(f) When batt and blanket insulation are cut to fit a non-standard framing, they shall be snuggly fitted to fill the cavity with limited compression.

(g) Batt insulation shall be cut to butt-fit around wiring and plumbing, or be split (delaminated) so that one layer can fit behind the wiring or plumbing, and one layer fit in front. The layers must be proportional to the obstruction's position in the cavity to avoid compressions and voids.

RA3.5.3.2.1 Narrow-Framed Cavities

(b) Narrow spaces less than 1 inch in width at windows and door jambs, shall be filled with minimally expansive foam sealing. In cases where the manufacturer's warranty would be void if minimally expanding foam is used to seal the gap between the window frame or door jamb, the cavity must be airtight and batt insulation cut to width and snuggly fitted (with limited compression) in the space.

RA3.5.3.2.3 Special Situations--Obstructions

(a) Insulation shall be delaminated or cut to fit around wiring ~~and plumbing without~~, plumbing, vents, and other obstructions with limited compression. Compression of insulation in these situations is limited to ≤ 30% of its' nominal thickness.

(b) Insulation shall be placed between the sheathing and the rear of electrical boxes and other obstructions that are not as deep as the cavity (i.e. communications boxes, medicine cabinets) ~~phone boxes~~.

(c) In cold climates, where water pipes may freeze (such as Climate Zones 2, 11-14 and 16) pipes shall have at least 1/2 of the insulation between the water pipe and towards the outside surface of the exterior wall. ~~If the pipe is closer to the exterior finish assembly layers, as~~ As much insulation as possible shall be placed between the pipe and the outside (without ~~excessive~~ compression), and remaining insulation shall be placed between the pipe and the interior assembly material.

RA3.5.3.2.5 Special Situations--Kneewalls, and Skylight Shafts~~, and Gable Ends~~

(a) Framing for kneewalls~~,~~ and skylight shafts ~~and gable ends~~ that separate conditioned from unconditioned space shall be insulated to meet or exceed the wall R-value specified on the Certificate of Compliance, and all other required compliance documentation.

(b) The insulation shall be installed without gaps ~~and with minimal~~ or compression.

(c) ~~For s~~Steel-framed kneewalls~~,~~ and skylight shafts~~, and gable ends,~~ , external surfaces of steel studs shall meet or exceed the mandatory minimum insulation requirements and be covered with continuous insulation unless otherwise specified on the Certificate of Compliance using correct U-factors from Joint Appendix JA4, Table 4.3.4 (or U-factors approved by the Commission Executive Director).

~~(h) In unvented attics, where insulation is applied directly to the underside of the roof deck, kneewalls, skylight shafts, and gable ends shall be insulated to meet or exceed the wall R-value specified on the Certificate of Compliance, and all other required compliance documentation.~~

RA3.5.3.2.6 Special Situations--HVAC/Plumbing Closet

Walls of interior closets for HVAC and/or water heating equipment, which require combustion air venting, shall be insulated to at least the same R-value as ~~the exterior~~ other demising walls (i.e., walls separating conditioned space and attached garage), or as specified on the Certificate of Compliance. ~~in compliance documentation.~~

RA3.5.3.2.10 Special Situations--Gable Ends in Unvented Attics

In unvented attics, where insulation is applied directly to the underside of the roof deck, framing for gable ends that separate the unvented attic from the exterior or unconditioned space shall be insulated to meet or exceed the wall R-value of the adjacent exterior wall construction as specified on the Certificate of Compliance.

RA3.5.3.3 Roof/Ceilings

(d) When batt and blanket insulation are cut to fit a non-standard cavity, they shall be snuggly fitted to fill the cavity ~~without~~ with limited compression.

(e) Batt and blanket insulation shall be cut to butt-fit around wiring and plumbing, or be split (delaminated) so that one layer can fit behind the wiring or plumbing, and one layer fit in front.

(f) Batt and blanket insulation that is thicker than ~~truss~~ the framing depth shall be installed so that the insulation expands to touch ~~adjoining cavity~~ adjacent insulation over each ~~truss~~ framing member.

(k) Facings and insulation shall be kept away from combustion appliance flues in accordance with flue manufacturers' installation instructions or labels on the flue.

RA3.5.3.3.1 Special Situations--Enclosed Rafter Ceilings

(a) In vented rafter ceilings, an~~An~~ air space shall be maintained between the insulation and roof sheathing as specified by California Building Code, Sections 1203.2 and R806.3, or as specified by the local building department.

~~(b) Facings and insulation shall be kept away from combustion appliance flues in accordance with flue manufacturers' installation instructions or labels on the flue.~~

~~(c)~~(b) Insulation installed in unvented rafter ceilings or to the underside of unvented roofs with an attic below shall have an R-value conforming to compliance documentation and the air barrier shall be uniform across the transition of roof to wall. The insulation shall be in contact with the air barrier.

~~**RA3.5.3.3.2 Special Situations--Attics and Cathedral Ceilings**~~

~~In unvented attics, where insulation is applied directly to the underside of the roof deck, all gable ends shall be insulated to the same R-value as the exterior walls as specified in the compliance documentation.~~

RA3.5.3.3.3 Special Situations--HVAC Platform

(a) Batt and blanket insulation shall be placed below ~~any~~ <u>all</u> platform<u>s</u> or cat-walk<u>s used</u> for HVAC equipment installation and access.

(b) Batt and blanket insulation shall be installed so that they will be in contact with the air barrier.

<u>(c) Batt and blanket insulation shall be installed under HVAC platform to the full depth and rated R-value as specified on the Certificate of Compliance, without gaps or compression. If necessary, HVAC platform shall be raised to accommodate ceiling insulation.</u>

<u>RA3.5.3.3.5 Special Situations--Below Roof Deck Insulation (Vented and Unvented Attics)</u>

<u>(a) Below roof deck insulation consisting of batts that nominally fill the cavity space between roof framing members shall be stapled, or supported with cabling, tension rods, or other support measures which maintain the batt uniformly against the roof deck with limited compression. Batts with facing directed to the attic space shall be face stapled. Inset stapling of underside batts is not allowed. Batts supported with cabling, tension rods, or other methods supporting the batt from below shall be supported at intervals less than or equal to 16”, and no further than 8” from the end of the batt. Batts that are directly stapled through the insulation material to the roof deck should maintain the batt uniformly against the roof deck with limited compression.</u>

<u>(b) When the batt thickness nominally exceeds the depth of the roof framing members, full-width batts must be used and the batt shall be secured as described in (a). Full depth insulation coverage at the bottom of the roof framing member is not required as part of the QII inspection process.</u>

<u>(c) For vented attics, below deck batt or blanket insulation shall be installed in a manner that does not obstruct eave, ridge, or eyebrow vents to allow for adequate attic ventilation. The required net free ventilation area of all eave and roof vents shall be maintained. Eave vent baffles shall be installed to prevent air movement under or into the batt.</u>

SECTION RA3.5.4 – LOOSE FILL INSULATION

RA3.5.4.1.1 Requirements for Walls, Roof/Ceilings and Floors

~~(l) Hard covers or draft stops shall be placed over all drop ceiling areas and interior wall cavities to keep insulation in place and stop air movement. If hard covers or draft stops are missing or incomplete, they shall be completed before insulation is installed.~~

~~(m) Required eave ventilation shall not be obstructed - the net free-ventilation area of the eave vent shall be maintained.~~

~~(n) Eave vent baffles shall be installed to prevent air movement under or into the batt.~~

~~(o) Insulation shall cover all recessed lighting fixtures. If the fixtures are not rated for insulation cover (IC) and air tight, the fixtures shall be replaced.~~

~~(p) All recessed light fixtures that penetrate the ceiling shall be listed for zero clearance insulation contact (IC), have a label that certifies it as airtight with leakage less than 2.0 cfm @ 75 Pa when tested to ASTM E283, and shall be sealed with a gasket or caulk between the light's housing and the ceiling.~~

RA3.5.4.1.3 Certificates

(a) All provisions of Residential Appendix RA2 shall be met. <u>All</u> ~~An~~ Insulation Certificate<u>s</u> of

Installation, completed and signed by the insulation installer, shall be provided ~~that states~~ stating the installation is consistent with the Certificate of Compliance, plans and specifications for which the building permit was issued. ~~The certificate shall also state the installing company name, insulation manufacturer's name and material identification, the installed R-value.~~ The insulation installer shall complete ~~the~~ all applicable sections of the Certificate of Installation form and attach a bag label or a manufacturer's coverage chart for every different type of loose-fill insulation material used.

