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Codes and Standards Enhancement (CASE) Initiative 2022 California Energy Code

Multifamily Restructuring

2022-MF-RESTRUC-F | Multifamily Envelope, HVAC | November 2020 FINAL CASE REPORT

Prepared by TRC

Please submit comments to info@title24stakeholders.com.

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Authors:	Elizabeth McCollum (TRC), Matthew Christie (TRC), Julianna Wei (TRC), Alea German (Frontier Energy), Nehemiah Stone (Stone Energy Associates)
Prime Contractor	TRC
Project Management:	California Statewide Utility Codes and Standards Team: Pacific Gas and Electric Company, Southern California Edison, San Diego Gas and Electric Company, Sacramento Municipal Utility District, and Los Angeles Department of Water and Power.

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Executive Summary

This document presents recommended code changes that the California Energy Commission will be considering for adoption in 2021. If you have comments or suggestions prior to the adoption, please email info@title24stakeholders.com*. Comments will not be released for public review or will be anonymized if shared.*

Introduction

The Codes and Standards Enhancement (CASE) Initiative presents recommendations to support the California Energy Commission's (Energy Commission) efforts to update the California Energy Code (Title 24, Part 6) to include new requirements or to upgrade existing requirements for various technologies. Three California Investor Owned Utilities (IOUs)—Pacific Gas and Electric Company, San Diego Gas and Electric, and Southern California Edison—and two Publicly Owned Utilities —Los Angeles Department of Water and Power and Sacramento Municipal Utility District (herein referred to as the Statewide CASE Team when including the CASE Author) —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 are 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 2022 Title 24 website for information about the rulemaking schedule and how to participate in the process: https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2022-building-energy-efficiency.

The overall goal of this CASE Report is to present a code change proposal for restructuring multifamily requirements. The report contains pertinent information supporting the code change.

Measure Description

Background Information

Under the current Title 24, Part 6 structure, multifamily buildings up to three habitable stories follow residential requirements, while multifamily buildings four habitable stories or greater follow some residential and some nonresidential building requirements. While this may have made sense when the codes were nascent and focused on the prevalent building types at the time, recent volume of multifamily building construction warrants attention to a multifamily building type. Codes based on analyses of single family homes do not adequately represent the equipment nor the enclosure of apartments. Likewise, analyses of nonresidential buildings cannot adequately capture the realities of multifamily equipment choices or schedules, or the residential aspects of air leakage and ventilation.

With the growing recognition of the relevance of multifamily buildings to California's affordable housing crisis, the Energy Commission has decided to treat multifamily buildings as their own type, rather than as a combination of low-rise residential and nonresidential codes. The multifamily restructuring proposal eliminates the arbitrary split between three and four habitable story multifamily building requirements, and proposes requirements based on the type of construction and mechanical equipment used, regardless of the building height.

Proposed Code Change

The Statewide CASE Team proposes adding three chapters to Title 24, Part 6 specifically for multifamily buildings. These chapters would cover mandatory requirements, prescriptive requirements, and addition and alteration requirements for multifamily dwelling unit and common use area spaces. The content for each chapter would include portions of Title 24, Part 6 currently housed under the low-rise residential and nonresidential sections, refined for specific application to multifamily buildings. The chapters would include unified requirements that apply to multifamily buildings of all heights, with categorization by assembly or system type, dwelling units or common use areas, and individual systems serving separate dwelling units or central systems serving multiple dwelling units. Generally, the unification will apply low-rise residential and nonresidential requirements to multifamily buildings as follows:

- Where cost effective and market viable, the more stringent residential requirements for roofs, walls, floors, and fenestration will apply to multifamily building envelopes by assembly type.
- Residential HVAC requirements of Sections 150.0, 150.1, and 150.2 apply to HVAC systems serving dwelling units. Nonresidential requirements of Sections 120.2 through 120.5, 140.4, and 141.0 apply to HVAC systems serving common use areas.
- Residential domestic hot water requirements apply to individual and central systems serving dwelling units. There is no resulting change in requirements because the 2019 high-rise residential requirements reference the low-rise residential requirements.
- Residential lighting requirements apply to dwelling unit lighting and outdoor

fixtures controlled from within dwelling units. Nonresidential lighting requirements apply to common area and outdoor spaces. This includes removal of the exception for nonresidential occupancies up to 20 percent of the conditioned floor area and the eight-car threshold for compliance with nonresidential outdoor lighting requirements.

- Nonresidential electric power distribution requirements will apply to all multifamily buildings.

This CASE Report includes feasibility, market, energy, and cost analyses the Statewide CASE Team conducted for proposed changes that result in increased stringency for a specific multifamily building type.

In addition to restructured 2019 requirements, the 2022 multifamily chapters may include new measures or changes adopted for residential and/or nonresidential buildings for 2022 Title 24, Part 6. The Energy Commission will consider each proposed measure individually, therefore these 2022 measure proposals are not discussed in this CASE Report and are not included in the draft code language included with this report. For more information on the proposed 2022 multifamily measures, view draft CASE Reports posted at https://title24stakeholders.com/measures/building-types/multifamily/2022/.

Scope of Code Change Proposal

The Statewide CASE Team examined a number of submeasures in which unification of low-rise residential and high-rise residential requirements would result in a change in stringency for a portion of multifamily buildings. These submeasures include:

- **Submeasure A: Envelope – Roof Assemblies**

  Mandatory Measures: Apply mandatory low-rise residential maximum U-factor of 0.043 for the ceiling or rafter roof to multifamily buildings with attics. Apply mandatory nonresidential maximum U-factors of 0.098 for metal roofs and 0.075 for wood framed and other roofs to non-attic roofs in buildings less than four habitable stories.

  Prescriptive Measures: Apply prescriptive low-rise residential requirements from Table 150.1-B to multifamily buildings with attics, including Option B (below deck insulation high-performance attic) and Option C (ducts in conditioned space) pathways. Add a prescriptive non-attic roof option (Option A) for all multifamily buildings which applies high-rise residential prescriptive U-factor requirements using both the metal building and wood-framed or other roof categories. The solar reflectance (ASR) and thermal emittance for the non-attic option would match 2019 requirements for high-rise residential roofing products for steep-slope roofs. Option A would include a low-slope roof requirement of

0.63 ASR and 0.75 thermal emittance in Climate Zones 9 through 11 and 13 through 15.

- **Submeasure B: Envelope – Wall U-Factor** Combine wall-U-factor requirements from the 2019 residential and nonresidential chapters into a single table of requirements, by wall assembly type, for all multifamily buildings. Stakeholder feedback on code compliance and enforcement cited potential complications resulting from the intersection of fire code (Title 24, Part 9) and energy code (Title 24, Part 6). The proposal differentiates wall assembly types by their fire rating for select wall assemblies. This allows high-fire rating wall types, which have constructability limitations and are more costly to insulate, to adhere to less stringent U-factor requirements than walls with lower fire ratings.

  The proposed wall assembly types, with varied mandatory and prescriptive requirements by climate zone, are the following:

  - Metal buildings
  - Framed (wood or metal), high fire rating (two- or three-hour)
  - Framed (wood or metal), low fire rating (zero or one-hour), and other wall types
  - Heavy mass (<15 Btu/ft^2-F)
  - Light mass (7-15 Btu/ft^2-F)

- **Submeasure C: Envelope – Quality Insulation Installation (QII)** Apply low-rise residential prescriptive QII requirements to all multifamily buildings up to 40,000 ft^2 of total building conditioned floor area (CFA). The proposed change applies to additions greater than 700 ft^2 CFA and does not apply to alterations.

- **Submeasure D: Envelope – Fenestration Properties**

  New Construction Mandatory Measures: Apply the low-rise residential mandatory maximum U-factor requirement of 0.58 to multifamily buildings greater than three habitable stories.

  New Construction Prescriptive Measures: Create a single set of fenestration energy performance requirements that apply across all multifamily buildings depending on the window type.

  The proposed code creates three window categories for newly constructed buildings, with climate-zone differentiation in both U-factor and SHGC.

  - Curtainwall and storefront windows: Decrease area weighted U-factor from requirement from 0.41 to 0.38 in Climate Zones 1 and 16. Create a maximum RSHGC of 0.35 in Climate Zone 1. Decrease the RSHGC from

0.26 to 0.25 in Climate Zone 16. Maintain visual transmittance (VT) requirement of 0.46.

- Performance Class AW rated windows (as per NAFS-2008, AAMA/WDMA/CSA 101/I.S.2/A440): Remove the distinct requirements between operable, fixed, and glazed doors and apply an area-weighted average. Maintain the current 2019 nonresidential requirements using a market-typical weighted blend of fixed window, operable window, and glazed doors in Climate Zones 2-15: U-factor of 0.40 and RSHGC of 0.24. Decrease the area-weighted average U-factor to 0.38 in Climate Zones 1 and 16 and assign an RSHGC requirement of 0.35 in Climate Zone 1. Maintain visual transmittance (VT) requirement of 0.37.
- All-other windows: Apply the current residential 0.30 area-weighted window U-factor requirement for all other windows, except for a 0.34 U-factor requirement in Climate Zones 6 and 7. Apply an 0.35 area weighted SHGC requirement in Climate Zone 1, and a 0.23 requirement in Climate Zones 2-16. Eliminate visual transmittance requirements for buildings four habitable stories or greater, for this window type only, for alignment with residential requirements.

This measure also harmonizes the residential and nonresidential prescriptive code compliance methods that account for window heat gain impacts of overhangs, side fins, and other permanently affixed features. The proposed measure will use the Relative SHGC (RSHGC) methodology for prescriptive compliance with all multifamily windows. Performance compliance will still leverage the side fin and overhang shading modeling algorithms embedded in approved compliance software tools.

Alterations: The proposed measures create a new table with four window categories each with climate-zone differentiation in both u-factor and SHGC; curtainwall/storefront/glazed doors, Performance Class AW fixed windows, Performance Class AW operable windows, and all-others. The proposed measure requirements are as follows:

- Curtainwall, storefront, and glazed doors:
    - U-Factor: Apply a U-factor requirement of 0.38 in Climate Zones 1 and 16. Apply a U-factor requirement of 0.41 in Climate Zones 2 through 15.
    - SHGC: Apply a SHGC requirement of 0.35 in Climate Zone 1. Apply a SHGC requirement of 0.26 in Climate Zones 2 through 15. Apply a SHGC requirement of 0.25 in Climate Zone 16.

- Performance Class AW fixed windows:
  - U-Factor: Apply a U-factor requirement of 0.38 in Climate Zones 1 through 5 and 9 through 16. Apply a U-Factor requirement of 0.41 in Climate Zones 6 through 8.
  - SHGC: Apply a SHGC requirement of 0.35 in Climate Zone 1. Apply a SHGC requirement of 0.25 in Climate Zones 2 through 5 and 9 through 16. Apply a SHGC requirement of 0.26 in Climate Zones 6 through 8.
- Performance Class AW operable windows
  - U-Factor: Apply a U-factor requirement of 0.43 in all Climate Zones.
  - SHGC: Apply a SHGC requirement of 0.35 in Climate Zones 1. Apply a SHGC requirement of 0.24 in Climate Zones 2 through 16.
- All-other windows:
  - U-factor: Apply the current residential 0.30 window U-factor requirement for all other windows, except for a 0.34 U-factor requirement in Climate Zones 6 and 7.
  - SHGC: Apply an 0.35 area weighted SHGC requirement in Climate Zone 1, and a 0.23 requirement in Climate Zones 2-16.

Buildings with performance Class AW windows may opt to meet prescriptive requirements using an area-weighted method based on the new-construction requirements tables.

Projects adding new windows to existing floor space are considered alterations.

Additions: The proposed code requirements are based on an area-weighted average of thermal properties for all fenestration, matching with the proposed window categories and requirements for newly constructed buildings.

For both alterations and addition, the proposal calls for less restrictive requirements when a small volume of fenestration is being added or altered.

- **Submeasure E: Envelope – Fenestration Area:** Apply the prescriptive low-rise residential 20 percent window-to-floor area maximum (inclusive of skylights) to high-rise buildings and the prescriptive high-rise residential 40 percent window-to-wall area maximum and five percent skylight to roof ratio to low-rise buildings. This measure would result in a dual metric. To comply prescriptively, the window area must comply with both limits simultaneously.

  The submeasure includes performance approach penalties for exceeding 40 percent window-to-wall ratio on the west-facing façade. The Standard Design shall match window-to wall ratio if less than 40 percent and will be 40 percent when the Proposed Design exceeds 40 percent. The submeasure does not include a maximum five percent window-to-floor area ratio for west-facing glazing from the residential requirements.

- **Submeasure F: Space Conditioning – Duct Insulation:** Apply high-rise requirements for R-4.2 mandatory duct insulation on supply ducts in conditioned space (regardless of whether they are HERS verified low-leakage ducts or not) to all multifamily buildings. The existing allowance in both low-rise and high-rise buildings for uninsulated ducts exposed to directly conditioned space remains. The low-rise requirements of R-6 mandatory duct insulation and R-8 prescriptive duct insulation in Climate Zones 1-2, 4, and 8-16 would apply for ducts in all other locations. This proposal does not result in increased stringency and does result in reduced stringency in certain situations. The impact of this reduced stringency is presented in Sections 4 and 6.
- **Submeasure G: Space Conditioning – Duct Leakage Testing:** Apply mandatory installer testing and reporting for duct sealing in multifamily buildings four habitable stories and greater with ducted systems serving individual dwelling units. New duct systems regardless of location must be tested to meet no greater than 12 percent total leakage or no greater than six percent leakage to outside. This proposed code change applies to all climate zones except Climate Zone 1. Altered duct systems and duct systems connected to altered space conditioning systems in existing buildings must be tested to meet no greater than 15 percent total leakage or no greater than 10 percent leakage to outside. This proposed code change applies to all climate zones except Climate Zones 1, 5, and 7. Diagnostic field verification and test protocols are described in Residential Reference Appendix RA3.1. Requirements for HERS verification for multifamily buildings up to three habitable stories would remain in effect.
- **Submeasure H: Space Conditioning – Space Cooling Airflow Rate and Fan Efficacy:** Apply mandatory installer testing and reporting of airflow and fan efficacy for new construction multifamily buildings four habitable stories and greater with ducted cooling systems serving individual dwelling units. Systems must meet 350 cfm per nominal ton of cooling or greater and either 0.45 W per cfm for gas furnaces or 0.58 W per cfm for all other air handlers. Diagnostic field verification and test protocols are described in Residential Reference Appendix RA3.3. Requirements for HERS verification for multifamily buildings up to three habitable stories would remain in effect.
- **Submeasure I: Space Conditioning – Refrigerant Charge Verification:** Apply prescriptive installer testing and reporting of refrigerant charge for multifamily buildings four habitable stories and greater with cooling systems serving

individual dwelling units. The prescriptive requirement applies to new construction and altered mechanical cooling systems in Climate Zones 2 and 8 through 15. Diagnostic field verification and test protocols are described in Residential Reference Appendix RA3.2. Requirements for HERS verification for multifamily buildings up to three habitable stories would remain in effect.

- **Combination G-I: Space Conditioning – New Construction Test Package:** All three verification measures (duct sealing, airflow rate and fan efficacy, and refrigerant charge) will apply to many new multifamily buildings, all with ducted cooling systems. As such, they have also been evaluated as a combined package and results are presented for the entire package. Refrigerant charge is only evaluated in Climate Zones 2 and 8 through 15 where it is proposed as a prescriptive requirement. Based on cost effectiveness results none of the proposed measures were justified in Climate Zone 1 and therefore are not recommended in that climate.

Table 1 summarizes the scope of the proposed changes and which sections of standards, Reference Appendices, Alternative Calculation Method (ACM) Reference Manual, and compliance documents would need to be modified as a result of the proposed change(s).

Table 1: Scope of Code Change Proposal by Submeasure

Measure Name	Type of Requirement	Sections of Code Unified	Sections of ACM Reference Manual Unified	Compliance Document(s) Unified
Roof Assemblies	Mandatory	150.0(a) and 120.7(a)	N/A	N/A
Roof Assemblies (Option A)	Prescriptive	150.1 and 140	Residential 2.6.1 and 2.6.6 and Nonresidential 5.5.3	CF1R-NCB-01-E, NRCC-ENV-E, CF2R-ENV-03, and CF2R-ENV-04
Wall U-Factor	Mandatory	150.0(b) and 120.7(b)	N/A	N/A
Wall U-Factor	Prescriptive	TABLE 150.1-B and TABLE 140.3-C	Residential 2.5.6.3 and Nonresidential 5.5.4	CF1R-NCB-01-E, NRCC-ENV-E, and CF2R-ENV-03
QII	Prescriptive	150.1(c)1E, TABLE 150.1-B, 140.3, and TABLE 140.3-C	Residential 3.5.1	CEC-CF1R-NCB-01-E, CEC-CF2R-ENV-21, CEC-CF3R-ENV-21, CEC-CF2R-ENV-22, CEC-CF3R-ENV-22, NRCC-ENV-01-E, NRCI-ENV-01-E, NRCV-ENV-01

Measure Name	Type of Requirement	Sections of Code Unified	Sections of ACM Reference Manual Unified	Compliance Document(s) Unified
Fenestration Properties	Mandatory	150.0(q)	N/A	N/A
Fenestration Properties	Prescriptive	TABLE 150.1-B and TABLE 140.3-C	Residential 2.5.6.6 and Nonresidential 5.5.7	CF1R-NCB-01-E, NRCC-ENV-E, and CF2R-ENV-01
Fenestration Area	Prescriptive	TABLE 150.1-B and TABLE 140.3-C	Residential 2.5.6.6 and Nonresidential 5.5.7	CF1R-NCB-01-E, NRCC-ENV-E, and CF2R-ENV-01
Duct Insulation	Mandatory	150.0(m)1B and 120.4(a)	N/A	N/A
Duct Insulation	Prescriptive	150.1(c)9 and 140.4*(no requirement)*	Residential 2.4.6.9	CF1R-NCB-01-E
Duct Sealing and Testing	Mandatory	150.0(m)11C, 120.4(a), and 140.4(l) *(only prescriptive requirement)*	N/A	CF2R-MCH-20a-and 20b, CF3R-MCH-20a and 20b, NRCC MCH-E, and NRCV-MCH-04-H
Airflow and Fan Watt Draw	Mandatory	150.0(m)13B&C and 140.4(no requirement)	N/A	CF2R-MCH-23a through 23f, CF3R-MCH-23a through 23f, CF2R-MCH 22a through 22d, CF3R-MCH-22a through 22d, and NRCC-MCH-E
Refrigerant Charge Verification	Prescriptive	150.1(c)7A and 140.4(no requirement)	Residential Section 2.4.5	CF2R-MCH-25a through 25f, CF3R-MCH-25a through 25f, and NRCC-MCH-E

Market Analysis and Regulatory Assessment

Title 24, Part 6 requirements for multifamily buildings are dispersed throughout Sections 100.0 through 150.2, spanning residential and nonresidential sections. Determining which requirements apply to each multifamily building depends on whether the building is up to or above three habitable stories in height and what percentage of the floor area is made up of dwelling units. By unifying and consolidating these requirements for multifamily buildings, the Statewide CASE Team intends to streamline compliance and enforcement for building departments, architects, developers, mechanical designers, energy consultants, installers, HERS Raters, and energy efficiency program implementers.

All submeasures proposed in this CASE Report originate from requirements in the 2019 residential or nonresidential chapters of Title 24, Part 6. These measures have been vetted through previous CASE studies for technical feasibility and market availability and have been implemented successfully in multifamily buildings in California.

Cost Effectiveness

The benefit-to-cost (B/C) ratio compares the benefits or cost savings to the costs over the 30-year period of analysis. Proposed code changes that have a B/C ratio of 1.0 or greater are cost effective. The larger the B/C ratio, the faster the measure pays for itself from energy cost savings. The B/C ratio by submeasure are summarized in Table 2. See Section 5 for the methodology, assumptions, and results of the cost-effectiveness analysis.

Table 2: Cost Effectiveness by Submeasure

Submeasure Name	Applicable Climate Zones	B/C ratio Range
Roof Assemblies	All	N/A
Wall U-Factor	CZ 1-5, 8-10, 13	1.09-3.43
QII	CZ 1-6, 8-16	1.11-2.91
Fenestration Properties	All	1.06-17.85
Fenestration Area	All	N/A
Duct Insulation	All	N/A
Duct Sealing and Testing	CZ 2-16	0.50-2.86
Airflow and Fan Watt Draw	CZ 2-16	2.66-9.49
Refrigerant Charge Verification	CZ 2, 8-15	3.74-11.44
HVAC Verification Package	CZ 2-16 (refrigerant charge CZ 2, 8-15)	1.20-7.61

Statewide Energy Impacts: Energy, Water, and Greenhouse Gas (GHG) Emissions Impacts

Table 3 presents the estimated energy and demand impacts of the proposed code change that will be realized statewide during the first 12 months that the 2022 Title 24, Part 6 requirements are in effect. First-year statewide energy impacts are represented by the following metrics: electricity savings in gigawatt-hours per year (GWh/yr), peak electrical demand reduction in megawatts (MW), natural gas savings in million therms per year (MMTherms/yr), and time dependent valuation (TDV) energy savings in kilo British thermal units per year (TDV kBtu/yr). See Section 6 for more details on the first-year statewide impacts calculated by the Statewide CASE Team. Section 4 contains details on the per-unit energy savings calculated by the Statewide CASE Team.

Table 3: First-Year Statewide Energy and Impacts

Measure	Electricity Savings (GWh/yr)	Peak Electrical Demand Reduction (MW)	Natural Gas Savings (MMTherms)	TDV Energy Savings (TDV million kBtu/yr)
Roof Assemblies (Total)	**0.39**	**0.15**	**(0.02)**	**9.48**
New Construction	0.39	0.15	(0.02)	9.48
Additions and Alterations	N/A	N/A	N/A	N/A
Wall U-Factor (Total)	**0.04**	**(0.02)**	**0.00**	**0.20**
New Construction	0.04	(0.02)	0.00	0.20
Additions and Alterations	N/A	N/A	N/A	N/A
QII (Total)	**0.03**	**0.02**	**0.01**	**1.5**
New Construction	0.03	0.02	0.01	1.5
Additions and Alterations	N/A	N/A	N/A	N/A
Fenestration Properties (Total)	**5.1**	**1.3**	**0.2**	**291**
New Construction	(0.3)	0.0	0.0	24
Additions and Alterations	5.3	1.3	0.2	267
Duct Insulation (Total)	**(0.04)**	**(0.00)**	**(0.00)**	**(3.97)**
New Construction	(0.01)	(0.00)	(0.00)	(0.83)
Additions and Alterations	(0.03)	(0.00)	(0.00)	(3.14)
Duct Sealing and Testing	**0.93**	**0.26**	**0.01**	**35.90**
New Construction	0.43	0.12	0.00	14.60
Additions and Alterations	0.50	0.14	0.01	21.30
Airflow and Fan Watt Draw	**5.24**	**1.62**	**(0.01)**	**169.16**
New Construction	1.59	0.50	(0.00)	51.93
Additions and Alterations	3.65	1.12	(0.01)	117.23
Refrigerant Charge Verification	**4.13**	**1.42**	0.00	**148.79**
New Construction	0.96	0.32	0.00	32.82
Additions and Alterations	3.17	1.10	0.00	115.97

Table 4 presents the estimated avoided GHG emissions associated with the proposed code change for the first year the standards are in effect. Avoided GHG emissions are measured in metric tons of carbon dioxide equivalent (metric tons CO2e). Assumptions used in developing the GHG savings are provided in Section 6.1.2 and Appendix C of this report. The monetary value of avoided GHG emissions is included in TDV cost factors included in the cost effectiveness analysis.

Table 4: First-Year Statewide GHG Emissions Impacts

Measure	Avoided GHG Emissions (Metric Tons CO2e/yr)	Monetary Value of Avoided GHG Emissions ($2023)
Roof Assemblies	10	$1,014
Wall U-Factor	34	$3,576
Quality Insulation Installation	51	$5,425
Fenestration Properties	2,503	$265,769
Fenestration Area	N/A	N/A
Duct Insulation	(35)	($3,717)
Duct Leakage Testing	295	$31,362
Airflow and Fan Efficacy	1,217	$129,256
Refrigerant Charge	994	$105,520
Total	5,068	$538,205

Water and Water Quality Impacts

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

Compliance and Enforcement

Overview of Compliance Process

The Statewide CASE Team considered methods to streamline the compliance and enforcement process for multifamily buildings in developing the proposed restructuring of Title 24, Part 6. Perhaps the greatest benefit in compliance and enforcement is that relevant multifamily requirements from Subchapters three through nine (Sections 120.0 through 150.2) would be consolidated into three subchapters of code language specific to multifamily buildings, reducing the need to jump from subchapter to subchapter to collect the requirements for a multifamily building.

The unification submeasures align low-rise and high-rise requirements and treat similar assemblies and mechanical systems equitably. This will impact compliance and enforcement by making requirements simpler for building officials to understand and allowing design teams to more easily identify compliance solutions across buildings that vary in number of stories on the same site. This unification will also allow utility incentive programs to address multifamily buildings of all sizes with a single program design.

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. Impacts that the proposed measure will have on market actors is described in Appendix E.

Field Verification, Diagnostic Testing, and Acceptance Testing

The proposed restructuring does not change field verification, diagnostic testing, or acceptance testing requirements, but does apply existing requirements to all multifamily buildings types, dependent on whether space conditioning systems serve individual dwelling units or multiple dwelling units and/or common use areas. The Statewide CASE Team recommends field verification and diagnostic testing for compliance with 2019 Title 24, Part 6 remain with the same entity when conducted by either a HERS Rater or acceptance test technician (ATT).

1. Introduction

This document presents recommended code changes that the California Energy Commission will consider for adoption in 2021. If you have comments or suggestions prior to adoption, please email info@title24stakeholders.com. Comments will not be released for public review or will be anonymized if shared.

The Codes and Standards Enhancement (CASE) initiative presents recommendations to support the California Energy Commission's (Energy Commission) efforts to update California Energy Code (Title 24, Part 6) to include new requirements or to upgrade existing requirements for various technologies. Three California Investor Owned Utilities (IOUs)—Pacific Gas and Electric Company, San Diego Gas and Electric, and Southern California Edison—and two Publicly Owned Utilities —Los Angeles Department of Water and Power and Sacramento Municipal Utility District (herein referred to as the Statewide CASE Team when including the CASE Author)—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 proposal presented herein are 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 2022 Title 24 website for information about the rulemaking schedule and how to participate in the process: https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2022-building-energy-efficiency.

The overall goal of this CASE Report is to present a code change proposal for multifamily restructuring. 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 public stakeholder workshops that the Statewide CASE Team held on February 8, 2019, February 25, 2019, and May 7, 2020.

The following is a brief summary of the contents of this report:

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

- **Section 3: Market Analysis** presents the market analysis, including a review of the current market structure. This section 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: Energy Savings** presents the per-unit energy, demand reduction, and energy cost savings associated with the proposed code change. This section also describes the methodology that the Statewide CASE Team used to estimate per-unit energy, demand reduction, and energy cost savings.
- **Section 5: Cost and Cost Effectiveness** presents the lifecycle cost and cost-effectiveness analysis. This includes a discussion of the materials and labor required to implement the measure and a quantification of the incremental cost. It also includes estimates of incremental maintenance costs, i.e., equipment lifetime and various periodic costs associated with replacement and maintenance during the period of analysis.
- **Section 6: First-Year Statewide Impacts** presents the statewide energy savings and environmental impacts of the proposed code change for the first year after the 2022 code takes effect. This includes the amount of energy that will be saved by California building owners and tenants and impacts (increases or reductions) on material with emphasis placed on any materials that are considered toxic in the state of California. Statewide greenhouse gas impacts are also reported in this section.
- **Section 7: Proposed Revisions to Code Language** concludes the report with specific recommendations with ~~strikeout~~ (deletions) and underlined (additions) language for the Standards, Reference Appendices, Alternative Calculation Manual (ACM) Reference Manual, Compliance Manual, and compliance documents.
- **Section 8: Bibliography** presents the resources that the Statewide CASE Team used when developing this report.
- **Appendix A: Statewide Savings Methodology** presents the methodology and assumptions used to calculate statewide energy impacts.
- **Appendix B: Embedded Electricity in Water Methodology** presents the methodology and assumptions used to calculate the electricity embedded in

water use (e.g., electricity used to draw, move, or treat water) and the energy savings resulting from reduced water use.

- **Appendix C: Environmental Impacts Methodology** presents the methodologies and assumptions used to calculate impacts on GHG emissions and water use and quality.
- **Appendix D: CBECC Software Specification** presents relevant proposed changes to the compliance software (if any).
- **Appendix E: Impacts of Compliance Process on Market Actors** presents how the recommended compliance process could impact identified market actors.
- **Appendix F: Summary of Stakeholder Engagement** documents the efforts made to engage and collaborate with market actors and experts.
- **Appendix G: Additional Details on Measure Analysis** presents additional relevant analysis details for the duct insulation submeasures.
- **Appendix H: Nominal Savings Tables** presents nominal savings for by submeasures.
- **Appendix I: Marked Up Standards** presents the full multifamily chapter language, with mark-up to show where language differs from the 2019 residential and nonresidential chapter language.

2. Measure Description

2.1 Measure Overview

The Statewide CASE Team proposes additional chapters for Title 24, Part 6, specific to multifamily buildings. The intent of the proposal is to:

1. Simplify compliance and enforcement by consolidating requirements for multifamily dwelling unit and common use areas into multifamily-specific chapters.
2. Create equity across multifamily building types, regardless of number of stories, through unified requirements.
3. Establish a platform from which the Energy Commission, Statewide CASE Team, and other stakeholders can investigate energy efficiency solutions unique to multifamily buildings (and distinct from single-family and nonresidential buildings) in future code cycles.

Per the proposed definition of multifamily building in Section 2.3.1.1, the proposed chapters would apply to multifamily buildings, defined as R-2 or R-4 occupancy. These generally include apartment buildings, condominiums, dormitories, townhouses greater than three habitable stories, dormitories, and assisted living facilities. Single family homes and other R-3 occupancy buildings would remain subject to the low-rise residential chapters, and hotel/motel and nonresidential buildings would remain subject to the nonresidential chapters. Mixed-use buildings would need to comply with the multifamily requirements for dwelling unit and common use areas and with applicable nonresidential requirements for all other portions of the building.

The three proposed chapters (Sections 160, 170, and 180) would cover mandatory requirements, prescriptive requirements and performance approach, and addition and alteration requirements for multifamily dwelling units and common area spaces. The content for each chapter would include portions of Title 24, Part 6 currently housed under the low-rise residential and nonresidential sections, marked-up for specific application to multifamily buildings. The chapters would include unified requirements that apply to multifamily buildings of all heights, with categorization by assembly or system type, and application to dwelling units or common areas. Generally, the unification would apply low-rise residential and nonresidential requirements to multifamily buildings as follows:

- Where cost effective, the more stringent of residential requirements for roofs/ceilings, walls, floors, and fenestration will apply to multifamily building envelopes by assembly type.
- Residential HVAC requirements of Sections 150.0, 150.1, and 150.2 apply to

HVAC systems serving dwelling units. Nonresidential requirements of Sections 120.2 through 120.5, 140.4, and 141.0 apply to HVAC systems serving common use areas.

- Residential domestic hot water requirements apply to individual and central systems serving dwelling units. There is no resulting change in requirements because the 2019 high-rise residential requirements reference the low-rise residential requirements.
- Residential lighting requirements apply to dwelling unit lighting and outdoor fixtures controlled from within dwelling units. Nonresidential lighting requirements apply to common area and outdoor spaces. This includes removal of the exception for nonresidential occupancies up to 20 percent of the conditioned floor area and the eight-car threshold for compliance with nonresidential outdoor lighting requirements.
- Nonresidential electric power distribution requirements will apply to all multifamily buildings.

In addition to restructured 2019 Title 24, Part 6 requirements, the multifamily chapters may include new measures or changes adopted for residential and/or nonresidential buildings for 2022 Title 24, Part 6. The Energy Commission will consider each proposed measure individually, therefore these 2022 measure proposals are not discussed in this CASE Report. For more information on the proposed 2022 multifamily measures, view CASE Reports posted at https://title24stakeholders.com/measures/building-types/multifamily/2022/.

This CASE Report includes feasibility, market, energy, and cost analyses the Statewide CASE Team conducted for proposed changes that result in increased stringency for a specific multifamily building type. Each submeasure is described below, organized by category (envelope and space conditioning).

For changes that result in decreased stringency for a specific multifamily building type, the Statewide CASE Team has conducted energy analyses to capture the energy impact by dwelling unit and statewide. Such changes are proposed only for one of the following scenarios:

- To align between divergent 2019 Title 24, Part 6 Standards for nonresidential and residential where the higher stringency standard cannot be shown as cost effective across all multifamily buildings, given variance between the software modeling platforms.
- Where differentiation by construction type, physical aspect, or performance rating is not applicable. For example, windows that do not have durability, water penetration, or wind penetration concerns in buildings up to three habitable

stories versus four habitable stories or more.

- When a common multifamily building component does not have a prescriptive option in current 2019 Title 24, Part 6 Standards. For example, non-attic roofs for low-rise multifamily.

2.1.1 Building Envelope

In general for multifamily envelope requirements, the Statewide CASE Team proposes to apply the more stringent residential requirements across all multifamily buildings, based on descriptive aspects of the assembly type such as material, fire rating, or assembly structure, instead of the number of habitable stories. Due to the current application of disparate requirements between low-rise residential buildings (up to three habitable stories) and high-rise residential buildings (four habitable stories or more), this proposal would have different levels of impact relative to the current code based on low-rise/high-rise designation. The proposed unification aims to eliminate the low-rise/high-rise divide and instead differentiate multifamily requirements by assembly types and fire safety and structural requirements. The proposed changes and impacts are summarized as follows:

2.1.1.1 Submeasure A Envelope: Roof Assemblies

This submeasure applies mandatory low-rise residential maximum U-factor of 0.043 for the ceiling or rafter roof to multifamily buildings with attics and mandatory nonresidential maximum U-factors of 0.098 for metal roofs and 0.075 for wood framed and other roofs to non-attic roofs in buildings less than four habitable stories.

The submeasure applies prescriptive low-rise residential requirements from Table 150.1-B to multifamily buildings with attics, including Option B (below deck insulation high-performance attic) and Option C (ducts in conditioned space). The submeasure would add a prescriptive non-attic roof option (Option A) for all multifamily buildings. Option A applies high-rise residential prescriptive U-factor requirements using the metal building and wood-framed or other roof categories. The solar reflectance (ASR) and thermal emittance for the non-attic option would match 2019 requirements for high-rise residential roofing products for steep-slope roofs. The option would include a low-slope roof requirement of 0.63 ASR and 0.75 thermal emittance in Climate Zones 9 through 11 and 13 through 15.

This submeasure would also impact roof additions and altered roofs when 50 percent or 2,000 ft^2, whichever is less, is altered.

2.1.1.2 Submeasure B: Envelope – Wall U-Factor

The wall assembly thermal resistance submeasure combines wall-U-factor requirements from the 2019 residential and nonresidential chapters into a single table of requirements, by wall assembly type, for all multifamily buildings. The approach references fire ratings for select wall assemblies in response to stakeholder feedback on code compliance and enforcement complications resulting from the intersection between fire code (Title 24, Part 9) and energy code (Title 24, Part 6). Fire rating references within the energy code would allow for high-fire-rating wall types that have constructability limitations and are more costly to insulate to adhere to less stringent U-factor requirements than walls with lower fire-ratings. Table 5, below, includes the proposed wall assembly type, with varied mandatory and prescriptive requirements by climate zone.