RA3.5.4.2.1 Narrow-Framed Cavities

(b) Narrow spaces less than 1 inch in width at windows and door jambs, shall be filled with minimally expansive foam sealing. In cases where the manufacturer’s warranty would be void if minimally expanding foam is used to seal the gap between the window frame or door jamb, the cavity must be airtight and filled with insulation snuggly fitted (with limited compression) in the space.

RA3.5.4.2.3 Special Situations-Obstructions

(c) In cold climates, where water pipes may freeze (such as Climate Zones 2, 11-14 and 16) pipes shall have at least 1/2 of the insulation between the water pipe and towards the outside surface of the exterior wall. ~~If the pipe is closer to the exterior finish assembly layers, as~~ As much insulation as possible shall be placed between the pipe and the outside (without ~~excessive~~ compression), and remaining insulation shall be placed between the pipe and the interior assembly material.

RA3.5.4.2.5 Special Situations--Kneewalls~~,~~ and Skylight Shafts~~, and Gable Ends~~

(a) Framing for kneewalls~~,~~ and skylight shafts ~~and gable ends~~ that separate conditioned from unconditioned space shall be insulated to meet or exceed the wall R-value specified on the Certificate of Compliance, and all other required compliance documentation.

(b) The insulation shall be installed without gaps ~~and with minimal~~ or compression.

(c) ~~For s~~Steel-framed kneewalls~~,~~ and skylight shafts~~, and gable ends,~~ shall meet or exceed the mandatory minimum insulation requirements and external surfaces of steel studs shall be covered with continuous insulation unless otherwise specified on the Certificate of Compliance using correct U- factors from Joint Appendix JA4, Table 4.3.4 (or U-factors approved by the Commission Executive Director).

~~(h) In unvented attics, where insulation is applied directly to the underside of the roof deck, kneewalls, skylight shafts, and gable ends shall be insulated to meet or exceed the wall R-value specified on the Certificate of Compliance, and all other required compliance documentation.~~

RA3.5.4.2.6 Special Situations--HVAC/Plumbing Closet

Walls of interior closets for HVAC and/or water heating equipment, which require combustion air venting, shall be insulated to at least the same R-value as ~~the exterior~~ other demising walls (i.e., walls separating conditioned space and attached garage), or as specified on the Certificate of Compliance. ~~in compliance documentation.~~

RA3.5.4.2.10 Special Situations—Gable Ends in Unvented Attics

In unvented attics, where insulation is applied directly to the underside of the roof deck, framing for gable ends that separate the unvented attic from unconditioned space shall be insulated to meet or exceed the wall R-value of the adjacent exterior wall construction as specified on the Certificate of Compliance.

RA3.5.4.3 Roof/Ceilings

(b) Baffles shall be placed at eaves or soffit vents of vented attics to keep insulation from blocking eave ventilation and prevent air movement under or into the insulation. The required net free-ventilation shall be maintained.

RA3.5.4.3.1 Special Situations--Enclosed Rafter Ceilings

~~(b) Insulation shall be kept away from combustion appliance flues in accordance with flue manufacturers' installation instructions or labels on the flue.~~

~~**RA3.5.4.3.2 Special Situations - Attics and Cathedral Ceilings**~~

~~In unvented attics, where insulation is applied directly to the underside of the roof deck, all gable ends shall be insulated to the same R-value as the exterior walls as specified in the compliance documentation.~~

RA3.5.4.3.3 Special Situations--HVAC Platform

(c) Loose-fill insulation shall be installed under HVAC platform to the full depth and rated R-value as specified on the Certificate of Compliance, without gaps or compression. If necessary, HVAC platform shall be raised to accommodate ceiling insulation

RA3.5.4.3.5 Special Situations – Below Roof Deck Insulation (Vented and Unvented Attics)

(a) Below roof deck loose-fill insulation shall be netted and installed per manufacturers' specifications.

(b) For vented attics, below deck loose-fill insulation shall be installed in a manner that does not obstruct soffit, eave, ridge or eyebrow vents to allow for adequate attic ventilation. Netting shall be installed in a manner that allows for the required net free area of soffit, eave, gable, and roof vents to be maintained after being filled. Eave vent baffles shall be installed to prevent air movement under or into the insulation.

(c) Netting shall be installed to seal around conduit, plumbing, roof penetrations and all other obstructions that penetrate the netting.

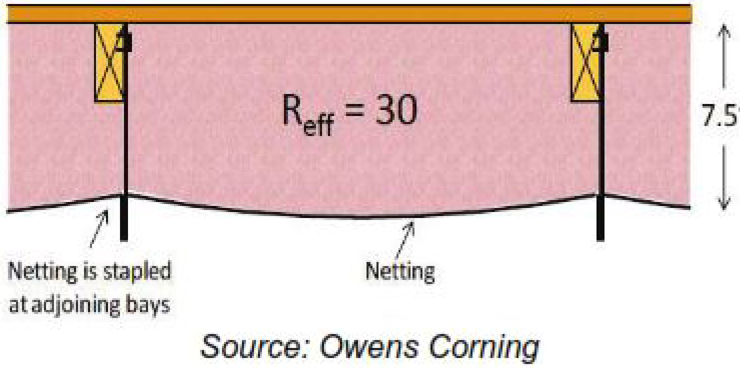
(d) Loose-fill insulation shall be installed uniformly in the netted cavity side-to-side, top-to-bottom, and front-to-back and be in continuous contact with the roof sheathing. Loose-fill insulation shall be installed to fit around wiring, conduit, plumbing, and other obstructions.

(e) The installer shall certify on the Certificate of Installation forms that the manufacturer's minimum weight-per-square-foot requirement has been met.

(f) The HERS Rater shall verify that the manufacturer's minimum insulation thickness and specified R-value has been installed.

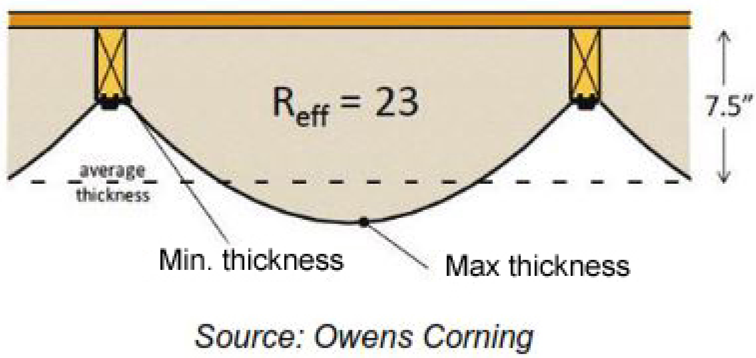
(g) The HERS Rater shall verify the minimum weight-per-square-foot requirement has been met. Verification shall be determined based on one representative sample and using manufacturer's recommended verification procedures. The HERS Rater shall record the weight-per-square-foot of the sample on the Certificate of Verification.

(h) Box netted installations are where netting is suspended from the top of roof framing member, or top chord, to provide a fill depth that completely encloses the top chord, creating a uniform insulation layer of loose-fill insulation across the entire underside of the roof deck. For these installations, netted insulation cavity thickness shall be uniform and meet the minimum insulation thickness.