The submeasure covers new construction buildings and additions but not alterations. Additions must comply with the new construction prescriptive requirements. Extension of existing wood framing is exempted. Alterations are subjected to less stringent U-factor levels that are not tied to the prescriptive requirements.

Associated, this proposed submeasure updates two performance modeling algorithm details to improve consistency between low-rise and high-rise modeling methods.

1. Use the current nonresidential modeling method that uses the same exterior wall surface areas and orientations in the Standard Design as in the Proposed Design.
2. Use the current residential modeling method that uses the same wall assembly type(s) in the Standard Design as in the Proposed Design for each wall segment.

Table 5: Proposed Wall U-factors by Wall Assembly Type and Climate Zone

Wall Type	Climate Zones	Mandatory Assembly U-factor	Prescriptive Assembly U-factor
Metal Buildings	CZ 1-10	Metal Buildings = 0.113 Spandrel Panels and Curtain Walls = 0.280	0.061
	CZ 11-16		0.057
Framed (wood or metal), high fire rating (2- or 3-hours)	CZ 1-5,8-10, 12 & 13	2x4 framing = 0.102 2x6 framing = 0.071 non-framed = 0.102	0.059
	CZ 6 & 7		0.065
	CZ 11 & 14-16		0.051
Framed (wood or metal), low fire rating (0- or 1-hours), and other wall types	CZ 1-5, 8-16		0.051
	CZ 6 & 7		0.065
Heavy mass (>15 Btu/ft^2-F)	CZ 1-3, 16	0.690	0.160
	CZ 4, 11, 14 & 15		0.184
	CZ 5, 13		0.211
	CZ 6-10		0.690
	CZ 12		0.253
Light mass (7-15 Btu/ft^2-F)	CZ 1-15	0.440	0.077
	CZ 16		0.059

2.1.1.3 Submeasure C: Envelope – Quality Insulation Installation (QII)

This submeasure applies the prescriptive requirements of quality insulation installation (QII) to include high-rise multifamily buildings of up to 40,000 ft^2 of total conditioned floor area. QII is currently a prescriptive requirement for multifamily buildings with three or fewer habitable stories in all climate zones except Climate Zone 7. The proposed change applies to additions greater than 700 ft^2 CFA and does not apply to alterations or to buildings using curtainwall assembly types.

2.1.1.4 Submeasure D: Envelope – Fenestration Properties

There are no nonresidential mandatory efficiency requirements for fenestration properties. This submeasure applies the low-rise residential mandatory weighted average maximum U-factor requirement to multifamily buildings greater than three habitable stories that use non-curtain wall fenestration types.

New Construction

For new construction buildings, this submeasure creates a single set of fenestration energy performance requirements that apply across all multifamily buildings depending on the window type. The thermal performance metrics used in the energy code include:

- U-factor, regarding conductive heat transfer across the windows;
- SHGC regarding radiative heat gain through the windows
- Visible transmittance (VT) regarding the amount of visible light that can pass through the space, impacting lighting energy loads

The current nonresidential code table includes four window categories (fixed, operable, curtainwall/storefront and glazed doors) while the residential code a single area-weighted average requirement (with some SHGC variation by climate zone). The proposed code creates three window categories, with variable requirements by climate zone, as shown in Table 6.

Table 6: Proposed Fenestration Thermal Properties by Type and Climate Zone; New Construction

Window Type	Climate Zones	U-Factor (maximum)	SHGC (maximum)	VT (minimum)
Curtainwall/ Storefront	CZ 1	0.38	0.35	0.46
	CZ 2-15	0.41	0.26	0.46
	CZ 16	0.38	0.25	0.46
Class AW	CZ 1	0.38	0.35	0.37
	CZ 2-15	0.40	0.24	0.37
	CZ 16	0.38	0.24	0.37
All Other	CZ 1	0.30	0.35	NR*

	CZ 2-5, 8-16	0.30	0.23	NR*
	CZ 6, 7	0.34	0.23	NR*
*NR = No requirement				

The new Class AW (architectural windows) category adheres to industry standard – AAMA/ WDMA/ CSA 101/ I.S.2/ A440 NAFS-2008 *North American Fenestration Standard/ Specification for windows, doors, and skylights* definitions of minimum performance and testing requirements for four classes of fenestration products based on air leakage resistance, water penetration resistance, uniform load resistance and forced-entry resistance. The Performance Classes are designated R, LC, CW, and AW in order of performance. Higher rated products typically rely on metal window framing materials which lead to high thermal bridging in the window frame and thus higher U-factors. The proposed code requires that windows be certified as NAFS rated to qualify for the category.

For multifamily buildings with three habitable stories and fewer, the Statewide CASE Team proposal includes an exception to have no SHGC requirement in Climate Zones 1, 3, 5, and 16, as the current residential code has no requirement in these climate zones. In the residential ACM, this is modeled as SHGC=0.35. This exception is to account for a modeling discrepancy in Climate Zones 3, 5, and 16 between CBECC-Res and CBECC-Com where CBECC-Res shows increased TDV energy use with lower SHGCs, and CBECC-Com shows decreased TDV energy use.

Prescriptive visible transmittance (VT) requirements are proposed for curtainwall/storefront windows that match the nonresidential code values. In multifamily spaces, modeling a variance in VT has no energy impact as there are no automated controls to interact with the space's natural daylighting. There are no proposed VT requirements for the all-others window category to match current residential code.

This submeasure also harmonizes the residential and nonresidential prescriptive code compliance methods that account for window heat gain impacts of overhangs, side fins, and other permanently affixed features. The residential code refers to this as adjusted-SHGC and the nonresidential code as RSHGC. Each uses a different methodology. The proposed measure will use the RSHGC methodology for prescriptive compliance with all multifamily windows. Performance compliance will still leverage the side fin and overhang shading modeling algorithms embedded in approve compliance software tools.

The submeasure proposes to create consistency between low-rise and high-rise performance modeling methods by having the Standard window area and orientation match the Proposed.

Alterations and Additions

For window alterations, the proposed code has different requirements by window type: curtainwall/storefront/glazed doors, Class AW fixed, Class AW operable, and all-others. Use of area-weighted averaging across fixed and operable window types for the Class AW category is not appropriate. A building owner may retrofit all operable windows at one time, but not it is fixed, which would not allow them to make the same tradeoffs between low U-factor fixed windows and higher U-factor operable windows. With vinyl windows, for the all-other category, the variation is not as pronounced. Projects adding new windows to existing floor space are considered alterations.

The proposed requirements result in increased stringency for buildings four habitable stories and greater and reduced stringency for buildings three habitable stories and fewer in Climate Zones 6 and 7. For window additions into new floor space, the proposed code requirements are based on an area-weighted average of thermal properties for all fenestration following new construction requirements. For both alterations and additions, the proposal calls for less restrictive requirements when a small volume of fenestration, <150 ft^2, is being added or altered.

Table 7: Proposed Fenestration Thermal Properties by Type and Climate Zone; Alterations and Additions

Window Type	Climate Zones	U-Factor (maximum)	SHGC (maximum)	VT (minimum)
Curtain wall / Storefront/ Glazed Doors	CZ 1	0.38	0.35	0.46
	CZ 2-15	0.41	0.26	0.46
	CZ 16	0.38	0.25	0.46
Class AW Fixed Windows	CZ 1	0.38	0.35	0.37
	CZ 2-5, 9-16	0.38	0.25	0.37
	CZ 6-8	0.41	0.26	0.37
Class AW Operable Windows	CZ 1	0.43	0.35	0.37
	CZ 2-16	0.43	0.24	0.37
All-others	CZ 1	0.30	0.23	NR
	CZ 2-5, 8-16	0.30	0.23	NR
	CZ 6, 7	0.34	0.23	NR
Alterations or Additions <150 ft^2	CZ 1	0.47	0.35	NR
	CZ 2-16	0.47	0.31	NR

Window additions in new floor space follow new-construction requirements. Window additions in existing floor space follow the requirements in Table 7.

The same low-rise building SHGC exception as proposed for new construction will apply with alterations and additions. This exception allows for no-SHGC-requirement in Climate Zones 1, 3, 5, and 16.

2.1.1.5 Submeasure E: Envelope - Fenestration Area

This submeasure applies the prescriptive low-rise residential 20 percent window-to-floor area maximum (inclusive of skylights) to high-rise buildings and the prescriptive high-rise residential 40 percent window-to-wall area maximum and 5 percent skylight to roof ratio to low-rise buildings. This measure would result in a dual metric. To comply prescriptively, the window area must comply with both limits simultaneously.

This submeasure provides a unified window area requirement to apply to all multifamily, where the current code uses different requirements and metrics based on the number of stories. The proposed code would enforce both a maximum window-to-conditioned floor area (CFA) ratio requirement for the overall glazing of 20 percent and maximum window wall ratio requirement of 40 percent. For the window-to CFA threshold, tenant-related spaces include dwelling units as well as common areas for sole use by the residents and property management staff.

The submeasure removes the west-facing glazing area restrictions for all multifamily buildings.

The submeasure covers new construction buildings, additions with greater than 700 ft^2 of conditioned floor area, and alterations that add greater than 150 ft^2 of window area.

2.1.2 Space Conditioning

These submeasures, in most cases, apply revised versions of the current low-rise residential requirements to all systems serving individual dwelling units and apply nonresidential requirements to systems serving common use areas and/or multiple dwelling units. There are no new requirements or changes in stringency for systems serving common areas and/or multiple dwelling units; therefore, the measure descriptions and subsequent analysis in this report focus on the impacts to individual dwelling unit requirements. The proposed changes and impacts are summarized as follows:

2.1.2.1 Submeasure F: Space Conditioning – Duct Insulation

The Statewide CASE Team evaluated duct insulation requirements for both ducts in conditioned space and ducts in unconditioned space. The original proposal was to create three new categories for supply-air and return-air duct insulation based on duct location, leveraging current requirements in both the low-rise residential and nonresidential sections of code. This change would have required mandatory R-4.2 duct insulation for verified low-leakage ducts within conditioned space, R-6 insulation for all other ducts within conditioned space, and R-8 insulation for ducts in unconditioned space; prescriptive duct insulation requirements would be eliminated. The allowance for uninsulated ducts enclosed in directly conditioned space would have remained.

This would have separately impacted multifamily buildings up to three habitable stories and multifamily buildings four habitable stories and greater with individual duct systems serving the dwelling units. For multifamily buildings up to three habitable stories, the change would have increased mandatory duct insulation requirements from R-6 to R-8 for ducts in unconditioned space. Existing prescriptive duct requirements are already R-8 in all climate zones except 3 and 5 through 7. For multifamily buildings four habitable stories and greater the change would have increased mandatory insulation requirements from R-4.2 to R-6 for supply ducts in conditioned space, unless verified as low leakage. For return ducts in conditioned space, the insulation requirement would have been increased from R-0 to R-6, except when verified as low leakage in which case it would have increased from R-0 to R-4.2.

Cost-effectiveness analysis did not justify the original proposed changes described above. To unify the requirements across all multifamily buildings, the recommendation presented in this CASE Report is to apply the existing high-rise mandatory requirements for R-4.2 duct insulation on supply ducts in conditioned space (regardless of whether they are verified low leakage ducts or not) to all multifamily buildings. The existing allowance for both low-rise and high-rise buildings for uninsulated ducts exposed to and directly surrounded by directly conditioned space remains. For ducts in all other locations including unconditioned space the low-rise requirements of R-6 mandatory duct insulation and R-8 prescriptive duct insulation in Climate Zones 1-2, 4, and 8-16 apply to all multifamily buildings with systems serving individual dwelling units.

These proposed changes apply to new construction and new or replacement ducts in alterations in most cases. One exception is ducts in unconditioned space in multifamily buildings three stories and fewer where R-8 duct insulation is prescriptively required only in Climate Zones 11 and 14 through 16 with R-6 required elsewhere. As with new construction this proposed code change in this CASE Report applies the existing requirements for altered ducts in unconditioned space for multifamily buildings three stories and fewer to multifamily buildings four stories and greater. However, market data indicates that multifamily buildings four stories and greater do not have individual duct systems serving dwelling unit in unconditioned space there is no statewide impact (see Section 3.2.1).

This proposal does not result in increased stringency and results in reduced stringency in the following situations:

- R-8 to R-6 duct insulation for new construction multifamily buildings four stories and greater with ducts in unconditioned space in Climate Zones 3, and 5-7.
- R-8 to R-6 duct insulation for new or replacement ducts in existing multifamily buildings four stories and greater with ducts in unconditioned space in Climate Zones 1-10, 12, and 13.

- R-6 to R-4.2 duct insulation for multifamily buildings three stories and fewer with ducts in conditioned space (not verified low leakage ducts or directly exposed to conditioned space).

The impact of this reduced stringency is presented in Sections 4 and 6. For additional details on the original proposal see Appendix G.

2.1.2.2 Submeasure G: Space Conditioning – Duct Leakage Testing

This proposal applies mandatory duct sealing and leakage testing per Section 150.0(m)11 for multifamily buildings three habitable stories and fewer to multifamily buildings four habitable stories and greater with ducted systems serving individual dwelling units. Duct systems, regardless of location, must be tested to meet no greater than 12 percent total leakage or no greater than 6 percent leakage to outside. Diagnostic field verification and test protocols are described in Residential Reference Appendix RA3.1. Neither third party verification by a HERS Rater nor registration with a HERS Registry is proposed for multifamily buildings four habitable stories and greater at this time. Compliance shall be demonstrated by the installing contractor and certified on the Certificate of Installation. The existing HERS verification requirement for multifamily buildings three habitable stories and fewer is proposed to remain. The 150.0(m)11 requirements apply to new construction and entirely new or complete replacement duct systems in alterations and additions. Based on the cost effectiveness results multifamily projects four stories and greater in Climate Zone 1 are exempt.

For alterations, this proposal applies the prescriptive leakage requirements per 150.2(b)D and 150.2(b)E for altered duct systems and space-conditioning systems in alterations and additions of multifamily buildings three habitable stories and fewer to multifamily buildings four habitable stories and greater. This requires duct sealing and testing to meet no greater than 15 percent total leakage or no greater than 10 percent leakage to outside regardless of duct system location. As with new construction testing compliance may be demonstrated by the installing contractor and certified on the Certificate of Installation. HERS Rater verification is not required. Based on the cost effectiveness results multifamily projects four stories and greater in Climate Zones 1, 5, and 7 are exempt.

For multifamily buildings four habitable stories and greater there is currently a prescriptive requirement that duct leakage be tested for both new and altered ducts for single zone systems serving less than 5,000 ft^2 with greater than 25 percent of duct surface area in unconditioned space. This rarely applies to multifamily units where ductwork is predominately located within conditioned space, typically within a soffit or interior walls. As a result, this proposal would impact multifamily buildings four habitable stories and greater by imposing new mandatory testing requirements.

2.1.2.3 Submeasure H: Space Conditioning – Space Cooling Airflow Rate and Fan Efficacy

This proposal applies mandatory system airflow and fan power testing per Section 150.0(m)13 for multifamily buildings three habitable stories and fewer to multifamily buildings four habitable stories and greater with ducted cooling systems serving individual dwelling units. Systems must meet 350 cfm per nominal ton of cooling or greater and either 0.45 W per cfm for gas furnaces or 0.58 W per cfm for all other air handlers. Diagnostic field verification and test protocols are described in Residential Reference Appendix RA3.3. Neither third party verification by a HERS Rater nor registration with a HERS Registry is proposed for multifamily buildings four habitable stories and greater. Compliance shall be demonstrated by the installing contractor and certified on the Certificate of Installation. The existing HERS verification requirement for multifamily buildings three habitable stories and fewer is proposed to remain. The 150.0(m)13 requirements apply to new construction and entirely new or complete replacement space-conditioning systems in alterations and additions. Based on the cost effectiveness results multifamily projects four stories and greater in Climate Zone 1 are exempt.

This proposal would impact multifamily buildings four habitable stories and greater by imposing new mandatory testing requirements.

There is no requirement for fan efficacy testing for altered space-conditioning systems. Airflow testing is required as part of the prescriptive refrigerant charge verification requirements for altered space-conditioning systems with mechanical cooling in alterations and additions in select climate zones. This proposed change is evaluated as part of the refrigerant charge verification submeasure.

2.1.2.4 Submeasure I: Space Conditioning – Refrigerant Charge Verification

This proposal applies prescriptive verification of refrigerant charge per Section 150.1(c)7A for multifamily buildings three habitable stories and fewer to multifamily buildings four habitable stories and greater with cooling systems serving individual dwelling units. The prescriptive requirement applies to Climate Zones 2 and 8 through 15. Diagnostic field verification and test protocols are described in Residential Reference Appendix RA3.2. Neither third party verification by a HERS Rater nor registration with a HERS Registry is proposed for multifamily buildings four habitable stories and greater. Compliance shall be demonstrated by the installing contractor and certified on the Certificate of Installation. The existing HERS verification requirement for multifamily buildings three habitable stories and fewer is proposed to remain. The 150.1(c)7A requirements apply to new construction and entirely new or complete replacement space-conditioning systems with mechanical cooling in alterations and additions.

For alterations, this proposal applies the prescriptive refrigerant charge verification and airflow testing per Section 150.2(b)Fii for altered space-conditioning systems with mechanical cooling in alterations and additions of multifamily buildings three habitable stories and fewer to multifamily buildings four habitable stories and greater. The proposal applies to Climate Zones 2 and 8 through 15. The refrigerant charge verification requirements are the same as with new construction; cooling coil airflow testing must meet 300 cfm per ton of nominal cooling capacity or greater. As with new construction testing compliance shall be demonstrated by the installing contractor and certified on the Certificate of Installation. HERS Rater verification is not required.

There are currently no comparable requirements under the nonresidential code and therefore this proposal would impact multifamily buildings four habitable stories and greater by imposing new prescriptive testing requirements.

2.1.2.5 Combination G-I: Space Conditioning – New Construction Test Package

Combination G-I includes all three HVAC verification measures above (duct sealing, airflow rate and fan efficacy, and refrigerant charge) would apply to multifamily buildings with ducted cooling systems. As such, the Statewide CASE Team evaluated them as a combined package, in addition to individually. Combining these measures as a package allows for cost-effective application across a greater number of climate zones, particularly in the case of duct leakage testing.

2.1.2.6 Other Changes

There are other code language changes because of this alignment that do not result in increased stringency to any building type. These are not discussed in detail in this report because they will have little or no impact on multifamily projects or do not result in increased stringency, although these changes are represented in the proposed revisions to code language in Section 7. Examples include the procedures for cooling and heating load calculations, determination of design conditions for load calculations, and HVAC system bypass duct requirements.

Bypass ducts are not allowed under the low-rise residential prescriptive code (150.1(c)13) and were prohibited as a best practice because of field studies that demonstrated performance issues in zoned systems with bypass ducts. Zoned systems are uncommon in multifamily buildings. Where they do exist bypass ducts can be particularly problematic due to limited access to dampers for repair where ductwork is typically in conditioned space and concealed within a soffit or ceiling. There are alternatives to bypass dampers that are not more costly, such as oversizing ducting to supply design airflow to any single zone and designing bonus supply branches to supply additional airflow to the zone calling for heating or cooling when the other zone turns off. This and other options including using variable speed equipment can be easily designed to meet the prescriptive airflow requirements and provide improved performance at the same time.

2.2 Measure History

Since the first energy codes were published, there has been a split between the coverage of residential and nonresidential buildings. This resulted in multifamily buildings being covered partially in one section and partially in another. Multifamily buildings up to three habitable stories followed residential requirements, while multifamily buildings four habitable stories or greater followed some residential and some nonresidential building requirements. Codes developed with analyses focused on single family homes do not adequately represent the equipment or building envelopes of multifamily buildings. Likewise, analyses of commercial buildings does not adequately capture multifamily equipment choices or schedules or the residential aspects of air leakage and ventilation.

This situation has caused confusion in Title 24, Part 6 compliance and enforcement. For example, two buildings in the same project, one three habitable stories and the other four habitable stories, have different requirements for fenestration, ventilation, space conditioning equipment, envelope performance, and air tightness. Design teams and building departments have expressed frustration about having to access two sets of manuals and two different software programs for such projects. Additionally, to the extent that multifamily buildings are part of the low-rise residential and nonresidential code development processes, they necessarily complicate them. Not only can multifamily buildings be best analyzed as a stand-alone type, but single family home and nonresidential building code development will benefit from removing that complication.

For several code development cycles, the Energy Commission has considered expanding the focus specifically on multifamily, but resource constraints prevented it. With the growing recognition of the importance of multifamily buildings to California's affordable housing crisis, the Energy Commission decided it was time to treat multifamily buildings as their own type, rather than straddling the low-rise residential and nonresidential codes. The current effort is intended to eliminate the arbitrary split between three-story and four-story multifamily building requirements and instead make requirements reflective of the type of construction and nature of equipment used, regardless of the building height.

2.2.1 Building Envelope

The building envelope includes both opaque and non-opaque components such as roofs, walls, windows, and attics, which provide a thermal barrier between indoor and outdoor environments. Design specifications and construction practices of building envelope can significantly affect occupant comfort levels and energy used to meet the heating and cooling loads.

Historically, many of the Title 24, Part 6 code updates have been researched and analyzed for single family or nonresidential buildings and then applied to multifamily buildings. The requirements may not always be well-suited for multifamily buildings, leading to compliance challenges and confusion among practitioners and inspectors. The problem is rooted in the current structure of the code, where low-rise projects must meet residential requirements, while high-rise projects must meet nonresidential requirements (with occasional adherence to residential requirements for certain energy measures). There is currently no clear, succinct set of multifamily requirements. Because there is not a single multifamily section, there are inconsistent requirements between high-rise and low-rise multifamily buildings, with some requirements that are not appropriate for multifamily construction. For example, low-rise residential requirements do not include a prescriptive compliance path for non-attic roofs, and it forces comparison to an attic roof assembly when the performance modeling approach is used. The performance-equivalent non-attic roof cannot be constructed cost effectively.

Findings from recent studies funded by Southern California Edison (SCE) provide evidence that support the need for a unified multifamily Title 24, Part 6 set of requirements and compliance software. SCE funded a modeling analysis study that examined software differences between CBECC-Res and CBECC-Com when modeling multifamily buildings (TRC 2018). The study demonstrated unequal Standard Design conditions and modeling algorithms, and therefore, unequal compliance margins for nearly identical buildings. SCE subsequently funded development of new multifamily prototypes based on current construction trends (TRC 2019). Construction trends identified during prototype research indicated no discernable difference between envelope characteristics of three-, four-, and five-story multifamily buildings. This finding suggests that a demarcation between low-rise buildings up to three habitable stories and high-rise four habitable stories or greater may be arbitrary and unfitting and unfitting for multifamily building envelopes.

Developing unified and consistent envelope requirements for all multifamily buildings can address many barriers to code compliance. The proposed envelope measures for multifamily buildings are based on the principles of consolidating and harmonizing low- and high-rise multifamily building standards while lowering energy use in the multifamily sector as a whole.

2.2.1.1 Submeasure A: Envelope – Roof Assemblies

The prescriptive options for low-rise multifamily buildings do not include roofs with no-attic, which exist on an estimated 67 percent of multifamily low-rise construction (see

Appendix A for data sources and methods). The updates to the 2016 Title 24, Part 6 code created a new and novel attic assembly method, the high-performance attic, which includes insulation on the roof deck in a vented attic in addition to the traditionally placed insulation on the attic floor as the primary thermal envelope barrier. The updates to the 2019 Title 24, Part 6 code increased the stringency of high-performance attics in most climate zones. Neither update considered the cost effectiveness for non-attic roofs, common in multifamily low-rise construction, that use the performance code for compliance.

Similarly, the nonresidential chapter never considered the application of an attic assembly for high-rise multifamily buildings. Though such instances are rare, when they do occur, they are typically on only a portion of the building for aesthetic reasons. However, the energy dynamic of such roof areas can be significant. Providing clear and consistent requirements for attic-roof areas across all multifamily benefits the industry.

2.2.1.2 Submeasure B: Envelope – Wall U-Factor

Current code requirements for wood framed walls between the residential and nonresidential chapters diverge by climate zone. Ten climate zones (1-5, 8-10, 12, and 13) have more stringent requirements in the residential code, and the other six climate zones have more stringent requirements in the nonresidential code. Previous code development research arrived at these requirements considering different wall assemblies, costs, prototypes, and using different software tools. Shorter buildings with less cumbersome fire-code requirements should allow for more cost-effective insulating options and low U-factor wall assemblies. The 2016 residential code updated wall requirements to consider 2x6 framing with rigid external insulation in most climate zones for a U-factor of 0.051. The 2019 residential code update increased the stringency of these requirements for single family buildings to 0.048 but did not find that the same change was cost effective in the garden style multifamily prototype. This indicates that the current nonresidential 0.042 U-factor requirement in Climate Zones 11 and 14-16 is not appropriate for multifamily buildings. A similar variation exists for Climate Zones 6 and 7, where residential code arrived at a 0.065 requirement as a recent limit for cost-effective, wood-framed walls, while nonresidential code arrived at a lower 0.059 requirement in the 2008 code update that has been maintained ever since.

Nonresidential code development research found that metal-framed walls are the predominant assembly method for commercial buildings that do not use structural steel with curtain walls (metal buildings). However in multifamily, metal framed walls are quite rare, involved in an estimated 0.7 percent of all multifamily dwelling units according to an Evergreen Economics survey of multifamily buildings in California (Evergreen Economics 2020). Metal framed walls, due to thermal bridging effects, are more difficult to insulate to low U-factors, which necessitates higher prescriptive U-factor allowances than for wood framed walls. To enforce cost-effective efficiency of wood framed walls, the nonresidential code maintained a split between metal framed and wood framed since at least the 1996 Title 24, Part 6 code, with significantly lower U-factor requirements for wood framed walls. Additionally, for performance modeling, the Nonresidential ACM assumes a metal framed wall as the standard for all buildings based on the finding that metal framed walls are predominant in non-residential buildings generally. This finding is inaccurate for multifamily buildings of four or more habitable stories. This code structure is not appropriate for multifamily buildings. Therefore, this proposal eliminates the metal-framed wall category entirely and uses the Proposed wall type as the basis of the Standard assembly for each wall.

2.2.1.3 Submeasure C: Envelope – Quality Insulation Installation

Title 24, Part 6 has included QII HERS verification for more than a decade. Based on data from the HERS registry provided by CalCERTS, 13 percent of registered low-rise multifamily projects took the QII performance credit in 2015-2016. For projects constructed from 2014 through 2019 the number increased to 45 percent for multifamily projects. The adoption of QII among multifamily buildings appears to be increasing.

QII became a prescriptive requirement under the 2019 Title 24, Part 6 code cycle for single-family and low-rise multifamily buildings. The 2019 residential QII CASE Study (Dakin and German 2017) found QII to be cost effective in all but Climate Zone 7. These results were based on lifecycle cost analyses derived from a one in four sampling rate and using an eight-unit garden style multifamily prototype. For the 2022 code cycle, the Statewide CASE Team is proposing QII to apply to all multifamily buildings up to 40,000 ft^2 CFA.

2.2.1.4 Submeasure D: Envelope – Fenestration Properties

Difference in the nonresidential and residential software platforms modeling window thermal properties results in energy use and savings estimates that do not conform with each other. In some cases, the results are directionally opposite—one software showing TDV savings, the other TDV losses. Varying U-factor has a less consistent result than varying SHGC, and the results are more pronounced in certain climate zones. Results across both metrics show the same fundamental issue. Differences in building prototypes, impacts of building height and exposure, or other realities of the energy models cannot fully account for the observed variance. Each code chapter, residential and nonresidential, arrived at the current prescriptive fenestration properties over multiple code cycles based on the results from these modeling platforms and their predecessors. The nonresidential code requirements are more lenient, especially regarding U-factor. This matches the variance observed in energy modeling—where the nonresidential software yields minor, or even negative savings in some climate zones, from modeling improved (lower) U-factors between 0.50 and 0.20, while the residential software shows relatively significant savings from the same modeling test.

2.2.1.5 Submeasure E: Envelope – Fenestration Area

Current nonresidential requirements are based on a window to wall area ratio to measure fenestration limits. Residential requirements are based on window to floor area. In both cases, the code-metric is most understood and commonly referenced by designers and architects of buildings within that building type. Because buildings fall within a relatively narrow band of wall to floor area ratios, the two metrics maintain a fairly consistent relationship to each other across the population of multifamily buildings. In rare cases, particularly tall high-rise buildings with a low wall to floor-area ratio, the window to wall area ratio limit becomes the more restrictive. The current prescriptive limits do not appear to have a verifiably limiting impact on current design practices in multifamily buildings.

2.2.2 Space Conditioning

2.2.2.1 Submeasure F: Space Conditioning – Duct Insulation

In many multifamily buildings, ducts distribute conditioned air throughout a dwelling unit. Thermal and air leakage losses can be significant, particularly when ducts are in unconditioned spaces. When ducts are in conditioned spaces, such as is typical in multifamily buildings with ductwork located in soffits and between floors, energy losses may still occur, but the thermal impacts are small.

Low-Rise Residential Code History

Duct insulation with a value of R-4.2 or greater became a mandatory requirement in the 1992 Title 24, Part 6 Standards, unless ductwork was enclosed entirely in conditioned space. This requirement remained essentially the same until the 2005 Title 24, Part 6 Standards when prescriptive insulation requirements were added for ducts in unconditioned space of R-4.2, R-6 or R-8, depending on climate zone and compliance method. The 2013 Title 24, Part 6 Standards increased the mandatory R-4.2 requirement to R-6 and increased the prescriptive requirements to R-6 or R-8 depending on climate zone. In the 2016 Title 24, Part 6 Standards the mandatory insulation requirement was dropped to R-4.2 for ducts located entirely in conditioned and verified as low-leakage by a HERS Rater (according to Reference Residential Appendix RA3.1.4.3.8). No exception was provided for ductwork enclosed entirely in conditioned space. The prescriptive duct insulation requirements were also revised to reflect two options, one with ducts located in an attic and another with ducts in conditioned space. The mandatory duct insulation requirements were further refined in the 2019 Title 24, Part 6 Standards to allow for uninsulated ducts if they are directly exposed to conditioned space or located within a wall cavity provided certain conditions are met.

Nonresidential Code History

Duct insulation with a value of R-4.2 or greater became a mandatory requirement in the 1995 Title 24, Part 6 Standards for nonresidential buildings including high-rise multifamily, unless ductwork was enclosed entirely in conditioned space. In the 2005 Title 24, Part 6 Standards, duct insulation requirements increased from R-4.2 to R-8 for ducts located in unconditioned spaces or outdoors. These requirements remain today in the 2019 Title 24, Part 6 Standards.

2.2.2.2 Submeasure G: Space Conditioning – Duct Leakage Testing

In many multifamily buildings, ductwork is used to distribute conditioned air throughout the unit. Thermal and air leakage losses can be significant, particularly when ducts are in unconditioned spaces. When ducts are in conditioned spaces, such as is typical in multifamily buildings with ductwork located in soffits and between floors, losses can still be non-trivial. This is particularly true of leakage losses where interstitial spaces are not sealed properly, and leakage may occur to the outdoors or other zones within the building. Even when properly sealed, any leakage is inadvertently conditioning spaces that may not be designed to be conditioned and reduces airflow to the directly conditioned space.

Low-Rise Residential Code History

The 1998 Title 24, Part 6 Standards introduced a compliance credit for residential duct systems with leakage rates at or below six percent of fan flow, as verified through HERS testing. This represented a substantial improvement over the assumed baseline of 22 percent leakage rate.

Beginning with the 2001 Title 24, Part 6 Standards, all ducts were prescriptively required to be sealed to less than or equal to six percent of fan flow and verified by a certified HERS Rater in all climate zones. The 2001 Title 24, Part 6 Standards added a compliance credit for locating ducts outside of unconditioned attics, such as crawlspaces or basements, and offered additional compliance credit for duct systems located entirely within conditioned space (including the air handling equipment).

The 2008 Title 24, Part 6 Standards offered new compliance credits for low-leakage ducts in conditioned space and for the use of low-leakage air handlers. The 2008 Title 24, Part 6 Standards update eliminated any alternatives to duct sealing in all climate zones for all prescriptive packages. Duct testing also became a requirement in all prescriptive methods of compliance in all climate zones, however the 2008 update eliminated requirements to have HERS verification for ducts installed in the crawlspace of a home. In the 2008 update, ducts in crawlspaces are given compliance credit over the Package D standard design and are verified by the building inspector.

The 2013 Title 24, Part 6 Standards update moved duct sealing and testing requirements from a prescriptive measure for newly constructed residential buildings to a mandatory measure. Requirements specific to multifamily buildings were added for 12 percent total leakage and 6 percent leakage to outside. The 2013 Title 24, Part 6 Standards update did not change leakage rates, application rules, or exceptions found in the 2008 Title 24, Part 6 Standards.

Nonresidential Code History

The 2001 Title 24, Part 6 Standards added a compliance credit for duct tightening for nonresidential buildings similar to what was introduced in the 1998 Title 24, Part 6 Standards for residential buildings with ducts in unconditioned spaces or outside of the building. The 2001 Title 24, Part 6 Standards used the same field verification mechanism for nonresidential buildings as was already in place for residential buildings.

The update to the 2005 Title 24, Part 6 Standards further increased requirements for duct sealing and insulation in nonresidential buildings. The 2005 Title 24, Part 6 Standards update added prescriptive requirements for duct sealing and leakage testing during installation, requiring that ductwork serving single zones less than 5,000 ft^2 and with more than 25 percent of the ducts in unconditioned space have leakage rates not exceeding six percent of the fan flow of the duct system.

2.2.2.3 Submeasure H: Space Conditioning – Space Cooling Airflow Rate and Fan Efficacy

Space conditioning system performance is affected by many factors, including airflow rate and fan power. Increasing airflow delivers more heating and cooling energy to the space and lower fan watt draw reduces electricity usage during fan operation. Studies have shown that low airflow and high fan watt draw can be common in new buildings, both of which lead to increased operation for HVAC equipment and longer periods of time to cool the space (California Energy Commission 2011).

The 2008 Title 24, Part 6 Standards update added prescriptive requirements for buildings with central forced air handlers in Climate Zones 10 through 15. The update required such systems to demonstrate airflow of greater than 350 cfm/ton of nominal cooling capacity and a watt draw of 0.58 Watts/cfm or less. The 2008 update also provided compliance credit for cooling coil airflows exceeding prescriptive requirements and for fan watt draws less than prescriptive requirements.

A CASE Report for the 2013 Title 24, Part 6 Standards update introduced mandatory minimum cooling coil airflow and fan watt draw requirements and applied these requirements to new construction as well as alterations of existing residential buildings (Statewide CASE Team 2011). The new requirements adopted in the 2013 Title 24, Part 6 Standards required airflow of greater than or equal to 350 cfm/ton and fan watt draw less than or equal to 0.58 watts/cfm. In the 2019 Title 24, Part 6 Standards update, fan watt draw requirements for furnaces only were further reduced from 0.58 Watts/cfm to 0.45 Watts/cfm (Statewide Codes and Standards Team 2017).

2.2.2.4 Submeasure I: Space Conditioning – Refrigerant Charge Verification

Air conditioner and heat pump system performance is affected by many factors, including improper amounts of refrigerant, improper evacuation, metering device malfunctions, and other refrigerant related problems. Studies have shown that many new air conditioners in California fail to achieve their rated efficiency due to refrigerant issues (California Energy Commission 2011).