<u>Figure RA3.5.4-1 Below Deck Loose Fill Insulation – Box Netted Installation</u>

<u>(i) For draped netted installations, where netting is attached directly to the bottom of the roof framing member, the HERS Rater shall verify that average insulation depth in the cavity meets the depth as specified by the Certificate of Compliance.</u>



<u>Figure RA3.5.4-2 Below Deck Loose Fill Insulation – Draped Netted Installation</u>

SECTION RA3.5.5 – RIGID BOARD INSULATION

RA3.5.5.1 Thermal Specification

~~(g) Hard covers or draft stops shall be placed over all drop ceiling areas and interior wall cavities to keep insulation in place and stop air movement. If hard covers or draft stops are missing or incomplete, they shall be completed before insulation is installed.~~

~~(h) Required eave ventilation shall not be obstructed - the net free-ventilation area of the eave vent shall be maintained.~~

~~(i) Eave vent baffles shall be installed to prevent air movement under or into the ceiling insulation.~~

~~(j) Insulation shall cover all recessed lighting fixtures. If the fixtures are not rated for insulation cover (IC) and air tight, the fixtures shall be replaced.~~

~~(k) All recessed light fixtures that penetrate the ceiling shall be listed for zero clearance insulation contact (IC), have a label that certifies it as airtight with leakage less than 2.0 cfm @ 75 Pa when~~

~~tested to ASTM E283, and shall be sealed with a gasket or caulk between the light's housing and the ceiling.~~

RA3.5.5.1.2 Certificates

All provisions of Residential Appendix RA2 shall be met. All ~~An~~ Insulation Certificates of Installation, completed and signed by the insulation installer, shall be provided ~~that states~~ stating the installation is consistent with the Certificate of Compliance, plans and specifications for which the building permit was issued. ~~The certificate shall also state the installing company name, insulation manufacturer's name and material identification, and the installed R-value.~~ The insulation installer shall also complete all applicable sections of the Certificate of Installation form and attach a product specification or data sheet for every insulation material used.

RA3.5.5.2.1 Narrow-Framed Cavities

(b) Narrow spaces less than 1 inch in width at windows and door jambs, shall be filled with minimally expansive foam sealing material. In cases where the manufacturer’s warranty would be void if minimally expanding foam is used to seal the gap between the window frame or door jamb, the cavity must be airtight and filled with insulation snuggly fitted in the space.

RA3.5.5.2.5 Special Situations--Kneewalls~~,~~ and Skylight Shafts~~, and Gable Ends~~

(a) Framing for kneewalls~~,~~ and skylight shafts ~~and gable ends~~ that separate conditioned from unconditioned space shall be insulated to meet or exceed the wall R-value specified on the Certificate of Compliance, and all other required compliance documentation.

(b) ~~For s~~Steel-framed kneewalls~~,~~ and skylight shafts~~, and gable ends,~~ shall meet or exceed the mandatory minimum insulation requirements and external surfaces of steel studs shall be covered with continuous insulation unless otherwise specified on the Certificate of Compliance using correct U-factors from Joint Appendix JA4, Table 4.3.4 (or U-factors approved by the Commission Executive Director).

(c) The backside of air permeable insulation exposed to the unconditioned attic space shall be completely covered with rigid board insulation or an air barrier.

RA3.5.5.2.6 Special Situations--HVAC/Plumbing Closet

Walls of interior closets for HVAC and/or water heating equipment, which require combustion air venting, shall be insulated to at least the same R-value as the ~~exterior~~ other demising walls (i.e., walls separating conditioned space and attached garage), or as specified on the Certificate of Compliance. ~~in compliance documentation.~~

RA3.5.5.2.10 Special Situations—Gable Ends in Unvented Attics

In unvented attics, where insulation is applied directly to the underside of the roof deck, framing for gable ends that separate the unvented attic from unconditioned space shall be insulated to meet or exceed the wall R-value of the adjacent exterior wall construction as specified on the Certificate of Compliance.

RA3.5.5.3 Roofs/Ceilings

(d) Insulation shall cover all recessed lighting fixtures. If the fixtures are not rated for insulation cover (IC) and air tight, the fixtures shall be replaced.

(e) All recessed light fixtures that penetrate the ceiling shall be listed for zero clearance insulation contact (IC), have a label that certifies it as airtight with leakage less than 2.0 cfm @ 75 Pa when tested to ASTM E283, and shall be sealed with a gasket or caulk between the light's housing and the ceiling.

RA3.5.5.3.2 Special Situations - Unvented Attics and Cathedral Ceilings

In unvented attics, where insulation is applied directly to the underside of the roof deck, all gable ends shall be insulated to the same R-value as the adjacent exterior walls as specified in the compliance documentation.

SECTION RA3.5.6 – SPRAY POLYURETHANE FOAM INSULATION

RA3.5.6.1.3 Requirements for Walls, Ceilings and Floors

~~(k) All recessed light fixtures that penetrate the ceiling shall be listed for zero clearance insulation contact (IC), have a label that certifies it as airtight with leakage less than 2.0 cfm @ 75 Pa when tested to ASTM E283, and shall be sealed with a gasket or caulk between the light's housing and the ceiling.~~

~~(l)~~(k) SPF insulation may be used as the air barrier provided it has been tested to conform to the air barrier performance conditions of the Standards (see Section RA3.5.2 for definitions).

~~(m) Hard covers or draft stops shall be placed over all drop ceiling areas and interior wall cavities to keep insulation in place and stop air movement. If hard covers or draft stops are missing or incomplete, they shall be completed before insulation is installed.~~

~~(n) Required eave ventilation shall not be obstructed - the net free-ventilation area of the eave vent shall be maintained.~~

~~(o) Eave vent baffles shall be installed to prevent air movement under or into the ceiling insulation.~~

~~(p) SPF shall not be applied directly to recessed lighting fixtures and left exposed. Recessed light fixtures insulated with SPF insulation shall be protected from ignition by a combination of one or more of the following methods: (1) be covered with a minimum of 1.5 inches of mineral fiber insulation, or (2) be enclosed in a box fabricated from 1/4 inch plywood, 18 gauge metal, 3/8inch hard board or gypboard. The exterior of the box may then be insulated with SPF provided: (1) the SPF insulation is covered with an approved ignition barrier coating tested and supported by an ICC Evaluation Services Report (ESR) or code compliance research report approved by the local agency; or (2) the exposed condition of the SPF insulation is supported by testing with an ICC ESR or research report approved by the local building department.~~

RA3.5.6.1.5 Certificates

All provisions of Residential Appendix RA2 shall be met. The Insulation Certificates of Installation shall be completed and signed by the SPF applicator stating that the installation is consistent with the Certificate of Compliance, plans and specifications for which the building permit was issued shall be provided. The certificate shall also state the installing company name, insulation manufacturer's name and material identification, and that the labeled installed nominal thickness, and installed R-value for SPF insulation meets those specified in Section 3, Thermal Specification. The SPF applicator shall also attach an R-value chart or an ICC ESR showing compliance with AC377 for each SPF insulation material used.

RA3.5.6.2.1 Narrow-Framed Cavities

(b) Narrow spaces less than 1 inch in width at windows and door jambs, shall be filled with minimally expansive foam sealing material or SPF insulation. In cases where the manufacturer’s warranty would be void if minimally expanding foam is used to seal the gap between the window frame or door jamb, the cavity must be airtight and filled with a different insulation product snuggly fitted (with limited compression) in the space.

RA3.5.6.2.5 Special Situations--Kneewalls~~,~~ and Skylight Shafts ~~and Gable Ends~~

(c) ~~For s~~Steel-framed kneewalls~~,~~ and skylight shafts~~, and gable ends,~~ shall meet or exceed the mandatory minimum insulation requirements and external surfaces of steel studs shall be covered with continuous insulation unless otherwise specified on the Certificate of Compliance using correct U-factors from Joint Appendix JA4, Table 4.3.4 (or U-factors approved by the Commission Executive Director).

~~(g) In unvented attics, where SPF is applied directly to the underside of the roof deck, all kneewalls, skylight shafts, and gable ends shall be insulated to the same R-value as the exterior walls and as specified in the compliance documentation.~~

RA3.5.6.2.6 Special Situations--HVAC/Plumbing Closet

Walls of interior closets for HVAC and/or water heating equipment that require combustion air venting, shall be insulated to at least the same R-value as the ~~exterior~~ other demising walls (i.e., walls separating conditioned space and attached garage), or as specified on the Certificate of Compliance. ~~in compliance documentation.~~

RA3.5.6.2.10 Special Situations—Gable Ends in Unvented Attics

In unvented attics, where insulation is applied directly to the underside of the roof deck, framing for gable ends that separate the unvented attic from unconditioned space shall be insulated to meet or exceed the wall R-value of the adjacent exterior wall construction as specified on the Certificate of Compliance.