The 2001 Title 24, Part 6 Standards introduced prescriptive HERS verification and diagnostic testing for refrigerant charge, including measurement procedures for residential ducted split system central air conditioners and ducted split system central heat pumps with no thermostatic expansion valve (TXV) in Climate Zones 2 and 8 – 15. These procedures included the Superheat Charging Method and the Temperature Split Method, in addition to an alternate procedure. The 2008 Title 24, Part 6 Standards removed the compliance credit for TXVs and added revised requirements for refrigerant charge testing, but those requirements created significant challenges for HERS Raters and contractors. Among these challenges were a lack of a wintertime HERS verification protocol, inattention to variable environmental conditions at the time of testing, a lack of consideration for microchannel condenser coils, and the use of the temperature split method of testing. These issues were addressed in the 2013 Title 24, Part 6 Standards update, wherein new testing and verification procedures were introduced in an attempt to eliminate then-existing compliance barriers.

A CASE Report prepared in 2014 for the 2016 Title 24, Part 6 Standards update addressed unresolved diagnostic testing and verification issues but did not anticipate any energy savings, and therefore, did not conduct cost-effectiveness analysis (Statewide Codes and Standards Team 2014). Rather, the report proposed clarifications and minor modifications to existing code language affecting HVAC system installers and HERS Raters. The report added liquid line filter drier verification to the standard installation process and added verification requirements to HERS procedures. Additionally, the 2014 CASE Report clarified that manufacturer installation specifications should be used as the basis for refrigerant charge verification. The report also renamed Charge Indicator Displays to Fault Indicator Displays “to reflect that a broader range of devices can be submitted for approval with the CEC”. This issue was revisited in the 2017 CASE Report, “Residential Quality HVAC Measures”, where a compliance option for fault detection and diagnosis devices was proposed. The same report also provided for an alternative verification method to refrigerant charge verification that measures system performance with increased efficacy.

2.3 Summary of Proposed Changes to Code Documents

Restructuring the multifamily requirements would require broad changes to the Title 24, Part 6 Standards, Reference Appendices, ACM Reference Manual, compliance manuals, and compliance documents. The Statewide CASE Team describes these generally and then more specifically by envelope and space conditioning measures, which result in changes to the requirements in addition to structural changes.

2.3.1 General Restructuring

2.3.1.1 Summary of Changes to the Standards

This proposal would add three subchapters to capture Title 24, Part 6 requirements specific to multifamily buildings and additionally result in removal of multifamily-specific language from the residential and nonresidential chapters. See Section 7.2 of this report for full multifamily subchapter language.

The Statewide CASE Team proposes three new subchapters for Title 24, Part 6, as outlined in Table 8, Table 9, and Table 10.

Table 8: Outline of Proposed Subchapter 10: Multifamily Buildings Mandatory Requirements

New Section	Content From	Change in Application of Requirements
160.1 BUILDING ENVELOPES		
(a) Ceiling and Roof Insulation	150.0(a, b) 120.7(a)	Residential requirements for attic roofs, nonresidential requirements for non-attic roofs (submeasure A)
(b) Wall Insulation	150.0(c), 120.7(b)	Single list of U-factor requirements by assembly type and fire rating (submeasure B)
(c) Floor and Soffit Insulation	150.0(d), 120.7(c)	None
(d) Vapor Retarder	150.0(g)	None
(e) Fenestration Products	150.0(q),	Residential requirements applied to high-rise multifamily buildings (submeasure D)
(f) Installation of Fireplaces	150.0(e)	None
160.2 VENTILATION AND INDOOR AIR QUALITY		
(a) General	New	None
(b) Dwelling Units	150.0(m)12	
(c) Common Use Areas	120.1	
(d) Parking Garages	Reference to 120.6(c)	
160.3 SPACE CONDITIONING SYSTEMS		
(a) Controls	150.0(i, m)	None

New Section	Content From	Change in Application of Requirements
(b) Systems Serving I Dwelling Units	150.0(h)	Residential requirements applied to systems serving dwelling units in high-rise buildings (space conditioning submeasures)
(c) Systems Serving Common Use Areas	120.2 through 120.5	None
160.4 WATER HEATING SYSTEMS		
(a) Individual Gas Systems	150.0(n)1	None
(b) Recirculation Loops	150.0(n)2	
(c) Solar Water Heating	150.0(n)3	
(d) Instantaneous Water Heating	150.0(n)4	
(e) Commercial Boilers	120.4	
(f) Insulation for Piping and Tanks	150.0(j), 120.3(b)	
160.5 INDOOR AND OUTDOOR LIGHTING		
(a) Dwelling Unit	150.0(k)	None
(b) Common Use Area	130.0, 130.1	
(c) Outdoor Lighting and Controls	130.2	
(d) Sign Lighting Controls	130.3	
(e) Lighting Control Acceptance	130.4	
160.6 ELECTRIC POWER DISTRIBUTION SYSTEMS		
(a) Service Electrical Metering	130.5(a)	None. Applies only to common use areas.
(b) Separation of Electrical Circuits	130.5(b)	
(c) Voltage Drop	130.5(c)	
(d) Circuit Controls	130.5(d)	
(e) Demand Responsive Controls	130.5(e)	
160.7 PROCESSES		
(a) Elevators	Reference to 120.6(f)	None
(b) Residential pools	Reference to 110.4	
160.8 SOLAR READY		
(a) Solar ready buildings	Reference to 110.10	None

Table 9: Outline of Proposed Subchapter 11: Multifamily Buildings Performance and Prescriptive Requirements

New Section	Subsections	Content From	Change in Application
170.0 GENERAL		150.0(a)	
170.1 PERFORMANCE APPROACH		150.0(b)	
170.2 PRESCRIPTIVE APPROACH			
(a) Building Envelope	Roof/Ceiling	150.1(c)1, 140.3 (a)	Residential or nonresidential requirement applied per climate zone.
	Wall Insulation	150.1(c)2	Single list of U-factor requirements by assembly type and fire rating (submeasure C).
	Fenestration	150.1(c)3	Residential requirements applied to high-rise buildings, except for NAFS class AW and curtain wall fenestration (submeasure D).
	Doors	150.1(c)5	None
	Raised Floors	150.1(c)4	None
	Quality Insulation Installation	150.1(c)11	Residential requirement applied to buildings up to 40,000 ft^2
(b) Space Conditioning Systems	Sizing and Equipment	140.4 (a)	Nonresidential requirements applied to systems serving low-rise buildings.
	Calculations	140.4 (b)	
	Dwelling Unit	150.1 (c)6, 7, 9, 10, 13	Residential requirements applied to systems serving dwelling units in high-rise buildings (space conditioning submeasures).
	Common Use Area	140.4(c) through (o)	None
(c) Daylighting for Common Use Areas		140.3(c)	None
(d) Water Heating		150.0(c)8	None
(e) Lighting		140.6, 140.7	None
(f) Photovoltaic		150.0(c)14	None

Table 10: Outline of Proposed Subchapter 12: Multifamily Buildings Additions, Alterations, and Repairs

New Section	Subsections	Content From	Change in Application
180.1 ADDITIONS			
(a) Prescriptive Approach	1. Envelope	150.2(a)1	Reference to unified prescriptive standard
	2. Ventilation and Indoor Air Quality	150.2(a)1	None
	3. Water Heater	150.2(a)1	None
(b) Performance Approach		150.2(a)2	None
180.2 ALTERATIONS			
(a) Mandatory	1. Roof/Ceiling Insulation	140.0(b)	High-rise residential requirement applied to non-attic roofs; residential requirement applied to attic roofs.
	2. Wall Insulation	140.0(b)	Nonresidential requirements applied across all multifamily buildings, by assembly type.
	3. Floor Insulation	140.0(b)	
(b) Prescriptive	1. Envelope	150.2(b), 141.0(b)2B	Fenestration properties (U-factor/SHGC) aligned with proposed new construction requirements.
	2. Space Conditioning	150.2	Residential requirements applied to systems serving individual dwelling units in high-rise buildings.
	3. Lighting	150.2	None
(c) Performance Approach		150.2	None
180.3 REPAIRS		150.2	
180.4 WHOLE BUILDING		150.2	

The proposed restructuring would alter or add definitions as follows.

SECTION 100.1 – DEFINITIONS AND RULES OF CONSTRUCTION

— **Section 100.1(b) – Definitions: Recommends new definitions for the following terms:**

- **Multifamily building:** building, other than a hotel/motel, of Occupancy Group R-2 or R-4
- **Common use area:** private use area, interior or exterior, within multifamily residential facilities where use is limited exclusively to owners, residents and their guests.

The sections below summarize how the standards, Reference Appendices, ACM Reference Manuals, and compliance documents that would be modified by the proposed restructuring. See Section 7 of this report for detailed proposed revisions to code language.

2.3.1.2 Summary of Changes to the Reference Appendices

The Statewide CASE Team recommends reference to the Residential Appendices for field verification measures for envelope and individual system HVAC systems. (HERS measures) For field verification and/or commissioning of common use area or central systems, the Statewide CASE Team recommends retaining reference to the Nonresidential Appendices. The multifamily restructuring proposal would require updates to Reference Appendices for references to sections moved from Sections 120.0 through 150.2 to the new multifamily chapters.

2.3.1.3 Summary of Changes to the ACM Reference Manuals

The Standard Design conditions for multifamily buildings would change with the proposed restructuring measure for alignment with the proposed prescriptive requirements. The Statewide CASE Team presents notable changes associated with the envelope and space conditioning submeasures in Section 2.3.2.3 and 2.3.3.3.

2.3.1.4 Summary of Changes to the Compliance Manuals

The Statewide CASE Team recommends creation of a Multifamily Compliance Manual, which will stand alone as a new, separate document dedicated to multifamily buildings, and will incorporate all multifamily requirements that are currently discussed in either the Nonresidential or Residential Compliance Manuals. A separate section within the Residential Compliance Manual or Nonresidential Compliance Manual is the next best option. The Statewide CASE Team may supplement this section and Section of the Final CASE Report, pending discussion with the Energy Commission.

2.3.1.5 Summary of Changes to Compliance Documents

The Statewide CASE Team proposes a single set of compliance documents per multifamily building. Section 7.5 describes a proposal to use the nonresidential compliance documents for multifamily buildings in order to best capture the requirements for multifamily and mixed-use buildings.

2.3.2 Building Envelope

2.3.2.1 Summary of Changes to the Standards

Roof Assemblies: The proposal adds a non-attic Option A to the multifamily component package options for roofs, which includes the nonresidential insulation and low slope and steep slope roofing product requirements from Section 140.3(a)1A and 140,3(a)1B. The proposal maintains roof insulation Option B and Option C from the low-rise residential requirements, and packages each with the current low-rise residential roofing product requirements for low slope and steep slope roofs.

Wall U-factor: The proposal consolidates and re-organizes wall assembly requirements from Table 150.1-B for residential and Table 140.3-C for nonresidential. The Statewide CASE Team proposes the adoption of seven wall assembly types, replacing categories used in the 2019 Title 24, Part 6 Standards:

- Metal buildings
- Framed (wood or metal), with high fire rating (two- or three-hour)
- Framed (wood or metal), with low fire rating (one- or two-hour), and other wall types
- Heavy mass (<15 Btu/ft^2-F)
- Light mass (7-15 Btu/ft^2-F)

For each category, the table specifies the prescriptive maximum assembly U-factor by climate zone.

Quality Insulation Installation: The proposal applies the QII requirements from 150.1(c)1E to all multifamily buildings up to 40,000 ft^2 CFA.

Fenestration Properties: The proposal aligns fenestration requirements from Code Table 150.1-B for residential and Table 140.3-C for nonresidential. The Statewide CASE Team proposes the adoption of three window categories differentiated by the window type.

- Curtainwall, storefront, and window-wall fenestration
- NAFS-2008 Performance Class AW windows
- All other windows

For each category, the table specifies maximum U-factor, maximum RSHGC, and minimum VT requirements by climate zone. The proposal adds an exception to the RSHGC requirement for low-rise buildings in Climate Zones 1, 3, 5, and 16 to have no-requirement.

For alterations and additions. the proposal creates a new alterations table with different requirements by window type and situation.

- Curtainwall, storefront windows, and glazed doors
- NAFS-2008 Performances Class AW windows
    - Fixed windows
    - Operable windows

- All other windows

For each category, the table specifies maximum U-factor, maximum RSHGC, and minimum VT requirements by climate zone. The proposal adds an exception to the RSHGC requirement for low-rise buildings in Climate Zones 1, 3, 5, and 16 to have no-requirement.

Window additions in new floor space adhere to new-construction requirements. Window additions in existing floor space are considered alterations.

Window Area Limits: The proposal recommends the use of both window area metrics from Code Table 150.1-B for residential and Table 140.3-C for nonresidential. These two metrics and thresholds are a maximum total area (as a percentage of conditioned floor area) of 20 percent and maximum window-to-wall ratio of 40 percent. This proposal also eliminates the five percent maximum west-facing area requirement currently in residential code but applies the performance penalty for buildings that exceed 40 percent west-facing window to wall area requirement embedded in the nonresidential ACM to all multifamily.

2.3.2.2 Summary of Changes to Reference Appendices

The proposed code change would not modify the Reference Appendices.

2.3.2.3 Summary of Changes to the ACM Reference Manuals

Notable changes to the Standard Design for multifamily buildings associated with the envelope submeasures include:

- Roof insulation and solar reflectance dependent on whether or not there is an attic
- Wall U-factor as determined by assembly type and fire rating
- Quality Insulation Installation for buildings up to 40,000ft^2 CFA
- Fenestration U-factor and RSHGC by window category and climate zone
- Window and wall orientation based on actual orientation rather than evenly distributed across orientations
- Window area equal to proposed window area up to either 20 percent window to floor area or 40 percent window to wall area, whichever is lower
- Applies the 40 percent west-facing window to wall area requirement currently in the nonresidential ACM to all multifamily buildings. Eliminate the maximum five percent west-facing window to floor area liming currently in the residential ACM

2.3.2.4 Summary of Changes to Compliance Manuals

The Statewide CASE Team strongly recommends creation of a Multifamily Compliance Manual. Current sections of the Compliance Manuals which would be impacted by the restructuring proposal include:

- Residential Compliance Manual Chapter 3: Building Envelope Requirements
  - 3.3 Fenestration and Opaque Doors
  - 3.4 Opaque Envelope, 3.4.3 Roofing Products
  - 3.5 Insulation Products
    - 3.5.3 Ceiling and Roof Insulation
    - 3.5.4 Wall Insulation
    - 3.5.8 Quality Insulation Installation (QII)
  - 3.6 Opaque Envelope in the Performance Approach
- Nonresidential Compliance Manual Chapter 3: Building Envelope
  - 3.2 Opaque Envelope Assembly
    - 3.2.4 Roofing Products and Insulation
    - 3.2.5 Exterior Walls
  - 3.3 Fenestration
  - 3.5 Performance Approach

2.3.2.5 Summary of Changes to Compliance Documents

The proposed code change would adopt the existing nonresidential NRCC-ENV-E. Fields would change as follows:

- The available drop-down Roof Materials fields and auto populated Required Performance fields would be updated based on Roof Slope field (in NRCC) to reflect appropriate requirement values.
- A new field to indicate whether an attic is present would be added, and the Required roof deck and ceiling insulation R-value fields would be updated based on to reflect the appropriate values.
- The Assembly Type field and corresponding Required U-Factor field would be updated to match the new wall categories and requirement values.
- The auto-populated Maximum Allowed U-factor and Maximum Allowed SHGC fields would be updated to reflect the appropriate requirement values.
- A new QII field with a checkbox to indicate compliance would be added. This

field would be displayed for buildings with up to 40,000ft^2 CFA.

- The Fenestration Type field options would be updated to match the new fenestration categories.
- The Maximum Allowed Fenestration Area (ft^2) field calculation would use and display both the window-to-CFA ratio and window-to-wall ratio requirements.

2.3.3 Space Conditioning

2.3.3.1 Summary of Changes to the Standards

The multifamily restructuring proposal applies residential space conditioning requirements from Sections 150.0(h), and 150.1(c)6, 7, 9, 10, and 13 to systems serving dwelling units and nonresidential requirements from Sections 120.2 through 120.5 and 140.4(c) through (o) to systems serving common use areas. The proposal changes space conditioning requirements for multifamily buildings with four or greater stories and space conditioning systems serving individual dwelling units, which comply with the nonresidential requirements under 2019 Title 24, Part 6. See Section 7.2 of this report for full multifamily subchapter language.

2.3.3.2 Summary of Changes to Reference Appendices

The proposed code change would not modify the Reference Appendices.

2.3.3.3 Summary of Changes to ACM Reference Manuals

The space conditioning submeasures would apply language from the Residential ACM Reference Manual Section 2.4 Building Mechanical Systems to space conditioning systems serving individual dwelling units, regardless of building height.

2.3.3.4 Summary of Changes to Compliance Manuals

The Statewide CASE Team recommends creation of a Multifamily Compliance Manual. Current sections of the Compliance Manuals that would be impacted by the HVAC submeasures include:

- Residential Compliance Manual Chapter 4: Building HVAC Requirements
- Nonresidential Compliance Manual Chapter 4: Mechanical Systems

2.3.3.5 Summary of Changes to Compliance Documents

The following existing low-rise residential Certificates of Installation (CF-2R) forms would be converted to nonresidential Certificates of Installation (NRCI) forms for use with all multifamily buildings regardless of number of stories.

- 2019-CF2R-MCH-20a-DuctLeakageTest-NewConst

- 2019-CF2R-MCH-20d-DuctLeakageTest-ExistingConst
- 2019-CF2R-MCH-20e-DuctleakageTest-SealingAccesibleLeaks
- 2019-CF2R-MCH-23a-AirflowRate-AllZonesCallingOnly
- 2019-CF2R-MCH-23b-AirflowRate-EveryZonalControlMode
- 2019-CF2R-MCH-23c-AirflowRate-BestThatIcanDo
- 2019-CF2R-MCH-23d-AirflowRate-MeasurementOnly-AllZonesCallingOnly
- 2019-CF2R-MCH-23e-AirflowRate-AllZonesCallingOnly-WithCFVCS
- 2019-CF2R-MCH-23f-AirflowRate-EveryZonalControlMode-WithCFVCS
- 2019-CF2R-MCH-22a-FanEfficacy-AllZonesCallingOnly
- 2019-CF2R-MCH-22b-FanEfficacy-EveryZonalControlMode
- 2019-CF2R-MCH-22c-FanEfficacy-AllZonesCallingOnly-WithCFVCS
- 2019-CF2R-MCH-22d-FanEfficacy-EveryZonalControlMode-WithCFVCS
- 2019-CF2R-MCH-25a-RefrigerantCharge-Superheat
- 2019-CF2R-MCH-25b-RefrigerantCharge-Subcooling
- 2019-CF2R-MCH-25c-RefrigerantCharge-WeighIn
- 2019-CF2R-MCH-25e-RefrigerantCharge-WinterSetup
- 2019-CF2R-MCH-25f-RefrigerantCharge-PackagedSystemManufacturerCert
- 2019-CF2R-MCH-28-ReturnDuctAndFilterGrilleDesign-Table1500-BorC

2.4 Regulatory Context

2.4.1 Existing Requirements in the California Energy Code

Title 24, Part 6 requirements for multifamily buildings are scattered throughout Sections 100 through 150, spanning residential and nonresidential sections. Which requirements apply to each multifamily building depend on whether the building is up to or above three habitable stories in height and what percentage of the floor area is made up of dwelling units.

The current high-rise and low-rise prescriptive requirements for the envelope submeasures are shown in Table 11. These requirements differ in categories and thresholds. Furthermore, fenestration and wall assembly requirements vary by climate zone.

Table 11: 2019 Prescriptive Envelope Requirements – High-Rise vs. Low-Rise Buildings

Submeasure	High-rise residential prescriptive requirements | 4+ habitable stories	Low-rise residential prescriptive requirements | 3 habitable stories or fewer
Roof Assemblies	0.20-0.75 ASR by roof slope and climate zone. 0.75 thermal emittance. Metal building: U-factor of 0.041. Wood framed and others: U-factors of 0.028, 0.034 or 0.039 by climate zone. No prescriptive measure for buildings with attics.	0.20-0.63 ASR by roof slope and climate zone. 0.75 thermal emittance. High-performance attics, options B or C. R-30 or R-38 on the attic floor by climate zone. R-0 or R-19 on the roof deck. No prescriptive measure for buildings without attics.
Quality Insulation Installation	No requirement or performance option.	Prescriptive requirement of field verification in CZ 1-6, 8-16.
Fenestration, by window type and climate zone	U-factor: 0.36-0.46 SHGC: 0.22-0.26 VT: 0.17-0.46	U-factor: 0.30 SHGC: 0.23 or NR VT: no requirement
Fenestration Area Metric	Window to wall area – maximum 40% overall and 40% west facing.	Window to floor area – maximum 20% overall, 5% west facing.
Wall (metal and framed) assembly U-factor	0.042-0.105 by wall type and climate zone.	0.051-0.065 by climate zone.
Wall (Mass and below grade) assembly U-factor	0.160-0.690 by wall type and climate zone.	0.053-0.200 by wall type and climate zone.
QII	No requirements or performance option.	Prescriptive requirement (except Climate Zone 7).

The current high-rise and low-rise requirements for the space conditioning submeasures are shown in Table 12.

Table 12: 2019 Mandatory and Prescriptive Space Conditioning Requirements – High-Rise vs. Low-Rise Buildings

Submeasure	High-rise residential requirements | 4+ habitable stories	Residential requirements | 3 habitable stories or fewer
Duct Insulation (unconditioned space)	Mandatory requirement for R-8. Requirements apply to supply and return ducts.	Mandatory requirement for R-6. Prescriptive requirement for R-6 in CZ 3, 5-7 and R-8 in CZ 1-2, 4, 8-16. Requirements apply to supply and return ducts.
Duct Insulation (conditioned space)	Mandatory requirement for R-4.2 on supply ducts. Uninsulated supply ducts allowed if enclosed in directly conditioned space. No requirement for return duct insulation.	Mandatory requirement for R-4.2 and prescriptive requirement for R-6 when a HERS Rater verifies low leakage ducts within conditioned space. Uninsulated ducts allowed if enclosed in directly conditioned space or within a wall cavity. Requirements apply to supply and return ducts.
Duct Leakage Testing	Prescriptive requirement of 6% total leakage for single zone systems serving <5,000 ft^2 with >25% of duct surface area in unconditioned space.	Mandatory requirement of 12% total leakage or 6% leakage to outside for all ducts, HERS verified.
Cooling Coil Airflow	No requirement, is modeled within the compliance software.	Mandatory ≥ 350 cfm/ton, HERS verified.
Fan Efficacy	No requirement, is modeled within the compliance software.	Mandatory 0.45 W/cfm gas furnace, 0.58 W/cfm all other air handlers, HERS verified.
Refrigerant Charge	No requirement or performance option.	Prescriptive requirement for HERS verification in CZ 2, 8-15.

2.4.2 Relationship to Requirements in Other Parts of the California Building Code

The California Building Code, Residential Code, Mechanical Code, Plumbing Code, Electrical Code, Fire Code, Existing Building Code, and Green Building Standard all have relationships with Title 24, Part 6 requirements for multifamily buildings. The proposed Title 24, Part 6 structure and content for multifamily buildings aims for greater alignment and consistency with other parts of Title 24. Some examples include:

- The definition of *multifamily building* is consistent with Part 2 and Part 2.5
- Envelope requirements are categorized by fire-rating requirement

Fire and structural requirements in Title 24, Part 2, Chapter 10 of the 2019 California Building Code have interactions with and implications on several of the envelope submeasures. The state's fire code, Title 24, Part 9, is adopted from 2018 International Building Code with amendments, and it dictates fire-resistance rating for exterior walls based on building type designations. California's fire code contains egress requirement as means of emergency exit in fire events. The requirement mandates placement of operable windows, which affects thermal performances of window products.

Section 603.10 of the 2019 California Mechanical Code (Title 24, Part 4) requires duct system joints and seams "be made substantially airtight" and sealed using "tapes, mastics, gasketing, or other means". This existing code requirement applies to all multifamily buildings and already requires a level of sealing that for some systems will be sufficient to meet the proposed total leakage targets.

2.4.3 Relationship to Local, State, or Federal Laws

The proposed fenestration category by the NAFS Performance Class is inspired by the 2018 Washington State Energy Code which created a separate category for "Performance Class AW windows" and made direct reference to fenestration products rated in accordance with the AAMA/CSA101/I.S.2/A440 test standards.

2.4.4 Relationship to Industry Standards

2.4.4.1 IECC Proposal for a Multifamily Chapter

The International Code Council considered creating a multifamily chapter of the International Energy Conservation Code (IECC) in their last cycle. Proposal CE272 included creation of a new chapter in the Commercial section of the IECC that consolidated all multifamily code provisions. The primary intent of CE272 was to provide clarity and to build the foundation for ongoing improvements to the code for multifamily buildings.

The envelope section of the multifamily chapter in CE272—where there are perhaps the most significant and complex differences between high- and low-rise requirements—directed low-rise projects to the envelope requirements in the residential section and high-rise projects to the envelope requirements in the commercial section. In the lighting and mechanical sections, CE272 would have restructured the requirements to direct the dwelling units to residential requirements and common areas to commercial requirements. Simple single zone mechanical systems serving dwelling units were subject to residential requirements, while complex systems and systems serving the common areas were directed to commercial requirements. Minor differences between the commercial and residential requirements may have had a minor impact on stringency.

At the final comment hearings for the 2018 IECC, the attending code officials voted not to hear amendments to the proposal that would have significantly improved it. This meant that an earlier, less robust version of the proposal went to voting and subsequently failed (International Code Council 2016).

Various stakeholders voiced substantial opposition if the proposal changed stringency for either high-rise or low-rise multifamily. The proposal was structured to minimize and avoid stringency changes, with the goal of bringing requirements together in future code changes. However, this led to a proposal that was more confusing, still containing different requirements and references for low-rise and high-rise multifamily buildings. It also meant that the advantages of moving to a single section for multifamily were diluted. The result was a proposal with a higher complexity and lower benefit. The significant structural change was ultimately more change than the voters were willing to address at the time.

The Statewide CASE Team proposal for multifamily subchapters in Title 24, Part 6, applied lessons from the failed IECC proposal CE272. This proposal includes unification of requirements across low-rise and high-rise buildings for simplicity and ease of compliance. The Statewide CASE Team also proposes housing all multifamily requirements for dwelling units and common use areas within the multifamily chapters, as opposed to referencing residential and nonresidential requirements.

2.4.4.2 American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Delineation of Low-Rise and High-Rise Standards

ASHRAE standards generally maintain a split between low-rise residential buildings (up to three habitable stories) and high-rise residential buildings (four or greater stories), similar to the low-rise/high-rise delineation in 2019 Title 24, Part 6. This is true in the ASHRAE 90.1 and 90.2 (Energy Standards), as well as 62.1 and 62.2 (Ventilation for Acceptable Indoor Air Quality). Title 24, Part 6 currently applies ASHRAE Standard 62.2 across all multifamily buildings, regardless of height.

2.5 Compliance and Enforcement

The Statewide CASE Team considered methods to streamline the compliance and enforcement process for multifamily buildings in developing the proposed restructuring of Title 24, Part 6 requirements for multifamily buildings. Perhaps the greatest benefit in compliance and enforcement is that all relevant multifamily requirements would be consolidated into three subchapters of code language. Building officials and design teams would no longer need a map of which requirements apply to which types of multifamily buildings, assemblies, and systems and where to find those requirements, and they would no longer need to navigate from subchapter to subchapter to collect the requirements for the building.

The unification submeasures, which align low-rise and high-rise requirements, will impact compliance and enforcement through equitable treatment of similar assemblies and mechanical systems. This will make understanding of requirements simpler for building officials and allow design teams to more easily identify solutions that result in compliance across low-rise and high-rise buildings that sit on the same site. This unification will also allow utility incentive programs to address multifamily buildings of all sizes under a single program design.

Additional compliance and enforcement impacts of unification across low-rise and high-rise requirements are described by submeasure below. Appendix E further presents how the proposed changes could impact various market actors.

2.5.1 Building Envelope

2.5.1.1 Submeasure A: Envelope – Roof Assemblies

- **Design Phase:** Designers specify roof assembly and roofing products and roof and ceiling insulation and provide necessary information to populate the CF1R/NRCC forms. Pertinent details include presence of an attic; insulation locations, types, and levels; roof pitch; roofing product solar reflectance; and thermal emittance specifications.
- **Permit Application Phase:** The design professional is responsible for the completion and submission of the certificate of compliance documents with roofing product information.
- **Construction Phase:** Once a roof's structural components are completed, roofing contractors install the roofing products specified in the construction documents. Minimal coordination between trades is involved in comparison to construction of other building assemblies.
- **Inspection Phase:** Roof product specifications and roof assembly details are listed on the CF2R-ENV-04-E/NRCI-ENV-01-E installation forms. Building inspectors will confirm that the installed roofing products and insulation match the indicated performance details and location.

There are no changes in compliance or enforcement processes and no additional coordination needs between trades anticipated from this submeasure.

2.5.1.2 Submeasure B: Envelope – Wall U-Factor

- **Design Phase:** Designers specify wall construction type and provide necessary information to populate the CF1R/NRCC forms. Pertinent details include frame type, dimensions, cavity and continuous insulation R-values, and the overall assembly U-factor.

- **Permit Application Phase:** The design professional is responsible for the completion and submission of the certificate of compliance documents, which include wall assembly specifications and a wall schedule. Designers (architects and engineers) who are used to specify wall assemblies to meet structural and fire rating requirements, will need to explicitly pass on the fire rating information to the energy consultant/modelers. This information becomes the determinant for the wall's thermal requirements since the proposed new wall categories align with both wall assembly type and their firing ratings.
- **Construction Phase:** Wall assembly construction, especially in larger multifamily buildings, requires all trades onsite. Framing contractor, insulation installer, electrical and plumbing contractors, and drywall installers are directly involved. The general contractor leads the coordination and scheduling of subcontractors, as well as managing quality and progress.
- **Inspection Phase:** The building's wall assembly details are listed on the CF2R-ENV-03-E/NRCI-ENV-01-E installation forms. Building department inspectors will confirm that the constructed assemblies match the indicated wall details.

The proposed wall categories account for wall assembly type and fire ratings. Additional coordination between designers and energy consultant/modelers are needed for the accurate relay of the information and successful construction, energy modeling, and inspection of wall assemblies.

2.5.1.3 Submeasure C: Envelope – Quality Insulation Installation

- **Design Phase:** The design team, including the developer and architect, specifies wall construction type and provide necessary information to populate the Certificate of Compliance (CF1R/NRCC) documents. Pertinent details include frame type, dimensions, cavity and continuous insulation types and R-values, and the overall assembly U-factor.
- **Permit Application Phase:** A design professional completes and submits the Certificate of Compliance (CF1R/NRCC) documents. Product specifications and schedules for framing and insulation components are also submitted as part of the permitting package.
- **Construction Phase:** The general contractor and HERS Rater would coordinate verification visit(s) such that wall area is visually accessible at the right construction stages (at rough-in and again after installation but before drywalls). As such it is important for the general contractor to communicate, establish expectations, and orchestrate the coordination between framing, insulation, and drywall installers, as well as other trades whose work depend on adequate access to wall and ceiling spaces.

- **Inspection Phase:** The general contractor would ensure the insulation installer completes and sign the Certificate of Installation (CF2R/NRCI) documents before or at the verification visit(s). The HERS Raters would perform verification and take notes of deficiencies and correction notes as applicable. The HERS Raters would take on the responsibility to populate, sign, and submit the Certificate of Verification (CF3R/NRCV) forms to the registry for building compliance purposes.

Coordination between the trades is needed to facilitate successful field verifications. The construction industry has built up familiarity and understanding of the scope, coverage, and process in current code where QII is a performance credit. Since existing requirements are for low-rise multifamily buildings only, contractors working on high-rise multifamily projects would not possess the experience and knowledge base unless they participated in LEED for Homes/Green Point Rated and similar voluntary programs, or have also worked with low-rise Title 24, Part 6 projects that took the performance credit.

2.5.1.4 Submeasure D: Envelope – Fenestration Properties

- **Design Phase:** The design team, including the developer and architect, makes decisions on window types and selections. Designers will provide window areas and performance specifications.
- **Permit Application Phase:** General contractor ensures fenestration schedules and National Fenestration Rating Council (NFRC) labels (or other certificates such as NFRC's Component Modeling Approach Software Tool) submitted as part of certificate of compliance documents. Both manufactured windows and curtain wall windows come with performance labels. Site-built windows products could either be lab certified with NFRC labels, or they could display a label with California Energy Commission's default U-factor and SHGC values[1].

  Designers (architects and engineers) who are used to selecting fenestration products based on their structural, wind load, rain resistance, forced entry protection, and aesthetics, will need to explicitly pass on the NAFS Performance Class certification information to the energy consultant/modelers. The information becomes the determinant for fenestration products' energy requirements.
- **Construction Phase:** Window contractor installs the products as designed. Installations are done in coordination with other trades on site, primarily the framing contractor.
- **Inspection Phase:** Window installer is responsible for populating the CF2R/NRCI-ENV-02-F Certificate of installation that documents the

[1] Product certifications for NFRC labels via the Computer Modeling Approach (CMA) are only allowed for nonresidential windows.

characteristics and performance specifications of the installed windows. The general contractor usually compiles the forms for submission prior to the field inspection.

There are no changes in compliance or enforcement processes and no additional coordination needs between trades anticipated from this submeasure. The proposed new Performance Class AW category is based on window products' NAFS Performance Class certifications. Additional coordination between designers and energy consultant/modelers are needed for the accurate relay of the information and successful construction, energy modeling, and inspection of fenestrations.

2.5.1.5 Submeasure E: Envelope – Fenestration Area

The compliance and enforcement processes are mostly the same as Submeasure D immediately above. In addition, during the permit application phase and inspection phase, the plan checker and inspector will need to account for both the window-to-wall area and the window to floor area ratios.

2.5.2 Space Conditioning

2.5.2.1 Submeasure F: Space Conditioning – Duct Insulation

- **Design Phase:** The mechanical designer recommends the insulation R-value for ductwork and coordinates with the architect on the location of the duct system and confirms there is adequate space for the proposed ductwork based on size and insulation. The energy consultant verifies that the recommended insulation levels meet code requirements.
- **Permit Application Phase:** The energy consultant completes the certificates of compliance. The architect typically submits the project and all accompanying documentation to the local building department.
- **Construction Phase:** The mechanical installer installs the HVAC system and ductwork. The mechanical installer completes the certificates of installation.
- **Inspection Phase:** Duct insulation is not verified by a HERS Rater or ATT. A building inspector conducts a final inspection.

There are no changes in the compliance or enforcement process anticipated for this submeasure. There are no additional coordination needs between trades and no HERS or ATT verification currently required or proposed. Within the current capabilities of the existing compliance software duct insulation is not modeled in the nonresidential software CBECC-Com. Duct insulation is only modeled for ducts in unconditioned space in the residential software CBECC-Res.

2.5.2.2 Submeasure G: Space Conditioning – Duct Leakage Testing

- **Design Phase:** The mechanical designer designs the space conditioning systems. They notate on the drawings equipment and material selections and commissioning requirements to ensure that if properly installed the distribution system will meet the allowable maximum leakage rates. The energy consultant verifies that the proposed performance specifications meet code requirements.
- **Permit Application Phase:** The energy consultant completes the Certificates of Compliance. The architect typically submits the project and all accompanying documentation to the local building department.
- **Construction Phase:** The mechanical installer installs the HVAC system and ductwork. The distribution system is sealed, and the ductwork is tested to determine the leakage percentage. If the leakage rate is higher than allowed, the installer inspects the system conducting additional sealing and re-tests until the leakage rate meets code requirements. The mechanical installer completes the Certificate of Installation.
- **Inspection phase:** For multifamily buildings three habitable stories and fewer a HERS Rater conducts verification testing of duct leakage and completes the Certificate of Verification forms. For all multifamily buildings, a building inspector conducts a final inspection.