RA3.5.6.3 Roof/Ceilings

(h) SPF insulation shall not be applied directly to recessed lighting fixtures. Recessed light fixtures insulated with SPF insulation shall be protected from ignition by a combination of one or more of the following methods: (1) be covered with a minimum of 1.5 inches of mineral fiber insulation, or (2) be enclosed in a box fabricated from 1/4 inch plywood, 18 gauge metal, or 3/8 inch hard board or gypboard. The exterior of the box may then be insulated with SPF provided: (1) the SPF insulation is covered with an approved ignition barrier coating tested and supported by an ICC Evaluation Services Report (ESR) or code compliance research report approved by the local agency; or (2) the exposed condition of the SPF insulation is supported by testing with an ICC ESR or research report approved by the local building department. ~~Recessed light fixtures must be either insulated with CBC approved materials (i.e., mineral fiber) or enclosed in a box fabricated from ½-inch plywood, 18 gauge sheet metal, 1/4-inch hard board, drywall or other approved materials. The exterior of the box may then be insulated with SPF. Fixtures that are not air tight and rated for insulation contact (IC) shall be removed and/or replaced.~~

7.3 ACM Reference Manual

This proposed measure will require modification to the description of the Standard Design of the Building in section 2 of the Residential ACM Reference Manual.

SECTION 2 – The Proposed Design and Standard Design

2.2.6 Insulation Construction Quality

STANDARD DESIGN

The Standard Design is modeled with ~~standard~~ improved insulation installation quality.

7.4 Compliance Manuals

Section 3.2 will need to be revised as follows.

3.2 What's New for ~~2016~~2019

The ~~2016~~<u>*2019*</u> *Building Energy Efficiency Standards* for residential buildings include increased efficiencies for several envelope measures, and there are improvements that have been made to better aid the designer, builder, and building official.

<u>Prescriptive requirement for building envelope now includes quality insulation installation (QII) in all climate zones for new construction and additions greater than 700 square feet (ft^2), except low-rise multifamily buildings in Climate Zone 7.</u>

Section 3.6 of Chapter 3 of the Residential Compliance Manual will need to be revised as follows.

Section 3.6.2 Prescriptive Approach

<u>3.6.2.4 Quality Insulation Installation (QII)</u>

New Section. Section 3.6.3.4 to be moved here and language revised to reflect change from compliance credit to prescriptive requirement. Specific edits to manual will be determined at the conclusion of the Energy Commission rulemaking process.

5.4 Prescriptive Requirements for Water Heating

5.4.1 Single Dwelling Units

There are ~~three~~ <u>two</u> options to comply with the prescriptive water heating requirements for newly-constructed single dwelling units. For ~~all three~~ <u>both</u> options, the water heater must comply with the mandatory requirements for water heaters. (See Section 5.3.) If a recirculation distribution system is installed, only demand recirculation systems with manual control pumps are allowed. The ~~three~~ <u>two</u> options are described below.

Option 1: Install a natural gas or propane instantaneous water heater with an input rating of 200,000 BTU per hour or less.

~~Option 2: Install a natural gas or propane storage water heater with a rated storage volume 55 gallons or less and an input rating of 105,000 BTU per hour or less. The dwelling unit must meet all of the requirements for Quality Insulation Installation (QII), which requires that a HERS Rater verify QII has been designed and installed in accordance with Energy Standards. The user must also do one of the following:~~

1. ~~Use a compact hot water distribution design, which requires a HERS Rater to verify that the system has been designed and installed in accordance with the Energy Standards (See Reference Appendix RA4.4.16.)~~
2. ~~Insulate all domestic hot water pipes which requires that a HERS Rater verify that the pipe insulation is designed and installed in accordance to the Energy Standards.~~

Option <u>2</u>~~3~~: Install a natural gas or propane storage water heater with a rated storage volume greater than 55 gallons and an input rating of 105,000 BTU per hour or less. The user must also do one of the following:

1. Insulate all domestic hot water pipes which requires that a HERS Rater verify that the pipe insulation is designed and installed in accordance to the Energy Standards.

~~If Option 2 is pursued, in which a gas storage water heater that is 55 gallons or less is installed instead of a gas instantaneous water heater, then QII will need to be considered at the start of the design process, and it must be coordinated with several players including the designer, the general and/or insulation contractor, and the HERS Rater. QII will be included as part of the first building inspection, typically well in advance of the actual water heater being installed.~~

~~For more information on QII compliance requirements see Chapter 3 (Building Envelope) of this compliance manual and RA3.5 of the Reference Appendix. QII is required for Option 2 but not for~~

~~Option 3. That is, if a natural gas or propane water heater less than 55 gallons is installed, the building must also comply with the QII requirements.~~

7.5 Compliance Documents

There are no proposed changes to the compliance documents.

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Appendix A: STATEWIDE SAVINGS METHODOLOGY

The projected residential new construction forecast that will be impacted by the proposed code change in 2020 is presented in Table 17.

The projected existing residential statewide building stock that will be impacted by the proposed code change as a result of additions and alterations in 2020 is presented in Table 17.

The Statewide CASE Team estimated statewide impacts for the first year that new single family and multifamily buildings comply with the 2019 Title 24, Part 6 Standards by multiplying per-unit savings estimates by statewide construction forecasts that the California Energy Commission Demand Analysis Office provided. The construction forecast from the Energy Commission presented annual new construction estimates for single family and multifamily dwelling units by forecast climate zones (FCZ). The Statewide CASE Team converted estimates from FCZ, which are not used for Title 24, Part 6, to building standards climate zones (BSCZ) using a conversion factors that the Energy Commission provided. The conversion factors, which are presented in Table 18, represent the percentage of dwelling units in a FCZ that are also in a BSCZ. For example, looking at the first column of conversion factors in see Table 18, 22.5 percent of the homes in FCZ 1 are also in BSCZ 1 and 0.1 percent of homes in FCZ 4 are in BSCZ 1. To convert from FCZ to BSCZ, the total forecasted construction in each FCZ was multiplied by the conversion factors for BSCZ 1, then all homes from all FCZs that are found to be in BSCZ 1 are summed to arrive at the total construction in BSCZ 1. This process was repeated for every climate zone. See Table 19 for an example calculation to convert from FCZ to BSCZ. In this example, BSCZ 1 is made up of homes from FCZs 1, 4, and 14.

After converting the statewide construction forecast to BSCZs, the Statewide CASE Team made assumptions about the percentage of buildings in each climate zone that will be impacted by the proposed code change. Assumptions are presented in Table 17.

Table 17: Projected New Residential Construction Completed in 2020 by Climate Zone[a]

Building Climate Zone	Single family Buildings					Multifamily Dwelling Units[b]				
	Total Buildings Completed in 2020	Percent of Total Construction in Climate Zone	Percent of New Buildings Impacted by Proposal	Buildings Impacted by Proposal	Percent of Total Impacted by Proposal in Climate Zone	Total Dwelling Units Completed in 2020	Percent of Total Construction in Climate Zone	Percent of New Dwelling Units Impacted by Proposal	Dwelling Units Impacted by Proposal	Percent of Total Impacted by Proposal in Climate Zone
1	465	0.6%	100%	465	0.6%	111	0.2%	100%	111	0.2%
2	3,090	2.4%	100%	3,090	2.4%	1,582	2.3%	100%	1,582	3.3%
3	11,496	5.7%	100%	11,496	5.7%	8,432	11.7%	100%	8,432	17.4%
4	7,435	5.4%	100%	7,435	5.4%	3,848	5.6%	100%	3,848	7.9%
5	1,444	1.1%	100%	1,444	1.1%	747	1.1%	100%	747	1.5%
6	6,450	4.1%	100%	6,450	4.1%	3,379	9.9%	100%	3,379	7.0%
7	5,779	5.5%	100%	5,779	5.5%	3,939	7.5%	0%	0	0.0%
8	9,948	6.1%	100%	9,948	6.1%	5,153	13.7%	100%	5,153	10.6%
9	12,293	5.4%	100%	12,293	5.4%	10,350	18.5%	100%	10,350	21.3%
10	18,399	17.2%	100%	18,399	17.2%	4,191	10.1%	100%	4,191	8.6%
11	3,947	5.9%	100%	3,947	5.9%	747	1.8%	100%	747	1.5%
12	19,414	19.3%	100%	19,414	19.3%	6,023	8.4%	100%	6,023	12.4%
13	7,034	12.0%	100%	7,034	12.0%	1,375	3.0%	100%	1,375	2.8%
14	3,484	3.1%	100%	3,484	3.1%	756	1.8%	100%	756	1.6%
15	3,203	3.5%	100%	3,203	3.5%	454	1.5%	100%	454	0.9%
16	3,188	2.9%	100%	3,188	2.9%	1,441	3.0%	100%	1,441	3.0%
Total	**117,069**	**100%**		**117,069**	**100%**	**52,528**	**100%**		**48,589**	**100%**

Source: Energy Commission Demand Analysis Office

a. Statewide savings estimates do not include savings from mobile homes.

b. Includes high-rise and low-rise multifamily construction.