The compliance and enforcement process for this Submeasure G is new for multifamily buildings four habitable stories and greater; however, it is similar to that which currently exists for low-rise residential buildings, except third-party HERS verification is not required. The existing field verification and diagnostic test requirements will not be modified. The new requirements mostly impact installers and inspectors. The mechanical installer will need to accommodate time for duct leakage testing during installation. All mechanical installers are familiar with the proposed performance requirements as sealing ductwork is required by code and should be part of their typical work. Mechanical installers that work on multifamily buildings both fewer than and greater than or equal to four habitable stories will also be familiar with this compliance process. Those that exclusively work on multifamily buildings four habitable stories and greater may need to familiarize themselves with this process. Some of these contractors already have and use duct testing equipment while others do not. The existing compliance documents that apply to low-rise residential buildings will need to be revised to also apply to multifamily buildings four habitable stories and greater.

The Statewide CASE Team does not anticipate compliance and enforcement challenges. The proposed process is already well-established for low-rise residential buildings. Many multifamily mechanical designers and installers work on buildings both fewer than and greater than or equal to four habitable stories. Plans reviewers and building inspectors that work on multifamily building also are expected to be familiar with the requirements.

2.5.2.3 Submeasure H: Space Conditioning – Space Cooling Airflow Rate and Fan Efficacy

- **Design Phase:** The mechanical designer designs the space conditioning systems. They notate on the drawings equipment and material selections and commissioning requirements to ensure that if properly installed, the mechanical system will meet the allowable maximum fan power and minimum airflow rates. The energy consultant verifies that the proposed performance specifications meet code requirements.
- **Permit Application Phase:** The energy consultant completes the Certificates of Compliance. The architect typically submits the project and all accompanying documentation to the local building department.
- **Construction Phase:** The mechanical installer installs the HVAC system and ductwork. The system is tested to determine the airflow rate and fan power. If the values do not meet the thresholds defined by code, the installer inspects the system and conducts remediation as necessary until the values meets code requirements. The mechanical installer completes the Certificates of Installation.
- **Inspection Phase:** For multifamily buildings three habitable stories and fewer a HERS Rater conducts verification testing of duct leakage and completes the Certificate of Verification forms. For all multifamily buildings, a building inspector conducts a final inspection.

The compliance and enforcement process for this Submeasure H is new for multifamily buildings four habitable stories and greater; however, the process is similar to what currently exists for low-rise residential buildings, except third-party HERS verification is not required. The existing field verification and diagnostic test requirements will not be modified. The new requirements mostly impact installers and inspectors. The mechanical installer will need to accommodate time for airflow and fan power testing during installation; all installers are generally familiar with the test procedures and have the necessary test equipment. All mechanical installers are familiar with the proposed airflow performance requirements as ensuring adequate delivery of airflow is critical to the quality of their work. Mechanical installers that work on multifamily buildings both fewer than and greater than or equal to four habitable stories will also be familiar with this process. Those that exclusively work on multifamily buildings four habitable stories and greater may need to familiarize themselves with this process. The existing compliance documents that apply to low-rise residential buildings will need to be revised to also apply to multifamily buildings four habitable stories and greater.

The Statewide CASE Team does not anticipate compliance and enforcement challenges. The proposed process is already well established for low-rise residential buildings. Many multifamily mechanical designers and installers work on buildings both fewer than and greater than or equal to four habitable stories. Plans reviewers and building inspectors that work on multifamily building also are expected to be familiar with the requirements.

2.5.2.4 Submeasure I: Space Conditioning – Refrigerant Charge Verification

- **Design Phase:** The mechanical designer designs the space conditioning systems. The energy consultant verifies that the proposed performance specifications meet code requirements and recommends refrigerant charge verification, if required, to meet performance targets for projects complying via the performance path.
- **Permit Application Phase:** The energy consultant completes the certificates of compliance. The architect typically submits the project and all accompanying documentation to the local building department.
- **Construction Phase:** The mechanical installer installs the HVAC system and ductwork. The cooling system should be installed and charged per manufacturer guidelines, regardless of whether refrigerant charge verification is applied for the project. When refrigerant charge verification is prescriptively required or used as a performance credit, the mechanical installer completes the Certificate of Installation.
- **Inspection Phase:** For multifamily buildings three habitable stories and fewer a HERS Rater conducts verification testing of duct leakage and completes the Certificate of Verification forms. For all multifamily buildings, a building inspector conducts a final inspection.

The compliance and enforcement process for this Submeasure I is entirely new for multifamily buildings four habitable stories and greater; however, it is similar to that which currently exists for low-rise residential buildings, except third-party HERS verification is not required. The existing field verification and diagnostic test requirements will not be modified. The new requirements mostly impact installers and inspectors. All mechanical installers are familiar with the proposed performance requirements as ensuring proper refrigerant charge is critical to the quality of their work. Mechanical installers that work on multifamily buildings both fewer than and greater than or equal to four habitable stories will also be familiar with this process. Those that exclusively work on multifamily buildings four habitable stories and greater may need to familiarize themselves with this process. The existing compliance documents that apply to low-rise residential buildings will need to be revised to also apply to multifamily buildings four habitable stories and greater.

The Statewide CASE Team does not anticipate compliance and enforcement challenges. This is a prescriptive requirement and can be traded off by using the performance approach to compliance. The proposed process is already well established for low-rise residential buildings. Many multifamily mechanical designers and installers work on buildings both fewer than and greater than or equal to four habitable stories. Plans reviewers and building inspectors that work on multifamily building also are expected to be familiar with the requirements.

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. It then considered how the proposed standard may impact the market in general as well as individual market actors. Information was gathered 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 actors. In addition to conducting personalized outreach, the Statewide CASE Team discussed the current market structure and potential market barriers for select envelope submeasures during public stakeholder meetings that they held on August 22, 2019 and March 26, 2020.

3.1 Building Envelope

3.1.1 Market Structure

Various market actors make decisions regarding the energy efficiency of the thermal envelope of multifamily buildings throughout the construction process—from design concept to construction.

The general roles of market actors in compliance verification are:

- Developer and owners make design decisions regarding the envelope, with support from professional services such as architects, structural engineers, procurement professionals, and construction contractors (both general contractors and specific trades).
- Energy consultants document energy code requirements and conduct energy modeling for the performance approach.
- Building inspectors, with specialized support from HERS Raters

Within the multifamily sector, there is high variability in the structure, level of coordination, and formalization of the design process. Generally, larger buildings follow a more formalized process and coordinated design team, while smaller buildings may be designed under a more fluid process and less coordinated team.

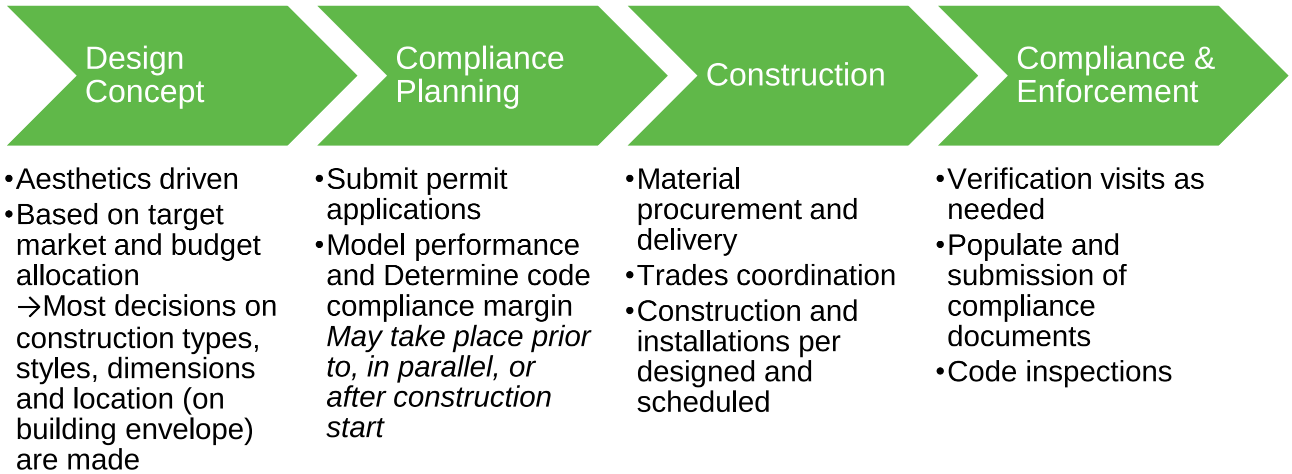

Figure 1: Thermal envelope construction process.

Generally, the developer will articulate the project's overall intentions, aesthetics, target market, and budget. The architect will embed these goals into an initial design. The structural engineer then reviews the initial design to determine envelope construction methods and options. Decisions critical to the envelope design are made at this stage without final energy performance specifications or energy code compliance impact analysis. This includes building height and size, wall assembly construction types (metal wall vs. framed, the use of concrete podiums or mass walls), glazing aesthetic and style, window type, sizes, and location, and the use of overhangs or side fins for permanent window shading.

At this stage, an energy consultant may be asked to conduct a preliminary energy model to support advising the design team on energy performance requirements in order to meet mandatory minimums and overall code compliance. This step can allow for adaptations in the preliminary design that support code compliance. However, this step is not universally practiced and can require, when skipped, more expensive changes to the building's envelope specification late in the process. Figure 1 illustrates the process graphically.

Table 13 summarizes the market actors involved in each step of the decision making and construction process. Specific nuances to the design decision process and market structure specific to each submeasure are detailed below.

Table 13: Thermal Envelope Market Actor Involvement by Construction Process

Stages	Design	Compliance Planning	Construction	Compliance and Enforcement
Designer	●			
Developer/Owner	●			
Architect/Engineer	●	●	●	
Plan Examiner		●		
Energy Consultant		●		●
Contractor/Installer			●	●
HERS Rater				●
Building Inspector				●

Submeasure A: Envelope – Roof Assemblies

Roof and ceiling insulation location, type, and performance are a function of roof assemblies. Depending on the presence of an attic versus non-attic roof and roof deck construction, a combination of insulations at the roof deck and ceiling may be specified. Roof product types are specified by designers and architects early in the design process based on energy and structural performances and aesthetics. Roofing and insulation contractors install the roof assembly based on the resulting construction specifications.

Submeasure B: Envelope – Wall U-Factor

Wall assemblies are decided early in the design process and influenced by structural requirements, fire code, cost, and building aesthetic. Designers choose between metal wall construction; wood or metal framed; masonry; timber framed; or a combination of those construction types. Early design decisions on wall assembly type limit the available range of design choices and adjustments to those possible given the assembly type.

Regardless of assembly types, walls construction takes place immediately after foundation work. Framing contractors build wood and metal framed walls onsite with pre-engineered and ordered parts. Plumbing, electrical, and mechanical trades come in after wall construction, but before the framing contractor (or a separate insulation contractor) installs cavity and exterior insulation. Weatherproofing design and materials can affect the insulation products used on the outside face of the wall (i.e. rigid continuous insulation vs. rock-wool. Masonry walls may be coupled with various insulating, weatherproofing, and veneer finish combinations on the interior and exterior surfaces.

Submeasure C: Envelope – Quality Insulation Installation

The energy consultant often decides in consultation with the rest of the design team whether to include QII to improve compliance margin using the performance approach, or as required if using the prescriptive approach (in most climate zones). QII verification, typically managed by the construction manager, takes place during construction and requires coordination between the installation trades and verifier. QII consists of two distinct stages of verification: an air-seal stage after framing when stud bays are exposed, and an insulation installation stage when insulation has been installed but before drywall or other internal finishes, such as shower stalls or cabinetry, cover visual access to the insulation. The air sealing inspection is to confirm that the cavity stud bays would have minimal likelihood of air movement through the insulation (which would render insulation less effective). The insulation installation inspection is to confirm that insulation was installed per manufacturer's instructions, without compressions, gaps, or voids, filling the cavity's volume in its entirety.

The 2019 residential standards QII protocol calls for direct inspection of 100 percent of the thermal envelope at each of these stages. Due to these verification protocols, HERS Raters visit each building site at minimum two times, one for each stage. However, for projects that have trouble coordinating the timing of inspection access relative to the trade's installation schedules and for large projects where the envelope could not be inspected within the span of one visit, it is possible and common for HERS Raters to visit multiple times, for each stage of inspection, in order to capture the entirety of the envelope. This is particularly likely for larger buildings and buildings with a more complicated envelope.

A failed QII verification, especially one that fails due to lack of visual access to conduct the protocol rather than observed insulation installation defects, can be prohibitive to mitigate as it would require the removal of internal finishes or installed insulation to grant mitigation and verification access. Additionally, by the time the project knows that it has failed QII, there are very few performance compliance options available to replace the energy impact of that failed QII using the performance approach. For this reason, a project that is using QII as a code compliance measure must plan and coordinate between the energy consultant, the insulation trades, the site foreman, and the HERS Rater.

The current QII protocol is based on residential wall assembly types and is not conducive to application to curtainwall assemblies. In some cases, curtain wall assemblies are shipped to the site fully sealed, preventing the capacity for either the air-sealing or insulation quality inspection altogether. The Statewide CASE Team determined that developing appropriate and applicable QII protocols for the diverse types of curtainwall assemblies would be prohibitive, and therefore proposes that curtain wall assembly types be absolved from the QII requirement regardless of the building's total conditioned floor area. QII Buildings that us curtainwall assemblies on only a portion of their envelope would still be required to have QII conducted on all other wall sections.

Submeasure D: Envelope – Fenestration Properties

Fenestration products include windows, sliding glass doors, French doors, and skylights. Fenestration products fall into two primary categories when installed in framed wall construction (often referred to as punched windows): manufactured and site-built. Field fabricated is a third category but is significantly less common. Curtain wall fenestration follows a different market structure described later in this section. For manufactured fenestration in framed walls, developers and their contractors may order fenestration products directly from distributors and have them delivered to the construction site as a unit. These products come in a wide variety of sizes and dimensions, and their energy performance characteristics are certified and displayed on their NFRC labels.

In contrast, window contractors assemble site-built fenestration within framed construction openings at the building site according to size and aesthetic specifications provided by the design team. Site-built fenestration is assembled with specific factory-cut or formed framing and glazing units. Site built fenestration is typically chosen to fulfill a custom aesthetic or to provide for larger fenestration that cannot be easily shipped when fully assembled. Field fabricated windows are those whose frame is built on-site and has no previous manufacturing component (not a subset of site-built fenestration). Field fabricated windows are comparatively uncommon.

For punched windows, architects will conduct load resistance calculations and determine if they need to specify NAFS Performance Class AW windows for the project.

Manufactured, site-built, and field fabricated fenestration are placed into an opening within the building envelope, based on specifications from the design team. The curtain wall fenestration market is similar to that for site-built. The building's design team specifies curtain wall fenestration size, aesthetics, and thermal properties, and they order customized products that meet the specification. The specified fenestration can either be assembled off site in a factory within panelized wall sections or delivered in components and assembled on site.

For all fenestration, architects work with developers and/or building owners early in the design process to decide fenestration size and construction type (punched window or curtain wall). These early design decisions set the direction of the code compliance options or path. Once that path is chosen, it is common for the project team to adjust product selection choices in response to cost and product availability. Often, energy consultants inform product selection to ensure energy code compliance.

Submeasure E: Envelope – Fenestration Area

The building design team decides window sizes and locations early in the design process. There are many factors driving a multifamily building's window selections including aesthetic preferences, daylighting intentions, cost (windows are generally more expensive than walls), and fire code. Subject matter experts conveyed that the energy code's window area limits are not a driving factor for fenestration design. Fire code requirements regarding operable windows, egress, and safety are critical, but the window area necessary to meet those requirements is insignificant relative to proposed energy code limits. Once design is complete, changes to window area is rare.

3.1.2 Technical Feasibility, Market Availability, and Current Practices

3.1.2.1 Submeasure A: Envelope – Roof Assemblies

The proposed submeasure combines roofing product and ceiling insulation requirements across high-rise and low-rise multifamily buildings by climate zones groups, based on the presence of an attic. The Statewide CASE Team made adjustments to multifamily buildings with non-attic roofs to U-factor requirements equivalent to those for an attic roof Option C (with ceiling insulation located between the attic and the conditioned space). This does not introduce additional product performance stringency, nor selection limitations beyond existing roof and ceiling insulation requirements.

A wide selection of insulation products exists in the market. Above roof deck rigid insulations can be made of polyisocyanurate (polyiso), polyurethane, and polystyrene. Polyiso products have the highest R-value per inch thickness and are the most economic on a per R value basis. Below roof deck and ceiling insulations utilize the same insulation types and products, with batt and loose-fill insulation products (with cellulose or mineral material) being the most common insulation products and spray polyurethane foam (SPF) used for niche applications.

This proposed submeasure aligns roofing product solar reflectance and thermal emittance requirements across multifamily buildings in climate zones groups, primarily based on presence of an attic and the roof slope.

The Cool Roof Rating Council (CRRC) is the entity that manages the rating and certification of roofing products for their durability and energy performance. As of December 2019, there were nearly 3,000 products registered in the CRRC database. Of these, 2,636 (and 89 percent) products meet the existing Title 24, Part 6 cool roof requirements for low-or steep-slope roofing. 183 manufacturers are represented in the CRRC database, and they encompass almost all major roofing product manufacturers. The distribution of compliant products is shown in Figure 2.