Table 18: Translation from Forecast Climate Zone (FCZ) to Building Standards Climate Zone (BSCZ)

		Building Standards Climate Zone (BSCZ)																
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**Total**
Forecast Climate Zone (FCZ)	**1**	22.5%	20.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	9.8%	33.1%	0.2%	0.0%	0.0%	13.8%	100%
	2	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	22.0%	75.7%	0.0%	0.0%	0.0%	2.3%	100%
	3	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	20.9%	22.8%	54.5%	0.0%	0.0%	1.8%	100%
	4	0.1%	13.7%	8.4%	46.0%	8.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	22.8%	0.0%	0.0%	0.0%	0.0%	100%
	5	0.0%	4.2%	89.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	6.6%	0.0%	0.0%	0.0%	0.0%	100%
	6	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	100%
	7	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	75.8%	7.1%	0.0%	17.1%	100%
	8	0.0%	0.0%	0.0%	0.0%	0.0%	40.1%	0.0%	50.8%	8.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%	100%
	9	0.0%	0.0%	0.0%	0.0%	0.0%	6.4%	0.0%	26.9%	54.8%	0.0%	0.0%	0.0%	0.0%	6.1%	0.0%	5.8%	100%
	10	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	74.9%	0.0%	0.0%	0.0%	12.3%	7.9%	4.9%	100%
	11	0.0%	0.0%	0.0%	0.0%	0.0%	27.0%	0.0%	30.6%	42.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100%
	12	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	4.2%	95.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	100%
	13	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	69.6%	0.0%	0.0%	28.8%	0.0%	0.0%	0.0%	1.6%	0.1%	0.0%	100%
	14	2.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	97.1%	100%
	15	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	99.9%	0.0%	100%
	16	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100%

Table 19: Converting from Forecast Climate Zone (FCZ) to Building Standards Climate Zone (BSCZ) – Example Calculation

Climate Zone	Total Statewide Single Family Homes by FCZ [A]	Conversion Factor FCZ to BSCZ 1 [B]	Single Family Homes in BSCZ 1 [C] = A x B
1	1,898	22.5%	427
2	8,148	0.0%	0
3	9,396	0.0%	0
4	16,153	0.1%	23
5	11,385	0.0%	0
6	6,040	0.0%	0
7	2,520	0.0%	0
8	12,132	0.0%	0
9	9,045	0.0%	0
10	21,372	0.0%	0
11	3,741	0.0%	0
12	4,746	0.0%	0
13	8,309	0.0%	0
14	518	2.9%	15
15	1,509	0.0%	0
16	159	0.0%	0
Total	117,069		**465**

Appendix B: Discussion of Impacts of Compliance Process on Market Actors

This section discusses how the recommended compliance process, which is described in Section 2.5, could impact various market actors. The Statewide CASE Team asked stakeholders for feedback on how the measure will impact various market actors during public stakeholder meetings that were held on September 14th, 2016 and March 14th, 2017 (Statewide CASE Team 2016). The key results from feedback received during stakeholder meetings and other target outreach efforts are detailed below.

Table 20 identifies the market actors who will play a role in complying with the proposed change, the tasks for which they will be responsible, their objectives in completing the tasks, how the proposed code change could impact their existing work flow, and ways negative impacts could be mitigated.

QII is currently a compliance credit and therefore many project teams are familiar with the requirements and necessary work flow associated with the verifications. However, the majority of projects (roughly 75 percent) do not currently use the QII compliance credit and therefore it will take some time for the industry to familiarize themselves with the process.

Table 20: Roles of Market Actors in the Proposed Compliance Process

Market Actor	Task(s) In Compliance Process	Objective(s) in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Title 24 Consultant	• Coordinate design with other team members (designer &/or builder) of the requirements and inspections needed for QII • Perform required calculations to confirm compliance • Complete compliance documents for permit application. Ensure that QII is included in CF1R • Review submittals & coordinate with designer to ensure QII is in specifications	• Clearly communicate QII requirements and ensure builder and construction team are aware of requirements and there are no surprises • Demonstrate compliance and energy performance goals are met	• Change from compliance credit to prescriptive measure will eliminate QII as a tool for meeting performance targets • Will need to rely on other efficiency measures to provide credit once provided by QII	• Ensure that QII requirements are clearly articulated in specifications and plans • Ensure that design team and builder are aware that QII is included as part of design and construction of the project and the expectations during construction
Builder / General Contractor	• Confirm bid from insulation contractor includes QII • Coordinate with insulation contractor and other subs to ensure everyone understands requirements and installation quality is met • Ensure building is properly air sealed and continuous air barrier is maintained • Coordinate with and schedule HERS Rater and Building Inspector for inspections • Completes CF2R for air sealing procedures of QII • Ensure construction managers/superintendents know all the requirements	• Meet project budgets and schedules • Minimize / eliminate inspection failures / callbacks • Ensure inspections due not cause schedule delays • Minimize paperwork required • Avoid warranty issues	• Will require more builders to be aware of QII requirements and measures needed to comply • Will need to verify that insulation quotes include QII and contractors are aware of HERS inspections and associated requirements • Will require builders to make sure QII requirements are being met in the field	• Clearly articulate goals and expectations to contractors and importance of meeting QII criteria • Ensure contracts and SOWs with subs are explicit with QII requirements. • Contracts include cost implications by not meeting criteria, including passing on re-inspection costs and costs of schedule delays resulting from non-compliance. • Ensure job superintendent understands expectations and knows when a job is ready for HERS Rater • Empower the rater to be the guarantor of quality and

Market Actor	Task(s) In Compliance Process	Objective(s) in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
	• Purchasing department verifies correct insulation specs			authority to determine compliance
Insulation Contractor	• Install insulation according to QII criteria • Ensure work is not compromised by other subs. • Make sure field crews are aware of requirements needed to meet QII • Complete CF2R for QII and registers the documents with the HERS Provider on the project site	• Meet builder's schedule • Complete installs w/o budget overruns • Minimize time spent on-site installing insulation • Minimize training needed for field crews • Avoid inspection failures & callbacks • Minimize paperwork required	• Will require contractors to be aware of QII requirements as more projects will include QII inspections • Will require contractors to make sure their crews are properly trained and aware of the requirements needed to meet QII • Additional time may be required for installer training	• Ensure installation crew is aware of expectations and requirements to minimize inspection failures and callbacks • Ensure crew has technical competency to deliver QII • Ensure that someone from company is responsible for QA and does walk-thru inspections to catch any issues before crew leaves job and call for HERS Rater inspection
Other Subs (HVAC, Electrical, Plumbing	• Ensure any work they are responsible for does not affect insulation or air barrier integrity	• Work trades are responsible for is not compromised by QII requirements • Minimize additional level of effort	• Will need to be aware of impacts of their work on meeting QII requirements	• Ensure that installation crews are aware of impacts of work on QII
Insulation Manufacturers	• Provide materials used for insulating homes (mineral fiber, cellulose, foam, batt and blown products)	• Provide guidance to installers on proper installation of products to meet QII	• Will need to make sure contractors using their products are installing them properly	• Actively engage with insulation contractors to ensure that they understand how to install products properly to meet QII criteria
Plans Examiner	• Verify that CF1R is consistent with building plans and meets compliance criteria for local jurisdiction	• Minimize amount of paperwork needed to review • Quickly and easily determine if plans/ specs match CF1R	• Will need to verify calculations match plans (this is not new)	• Compliance documents should easily identify if QII inspection is required

Market Actor	Task(s) In Compliance Process	Objective(s) in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Building Inspector	• Verify that all required HERS inspections listed on CF1R have CF2R and CF3R paperwork • Verify that all paperwork is in order and CF2R and CF3Rs are signed off and certified • Sign off permit	• Minimize amount of time and paperwork needed to approve installation	• No impact. Inspector already has to verify CF2R and CF3R for QII • Will see more projects with QII	•
HERS Rater	• Review CF2Rs and documents materials used on site • Inspect both air sealing and insulation components (min two – three site visits) • Verify QII requirements are being met • Makes sure all parties are aware of responsibilities and expectations • If project does not pass, communicate issues with responsible parties and require re-inspection • Complete and submit CF3Rs to HERS Registry	• All projects meet QII criteria and pass without issues • Minimize the amount of inspection failures and callbacks • Minimize time spent and number of visits required to complete inspections quickly and under budget • Maintain positive working relationships with builder and construction team • Avoid QC issues with HERS Provider	• No change. QII and blower door are already part of the services that HERS Raters offer	• Be a QII Advocate. Work with project team to ensure everyone understands the value and importance of QII • Work with builder to ensure that goals and expectations are set by team to achieve compliance • Provide on-site pre-installation training with construction team prior to installation inspections
Building Owner	• Little direct involvement unless spec builder • Develop project goals including programming, schedules, & budget	• Coordination with project team • Minimize amount of paperwork needed to complete process • Project completed to expected standards and within budget	• Will need to consider scheduling and costs of HERS Rater if not familiar with QII	• Support GC and HERS Rater in ensuring that meeting QII is important to successful completion of project. • Be an advocate for proper insulation as a requirement for quality building

Market Actor	Task(s) In Compliance Process	Objective(s) in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
HERS Provider	• Provide service, support, training and certification to HERS Raters • Maintain and operate the HERS Registry • Provide QA field inspections of HERS Raters	• Ensure that CF2Rs and CF3Rs for QII are uploaded to HERS Registry • Ensure that HERS Raters are following the inspection and compliance criteria and maintaining level of professionalism	• No change • More projects will use QII than in past but already processing projects with QII and training HERS Raters in QII procedures	• Provide better clarity to HERS Raters on what is required to meet QII

Appendix C: PROTOTYPE DETAILS

Following are details on the residential prototypes applied in this analysis. Table 21 is a re-creation of the table in Section 4.2. Table 22 provides details on the CBECC-Res modeling inputs and Figure 3 through Figure 5 show graphical representations of the three prototype buildings.

Table 21: Prototype Buildings used for Energy, Demand, Cost, and Environmental Impacts Analysis

Prototype ID	Occupancy Type (Residential, Retail, Office, etc.)	Area (ft^2)	Number of Stories	Statewide Area (million ft^2)
New Construction Prototype 1	Residential single family	2,100	1	110.6
New Construction Prototype 2	Residential single family	2,700	2	173.8
New Construction Prototype 3	Residential low-rise multifamily	6,960	2	45.7

Table 22: Prototype Multiplier Details

Item	Description	Unit	New Construction Prototype 1	New Construction Prototype 2	New Construction Prototype 3
1	Number of Dwelling Units		1	1	8
2	Floor Area	Square feet	2,100	2,700	6,960
3	Slab Perimeter	Linear feet	162	128	292
4	Wall Area	Square feet	1,018	2,130	3,760
5	Wall Area between house and garage	Square feet	250	250	0
6	Wall Area between house and attic	Square feet	0	42	0
7	Window Area	Square feet	420	540	1,044
8	Window Perimeter	Linear feet	351	457	1,114
9	Door Area	Square feet	20	20	160
10	Door Area between house and garage	Square feet	20	20	0
11	Door Perimeter	Linear feet	19	19	155

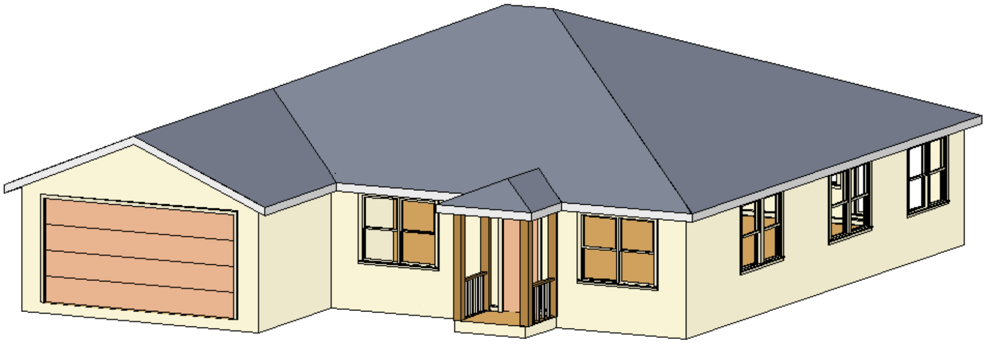

Figure 3: 2,100 ft^2 single family prototype configuration

Figure 4: 2,700 ft^2 single family prototype configuration

Figure 5: 6,960 ft^2 multifamily eight-unit building prototype configuration

Appendix D: QII Credit and Insulation Degradation Details

The QII compliance credit is calculated based on the impact of three components as summarized in Table 4 of the 2016 Residential ACM Reference Manual (see Figure 6):

- Wall, floor, attic roof, and cathedral ceiling insulation degradation
- Ceilings below attic insulation degradation
- Ceiling below attic thermal defects, which assumes heat transfer from conditioned to unconditioned space when a temperature difference is achieved

Table 4: Modeling Rules for Standard Insulation Installation Quality

Component	Modification
Walls, Floors, Attic Roofs, Cathedral Ceilings	Multiply the cavity insulation R-value/inch by 0.7
Ceilings below attic	Multiply the blown and batt insulation R-value/inch by 0.96-0.00347*R
Ceilings below attic	Add a heat flow from the conditioned zone to the attic of 0.015 times the area of the ceiling below attic times (the conditioned zone temperature - attic temperature) whenever the attic is colder than the conditioned space

Figure 6: Table 4 of 2016 Residential ACM Reference Manual – modeling rules for standard insulation installation quality

The Statewide CASE Team compared exterior wall assembly degradation assumptions assumed in the 2016 Residential Title 24, Part 6 ACM Reference Manual with the RESNET insulation grades. Table 4 of the ACM Reference Manual states that unless QII credit is taken, wall cavity insulation R-value per inch is multiplied by 0.7. For a 2x6 wall with R-21 cavity insulation, an R-value of 14.7 will be used for the cavity. For a wall with QII credit taken, the full value of the wall cavity insulation is assumed.

RESNET insulation grades assume the following:

- Grade 1 assumes the full R-value of the wall insulation. In practice, occasional very small gaps are acceptable and up to two percent of the area can have compression or incomplete fill but compression in the two percent area cannot exceed 30 percent of the cavity depth.
- Grade 2 assumes up to two percent of the wall cavity has no insulation and up to ten percent of the area can have compression or incomplete fill and again must be filled to at least 70 percent of their intended insulation depth. It is modeled assuming two percent of the wall cavity has no insulation.
- Grade 3 is modeled assuming that five percent of the wall cavity has no insulation, and is a wall that does not meet either Grade 1 or 2 levels.

Using the ASHRAE series and parallel path procedures for estimating wall assembly U-factors, for a 2x6 wall with R-21 cavity insulation and R-4 exterior insulation, the ACM assumption that the cavity wall insulation value is degraded by 30 percent is equivalent to RESNET for Grade 3 that five percent of the wall cavity has no insulation. This comparison is summarized in Table 23.

Table 23: Title 24 ACM Assumptions for Wall Insulation Degradation Comparison with RESNET Grades

2x6 Frame Wall, 16" o.c., R-21 batt + R-4 rigid exterior	Assembly U-Factor (Btu/hr-ft^2-°F)	Cavity Insulation Adjustment Factor
Title 24 QII/RESNET Grade 1	0.051	1.0
Title 24 No QII	0.060	0.7
RESNET Grade 2 (assumes 2% missing cavity insulation)	0.055	2% of cavity area missing insulation
RESNET Grade 3 (assumes 5% missing cavity insulation)	0.061	5% of cavity area missing insulation

RESNET Grade 2 insulation modeling assumptions will be equivalent to an assumption that the cavity wall insulation value is 0.85 of the full cavity R-value for the 2x6 R-21 + R-4 wall.

Appendix E: LITERATURE REVIEW & INDUSTRY RESEARCH

The Statewide CASE Team reached out to representatives of the North American Insulation Manufacturers Association (NAIMA) who provided the following resources:

- Johns Manville Study: Presentation slides on the Impact of Insulation Installation Quality, June 2010 (Fisler and Smith 2010). Using hot box test, the study compared face stapled, inset stapled batts, and installations with minor gaps. This study concluded there is minimum impact on performance. All test walls were sealed and gaps were minimal. Our impression based on the photos provided, is that all of these installations were fairly good implementations of insulation in controlled situations in clear wall cavities with minimal wiring, plumbing, and obstructions. Thus this is not capturing the areas where QII addresses conditions found in the field: careful fitting of insulation around electrical boxes, drains and piping. Additionally, by having well sealed stud cavities, this eliminates one of the benefits of careful insulation installation: resistance to airflow through the stud cavity (see next study). However, this study under controlled conditions helps quantify the full benefit of QII.
- Building Science Corporation Report: Thermal Metric Project Summary Report – June 2015 Update (Building Science Corporation 2015). The study focused on the impact of air sealing and different insulation types and was a lab study using a hot box in conjunction with a pressure differential imposed on the test walls. In each case an effort was made to install the insulation properly, with the exception of one 2x4 wall with open cell spray foam where they compared an ‘unacceptable’ with an ‘acceptable’ installation; the ‘acceptable’ case showed a 5-22 percent improvement assembly R-value, depending on pressure differential across the assembly. Following are some of the more pertinent conclusions from the report. The first two bullets below discuss the interactive effect of air sealing and insulation quality.
    - When walls are constructed with the same installed R-value in the stud space, and are air sealed both inside and outside (i.e., there is effectively zero air leakage through the assembly), they exhibit essentially the same thermal performance regardless of the type of insulation material used.
    - All of the tested wall assemblies were subject to thermal bridging regardless of the type of insulation material used in the stud space. Thermal bridging through the framing resulted in a roughly 15 percent decrease in thermal performance for the test walls (both 2x4 and 2x6 walls without exterior foam sheathing).
    - All wall assemblies experienced a loss in thermal performance due to air movement through the assembly. This is true for all of the assemblies tested regardless of the type of insulation material used (e.g., cellulose, fiberglass, open-cell spray foam (ocSPF), closed-cell spray foam (ccSPF), or extruded polystyrene (XPS)).
    - The energy impact of airflow depends on the flow path, the interaction between the air and the solid materials in the assembly, the installed R-value of the assembly, as well as pressure and temperature differences across the assembly.
    - Conventional energy models (i.e., those that account for air leakage energy using Q=m*cp * deltaT, the mass flow and heat capacity of air times the difference between that air and inside conditioned air) over-predicted the negative energy impact on walls that have a significant interaction effect (e.g., air moving through insulation) compared to test results.

While both of these studies provide useful information, they are based on simple wall assemblies and do not address the challenges and complicating factors found in the field. They also focus on how different cavity insulation products perform in the field compared to modeled estimates when properly installed.

The Statewide CASE Team also reviewed an Owens Corning training video on meeting the 2013 QII requirements with batt insulation (Owens Corning 2014).[8] The information in the video provides good visual information on proper installation of batt insulation. There is one part of the video that is in conflict with the 2013 QII requirements. In the video section about filling the wall cavity, it states that batts must fully fill cavity to 90 percent and that small voids less than 3/4" are allowed as long as void area is less than ten percent of batt surface area. It is unclear where this language comes from since it is not explicitly stated in section RA3.5 of the 2013 Reference Appendices. Sections RA3.5.3.1.1 and 3.5.3.2 state that “there shall be no gaps, nor shall the insulation be doubled-over or compressed”. Under the definitions (Section RA3.5.2), the following are defined:

- Compression: Limited compression is allowed at plumbing, vents, and other obstructions and in cavities of non-standard framing. Compression of insulation in these situations by more than 50 percent is excessive and shall not be allowed.
- Gaps: Gaps in insulation are avoidable and are not permitted.
- Inset Stapling: The void created by the flange inset shall not extend more than two inches from the stud on each side.

[8] https://www.youtube.com/watch?v=3wEFFGJKQgA

Appendix F: Results from HERS Rater Interviews and HERS Rater Costs

A HERS Rater survey was completed in the fall of 2016. Findings from the survey include:

- Builders still struggle with QII compliance
- Lack of installer training and high worker turnover sited as the biggest challenge to compliance
- Batt insulation makes up 80 percent of wall insulation installs
- From survey results, 70 percent of projects taking QII credit only when necessary for compliance
- Most failures occur during wall insulation inspection phase
- Most common failures include voids, trimming around pipes & wires, air sealing and air barriers
- Average one-three additional site visits are required due to inspection failures
- Inspection failures are much more likely with batt insulation
- Some HERS Raters have lost work for failing QII inspections as builders look for more favorable inspectors
- Insulation is not installed correctly unless QII inspection is completed and enforced

A well-respected consultant who has worked with both HERS Raters and energy consultants on Title 24, Part 6 codes training was also interviewed about QII. His concern is that the QII credit is very large but compliance is based on a qualitative visual inspection and thus subject to interpretation by the HERS Rater. The result is very uneven treatment for the QII measure in the field, resulting in uncertain performance coupled with a large compliance credit. Blower door testing, on the other hand, is a quantitative diagnostic assessment that receives relatively little credit in the Alternative Calculation Method (ACM).

Insulation performance for most insulation products will be seriously degraded if the building assembly is not sealed properly. QII inspections do include visual air sealing inspections but most HERS Raters in the survey agree that these visual inspections are not effective as a tool to quantify actual leakage because they end up being more qualitative than quatitative. At the Envelope Stakeholder meeting, other issues with QII were raised. At present the HERS inspection form has “pass” and “fail” boxes but failed forms are just returned to the builder and a HERS Rater can’t upload a “failed” project into the HERS Registry. Allowing for failed projects to be uploaded would allow for a tracking of the job from “fail” to “pass”. A more systematic problem exists in the business model whereby builders hire the rater and therefore have significant leverage in influencing the process. This applies to the rater verification business model and would require a significant policy change to correct (such as having local jurisdictions assess fees to administer QII inspections).

HERS Rater Costs

HERS verifications costs were obtained from interviews with eight raters and one builder. Raters reported that they typically conduct two to four HERS inspections on each project and total costs per project ranged from $160 to $1,200 for single family homes, with an average cost of $433. For this analysis, three site visits were assumed. The first two inspections assume site visits for QII inspections only. The third visit assumes the final QII inspection is combined with two additional HERS inspection measures, resulting in a lower cost for the QII portion of the final visit. Costs for sampled units are based on the average cost for a single inspection of $183. Multifamily costs assume four site visits per building and a per-visit cost for the 8-unit prototype building of $225 ($225 x 4 = $900). The assumption includes inspection of all units during same visit.

Table 24: HERS Rater Costs for QII

HERS Verification	**Single Family**
	2,430 ft^2 Prototype
QII Tested	
QII - only site visit ($/visit)	$183
Site visit combined w/ other measure ($/visit)	$67
Tested, Total Inspection Cost (3 visits)	$433
HERS Verification (Sampled)	$183
HERS Testing Rate	1-in-2
Average Cost per Home [($433 + $183)/2]	$308

Table 25: HERS Rater Costs for Multifamily QII

HERS Verification	**Multifamily**
	6,960 ft^2 **Eight-Unit Building**
QII - All units tested (4 site visits per building)	$900
HERS Verification (Sampled Cost/Building)	$400
HERS Testing Rate	1-in-4
Average HERS Cost per Building [($900*1 + $400*3)/4]	$525

Appendix G: ENERGY AND COST-EFFECTIVENESS RESULTS BY PROTOTYPE

This section presents energy and cost-effectiveness results for the individual prototypes.

Per-Unit Energy Impacts Results

Energy savings and peak demand reductions for the three residential new construction prototypes are presented in Table 26, Table 27, and Table 28.

Table 26: First-Year Energy Impacts per Dwelling Unit – 2,100 ft^2 Single Family Prototype

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	46	0.00	53.91	12,516
2	28	0.03	29.66	8,211
3	23	0.00	27.11	6,552
4	25	0.04	20.99	7,077
5	23	0.00	27.67	6,573
6	18	0.02	15.98	4,767
7	9	0.02	9.58	2,583
8	35	0.11	9.45	6,132
9	60	0.13	12.17	7,665
10	70	0.12	14.49	7,644
11	134	0.13	27.66	13,188
12	63	0.15	26.04	11,340
13	149	0.15	22.87	13,020
14	123	0.14	27.81	13,041
15	273	0.21	4.41	13,230
16	54	0.04	47.25	12,054

Table 27: First-Year Energy Impacts per Dwelling Unit – 2,700 ft^2 Single Family Prototype

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	46	0.00	54.88	12,744
2	36	0.04	32.11	9,747
3	23	0.01	27.69	6,831
4	33	0.06	24.33	8,640
5	22	0.00	28.02	6,669
6	19	0.02	17.38	5,130
7	10	0.02	10.22	2,862
8	39	0.10	10.84	6,561
9	69	0.13	13.88	8,262
10	81	0.13	16.01	8,856
11	150	0.13	30.97	13,770
12	81	0.16	29.10	13,635
13	165	0.18	25.96	14,661
14	141	0.16	31.26	14,796
15	333	0.26	6.06	16,308
16	62	0.05	54.38	13,851

Table 28: First-Year Energy Impacts per Building – Multifamily Prototype

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	48	-0.02	91.84	21,228
2	58	0.05	57.88	16,495
3	-3.5	0.00	36.89	8,422
4	81	0.15	40.17	14,686
5	-36	-0.08	32.23	5,150
6	5	0.03	17.73	5,359
7	-15.5	0.03	1.89	1,114
8	81	0.14	8.66	8,770
9	126	0.24	15.52	13,363
10	124	0.20	19.85	13,015
11	250	0.26	54.04	26,239
12	159	0.21	52.45	22,411
13	277	0.29	46.24	25,404
14	232	0.24	54.28	24,778
15	518	0.42	2.44	24,778
16	130	0.08	107.37	27,840

Energy Cost Savings Results

Per-unit energy cost savings over the 30-year period of analysis are presented in Table 29, Table 30, and Table 31 for the three residential new construction prototypes.

Table 29: TDV Energy Cost Savings Over 30-Year Period of Analysis – per Dwelling Unit – 2,100 ft^2 Single Family Prototype

Climate Zone	30-Year TDV Electricity Cost Savings (2020PV $)	30-Year TDV Natural Gas Cost Savings (2020PV $)	Total 30-Year TDV Energy Cost Savings (2020PV $)
1	$222	$1,944	$2,165
2	$302	$1,119	$1,421
3	$109	$1,025	$1,133
4	$425	$799	$1,224
5	$109	$1,028	$1,137
6	$211	$614	$825
7	$91	$356	$447
8	$694	$367	$1,061
9	$857	$469	$1,326
10	$767	$556	$1,322
11	$1,232	$1,050	$2,282
12	$970	$992	$1,962
13	$1,377	$876	$2,252
14	$1,188	$1,068	$2,256
15	$2,114	$174	$2,289
16	$320	$1,766	$2,085

Table 30: TDV Energy Cost Savings Over 30-Year Period of Analysis – per Dwelling Unit – 2,700 ft^2 Single Family Prototype

Climate Zone	30-Year TDV Electricity Cost Savings (2020PV $)	30-Year TDV Natural Gas Cost Savings (2020PV $)	Total 30-Year TDV Energy Cost Savings (2020PV $)
1	$229	$1,976	$2,205
2	$476	$1,210	$1,686
3	$131	$1,051	$1,182
4	$570	$925	$1,495
5	$107	$1,046	$1,154
6	$224	$663	$887
7	$117	$378	$495
8	$719	$416	$1,135
9	$897	$532	$1,429
10	$916	$617	$1,532
11	$1,210	$1,172	$2,382
12	$1,256	$1,102	$2,359
13	$1,546	$990	$2,536
14	$1,364	$1,196	$2,560
15	$2,588	$234	$2,821
16	$374	$2,023	$2,396

Table 31: TDV Energy Cost Savings Over 30-Year Period of Analysis – per Building – Multifamily Prototype

Climate Zone	30-Year TDV Electricity Cost Savings (2020PV $)	30-Year TDV Natural Gas Cost Savings (2020PV $)	Total 30-Year TDV Energy Cost Savings (2020PV $)
1	$301	$3,371	$3,672
2	$650	$2,203	$2,854
3	$48	$1,409	$1,457
4	$1,011	$1,529	$2,541
5	-$325	$1,216	$891
6	$241	$686	$927
7	$132	$60	$193
8	$1,180	$337	$1,517
9	$1,722	$590	$2,312
10	$1,481	$771	$2,252
11	$2,480	$2,059	$4,539
12	$1,878	$1,999	$3,877
13	$2,613	$1,782	$4,395
14	$2,203	$2,083	$4,287
15	$4,190	$96	$4,287
16	$807	$4,010	$4,816

Lifecycle Cost-Effectiveness

Results per unit lifecycle cost-effectiveness analyses are presented in Table 32, Table 33, and Table 34 for the three residential new construction prototypes.

Table 32: Lifecycle Cost-Effectiveness Summary per Dwelling Unit – 2,100 ft² Single Family Prototype

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2020PV $)	Costs Total Incremental Present Valued (PV) Costs[b] (2020PV $)	Benefit-to-Cost Ratio
1	$2,165	$396	5.47
2	$1,421	$396	3.59
3	$1,133	$396	2.86
4	$1,224	$396	3.09
5	$1,137	$396	2.87
6	$825	$396	2.08
7	$447	$396	1.13
8	$1,061	$396	2.68
9	$1,326	$396	3.35
10	$1,322	$396	3.34
11	$2,282	$396	5.76
12	$1,962	$396	4.95
13	$2,252	$396	5.69
14	$2,256	$396	5.70
15	$2,289	$396	5.78
16	$2,085	$396	5.26

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes present value maintenance cost savings if PV of proposed maintenance costs is less than the PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement and maintenance costs over the period of analysis. Costs are discounted at a real (inflation adjusted) three percent rate. Includes incremental first cost if proposed first cost is greater than current first cost. Includes present value of maintenance incremental cost if PV of proposed maintenance costs is greater than the PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

Table 33: Lifecycle Cost-Effectiveness Summary per Dwelling Unit – 2,700 ft^2 Single Family Prototype

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2020PV $)	Costs Total Incremental Present Valued (PV) Costs[b] (2020PV $)	Benefit-to-Cost Ratio
1	$2,205	$396	5.57
2	$1,686	$396	4.26
3	$1,182	$396	2.98
4	$1,495	$396	3.77
5	$1,154	$396	2.91
6	$887	$396	2.24
7	$495	$396	1.25
8	$1,135	$396	2.87
9	$1,429	$396	3.61
10	$1,532	$396	3.87
11	$2,382	$396	6.01
12	$2,359	$396	5.96
13	$2,536	$396	6.40
14	$2,560	$396	6.46
15	$2,821	$396	7.12
16	$2,396	$396	6.05

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes present value maintenance cost savings if PV of proposed maintenance costs is less than the PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement and maintenance costs over the period of analysis. Costs are discounted at a real (inflation adjusted) three percent rate. Includes incremental first cost if proposed first cost is greater than current first cost. Includes present value of maintenance incremental cost if PV of proposed maintenance costs is greater than the PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

Table 34: Lifecycle Cost-Effectiveness Summary per Building – Multifamily Prototype

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2020PV $)	Costs Total Incremental Present Valued (PV) Costs[b] (2020PV $)	Benefit-to-Cost Ratio
1	$3,672	$877	4.19
2	$2,854	$877	3.25
3	$1,457	$877	1.66
4	$2,541	$877	2.90
5	$891	$877	1.02
6	$927	$877	1.06
7	$193	$877	0.22
8	$1,517	$877	1.73
9	$2,312	$877	2.64
10	$2,252	$877	2.57
11	$4,539	$877	5.18
12	$3,877	$877	4.42
13	$4,395	$877	5.01
14	$4,287	$877	4.89
15	$4,287	$877	4.89
16	$4,816	$877	5.49

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2016, 51-53). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes present value maintenance cost savings if PV of proposed maintenance costs is less than the PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement and maintenance costs over the period of analysis. Costs are discounted at a real (inflation adjusted) three percent rate. Includes incremental first cost if proposed first cost is greater than current first cost. Includes present value of maintenance incremental cost if PV of proposed maintenance costs is greater than the PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.