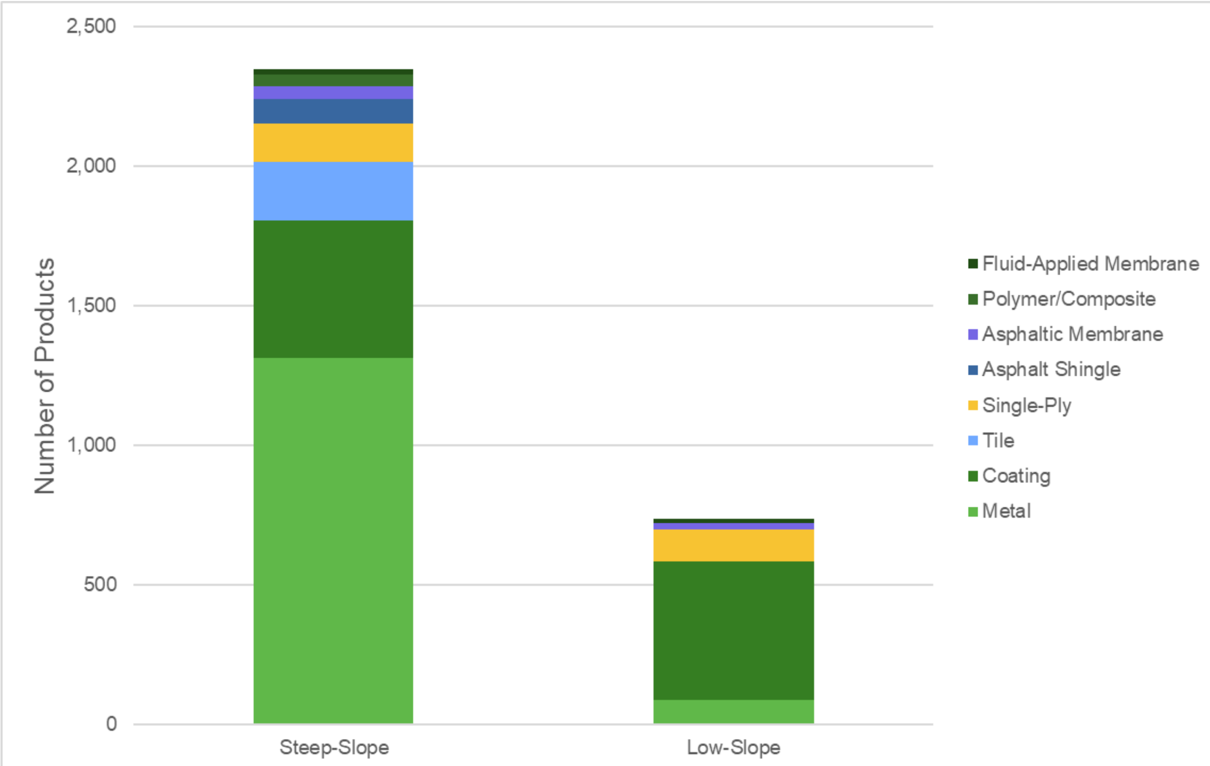

Figure 2: Number of CRRC-registered products that meet current Title 24, Part 6 minimum criteria for ASR and thermal emittance.

Source: Cool Roof Rating Council

Of the 2,636 products that meet the prescriptive cool roof requirements, 768 products meet requirements for low-slope roofing, and 2,465 products meet requirements for steep-slope roofing. 62 percent of products are listed as appropriate for both low-slope and steep-slope installations. These include single-ply, fluid applied membrane, asphaltic membrane, and metal coating products, which are the products most commonly installed on low-slope roofs.

3.1.2.2 Submeasure B: Envelope – Wall U-Factor

This proposed submeasure creates a new list of wall construction types, each with its own assembly U-factor requirements by climate zone. The new list pulls from the construction types (and U-factor requirements) currently used in the nonresidential and residential standards. The proposal was designed to achieve simplification of code compliance for a unified multifamily code. The Statewide CASE Team research pointed to technical and market availability barriers to complying with a unified wall assembly thermal resistance requirement for wood or metal framed walls due to the confluence between energy code, fire code, and structural code.

Technical Feasibility

Fire code mandates that certain walls fulfill a zero-hour, one-hour, two-hour, or three-hour fire rating. Generally, walls in larger and taller buildings and walls with less separation from a neighboring structure must meet a higher hour-rating. For wood and metal framed walls, the available assembly and insulating options that achieve both a two-plus-hour fire rating and achieve low assembly U-factors have:

- Limited availability
- Higher cost
- Complicated construction methods (regarding assembling thick continuous insulation layers)
- Secondary impacts: The builder must choose a thicker overall wall assembly, which results in a smaller conditioned floor area given the same building exterior footprint.

Additionally, fire ratings are typically tested at the assembly level. Innovative solutions that might combine new high R-value density insulation products are therefore slow to complete fire testing and reach the market. To resolve this overall challenge, the Statewide CASE Team proposes that for wood and metal framed wall assemblies, the Title 24, Part 6 Standards should have two different categories of assembly U-factor: one for walls rated either zero or one hour, and one for walls rated two or three hours. A building's fire rating is determined by combined factors of its construction type, height, number of stories, and sprinkler system. Due to this multifactor method of determining fire rating, there is some overlap of ratings by number of stories but generally buildings up to five stories can have zero or one-hour ratings, and taller buildings will have a two- or three-hour fire rating requirement. A building's fire rating is well understood and known by building designers and architects. There are also fire-rating variances based on the proximity of a neighboring building. Having another building close can force an increased a fire rating for a specific wall, but for residential occupancy classes, those considerations only impact the determination between zero-hour or one-hour and would not result in a change of energy requirements under this proposal.

Similarly, structural codes require high shear strength for taller buildings and present a feasibility challenge to meeting stringent U-factor levels. Certain exterior rigid insulation and cladding options (such as three-coat stucco over one-inch rigid foam board) that are common in low-rise buildings cannot meet shear strength requirements of taller buildings (typically five stories or more). Both technical limitations, from wall assembly fire rating and shear strength, apply to high-rise buildings. The overlap in technical feasibility emphasizes and solidifies the Statewide CASE Team's decision to delineate wall assembly U-factor requirements based on fire-code ratings.

From this point forward, discussion in this section focuses on considerations associated with consolidating mass wall construction types. While these issues are not directly concerned with technical feasibility, the divergence of categories poses a challenge to high-rise/low-rise alignment. The discussion below provides the rationale behind and assesses the impact from the proposed consolidated categories.

For thermal mass and below grade walls, the current residential and nonresidential standards use different metrics to delineate energy code prescriptive categories. This proposal reduces the number of prescriptive categories and applies the new categories across all multifamily construction to reduce compliance complication. The current residential standard has four relevant categories, with different assembly U-factor requirements for above-grade and below-grade walls, and within each of those classifications there are different requirements for internally and externally insulated walls (referencing if the insulating layer is primarily on the outside of the wall, thus exposing the thermal mass to the conditioned area, or inside the wall, thus keeping the thermal mass outside the building's thermal envelope).

The Statewide CASE Team's review of prior standards and subject matter expert interviews indicated that the externally insulated prescriptive categories were added during the 2013 code cycle (with less stringent U-factor requirements than those for internally insulated) to move the market towards higher adoption rates of externally insulated mass and reap temperature stabilizing benefits of exposed internal thermal mass.

In contrast, the current nonresidential standards have two categories based on the thermal mass' heat capacity: one for 7-15 Btu/ft^2-F and one for greater than 15 Btu/ft^2-F. The Statewide CASE Team proposal collapses these six multifamily-related categories into two that serve the entire multifamily market:

1. Heavy thermal mass (greater than 15 Btu/ft^2-F), which follow the prescriptive and mandatory U-factors of the current nonresidential standards of the same name.
2. Light thermal mass (7-15 Btu/ft^2-F), which follows the prescriptive U-factors of the current residential standard's internally insulated mass category. These walls will follow the mandatory maximum U-factor requirements from the current nonresidential requirements for light mass.

Below-grade walls, which are rare in multifamily developments, can comply with code by following the performance path. The proposal applies mandatory maximum U-factor requirements from current nonresidential standards for all above grade mass walls to reduce conflicts with fire code. Podium style buildings often require high fire rated mass walls on the lower floors that cannot be cost-effectively constructed to the current residential mandatory maximum U-factor requirements. Prior CASE Teams derived those limits in the context of mass walls in single family homes that do not have the same fire rating conflicts.

The primary purpose of the re-categorization is simplification. Various data sources confirm that mass and below grade walls are infrequently used in multifamily buildings. Additionally, most multifamily construction projects already use the performance approach for code compliance. Therefore, the reduction of mass and below grade wall prescriptive categories will impact few projects. Internally insulated thermal mass walls are the more common of the two options, and projects that prefer to use external insulation can take the performance approach to model the thermal mass benefit of that choice.

Table 14 below assesses the impact on each wall category based on Climate Zone 12's prescriptive requirements (as representative of the typical variation).

Table 14: Market Impact Analysis on Mass Wall and Below Grade Wall Assembly Prescriptive Categories in Multifamily Buildings – Climate Zone 12

Wall type	Current U-factor	Proposed U-factor	Change	Analysis
Heavy mass – High Rise	0.253	0.253	Equivalent	
Light mass – High Rise	0.170	0.070	More stringent	Unlikely to exist in the market
Heavy mass internally insulated – low rise	0.070	0.253	Less stringent	Unlikely to exist in the market
Heavy mass externally insulated – low rise	0.125	0.253	Less stringent	Unlikely to exist in the market
Light mass internally insulated – low rise	0.070	0.070	Equivalent	
Light mass externally insulated – low rise	0.125	0.070	More stringent	Performance path option gives credit for choosing externally insulated thermal mass benefits
Below-grade internally insulated – low rise	0.070	0.070	Equivalent	
Below-grade externally insulated – high rise	0.200	0.070	More stringent	Performance path option gives credit for choosing externally insulated thermal mass benefits

Market Availability and Current Practices

Multifamily buildings are predominantly of wood frame construction, as shown in Figure 3. Subject matter expert interviews revealed that wood-framing above a concrete podium is particularly common, though concrete podium floors are most often for parking, bicycle storage, and other building amenities, and not for any dwelling units. Use of metal framing is considerably rare. Between three data sources; PG&E's California Multifamily New Homes (CMFNH) program data, CoStar, and an Evergreen Economics survey, there were only three instances of metal framed construction. Metal buildings (structural steel) are relatively common for taller buildings, growing in market share as building height increases.

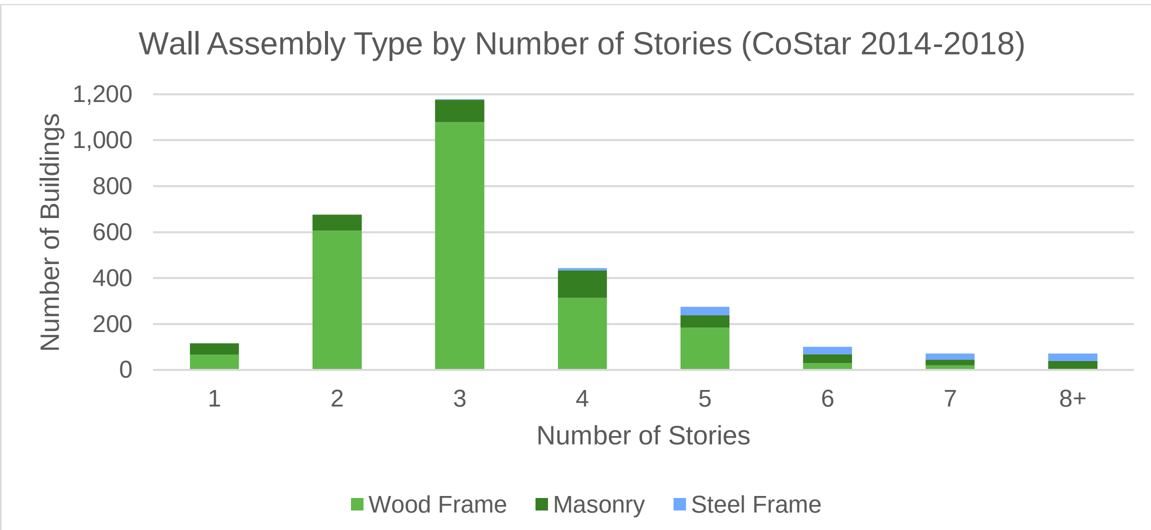

Figure 3: Wall construction type by number of habitable stories.

Source: (CoStar n.d.)

Wall construction is not restricted in any way by product availability. The products necessary to achieve the proposed construction assembly U-factors, across all wall types, are ubiquitous. Achieving especially low U-factor walls is most restricted by the wall thickness builders are willing to consider (due to its impact on conditioned floor area), and therefore, the R-value per inch of cost-effective insulating materials. Experts expressed that some insulating materials with particularly high R-value per inch (for example phenolic foam) are entering the market, which may improve the potential of low U-factor walls without the same loss of conditioned floor area.

3.1.2.3 Submeasure C: Envelope – Quality Insulation Installation

The proposed code change leverages existing requirements and applies them across all multifamily buildings up to 40,000 ft^2 of total conditioned floor area, rather than a subset based on the number of habitable stories (three or fewer for the current residential code and four or more for nonresidential code). Overall technical feasibility is not a barrier for the proposed QII code requirement. The materials, methods, and construction norms are all within current technical limits. However, extending QII verification to high-rise multifamily buildings presents challenges because the third-party verification process for non-mechanical equipment is not used in high-rise projects.

The energy savings from the proposed QII code change are expected to last for the entirety of building lifetime, 30 years, with minimal degradation over time. The proposed code change improves the thermal performance and overall quality of envelope construction and results in enhanced occupant comfort. There are no anticipated changes in maintenance routines associated with QII.

The Statewide CASE Team used subject matter experts (SMEs) and stakeholder feedback as the principle means of soliciting, then vetting, code requirement options. The Statewide CASE Team solicited general proposal feedback, study approach, and relevant technical and market data sources via phone interviews and email correspondence with 16 SMEs. The SMEs represent views and experience from market actors including manufacturers, insulation installers, designers, energy consultants, HERS Raters, and voluntary efficiency program implementers.

Technical Feasibility

The Statewide CASE Team proposes to extend QII verification to high-rise multifamily buildings, which had in previous codes applied to low-rise buildings either prescriptively or for performance credit. There are two critical challenges in applying QII to all multifamily buildings:

1. Verification for larger buildings becomes logistically challenging and cost prohibitive due to staged construction and timing of access for verification activities, and
2. Performance compliance mechanisms, such as derate factors and verification protocols, only exist for low-rise buildings and were derived from single-family home norms that do not necessarily work well in multifamily settings.

SMEs described challenges in inspecting larger multifamily buildings. Experts varied in their sense of what constitutes a large multifamily building, but it is generally in the range of 40 units or greater, which correlates well to a 40,000 ft^2 threshold. For such buildings, wall-assembly air-sealing, insulation installation, and installation of interior finishes (such as drywall) are not scheduled uniformly across the building envelope, but are instead staged over time, with some steps occurring in parts of the building concurrent to other steps occurring elsewhere. Often, staging is floor-by-floor. Installation of certain interior finishes, such as shower stalls, kitchen cabinets, and stairwell framing often occurs separately and earlier than the rest of a wall's interior finish.

The current QII verification protocol relies on two inspection points, each intended to visually verify 100 percent of the building's insulated thermal envelope (walls, attic/roof, and floors over unconditioned space) in a single visit. One inspection point is for air sealing of the envelope with all cavities un-insulated and exposed, the second is with cavity insulation installed but without interior finishes covering it. For some assembly types, a third visit is required to verify aspects of full air sealing that occur late in construction. The protocol calls for inspection of other insulating surfaces, such as continuous insulation layers, either external or internal to framed cavities. For staged construction, it is impossible to conduct these inspections in one visit each. Verifiers of larger buildings informed the Statewide CASE Team that managing logistics and scheduling, even of multiple visits, can be prohibitively complicated, which results in missed opportunities to inspect certain envelope sections at the required inspection points and therefore failed compliance with QII's requirements.

The Statewide CASE Team considered multiple metrics and specific criteria to serve as the upper threshold for buildings the extended QII requirement. The metrics include conditioned floor area (CFA), dwelling unit floor area, number of dwelling units, number of stories, thermal envelope surface area, as well as multi-criteria combinations. The Statewide CASE Team's decision to use CFA was driven by it being an uncomplicated standard data point for all multifamily buildings, and for being the most determinant of the options available on whether thermal envelope assemblies would be completed in multiple stages.

The Statewide CASE Team formulated the CFA metric based on a combination of SME interviews and stakeholder surveys results. Experts and stakeholder considerations included the likelihood of construction staging practices and an assessment impact on verification time (and consequently number of visits and costs) likely for full-QII at varying building sizes. The Statewide CASE Team determined that 40,000 ft^2 was an appropriate upper bound to apply the QII verification requirement.

Market Availability and Current Practices

The Energy Commission oversees the HERS Providers who train and certify HERS Raters. CalCERTS and ConSol Home Energy Efficiency Rating Services Inc. (CHEERS) are the two HERS Providers. CalCERTS (CalCERTS n.d.) reported having more than 600 active Raters providing 5,600 home ratings in 2018. ATT personnel currently performs compliance verification for lighting and mechanical systems in high-rise multifamily buildings but not for envelope related measures such as QII. This measure, if performed by an ATT, would present a new type of ATT verification services for multifamily new construction buildings. This report presumes that HERS Raters would be leveraged for this verification process rather than ATT professionals.

CalCERTS data show that 45 percent of low-rise multifamily buildings built under 2013 and 2016 Title 24, Part 6 codes took advantage of the QII performance credit for buildings. PG&E's above-code multifamily incentive program, California Multifamily New Homes (CMFNH) (CMFNH n.d.) data shows 29 of 94 unique buildings—just over 30 percent of participating low-rise buildings—reported electing to go through QII HERS verification on their compliance documents. Since QII only recently became a prescriptive requirement for low-rise multifamily buildings under the 2019 code cycle, industry experts expect that use of QII HERS verification, even in buildings that use the performance approach for compliance, would increase sharply.

The proposed code change would increase the number of buildings that require QII verification. This in turn would increase the demand for trained and available HERS Raters, and the demand on the HERS registry to compile compliance documentation. Staff at CalCERTS stated that they are confident in their ability to update and expand the registry itself to capture QII documentation from this larger quantity of buildings. Likewise, they are confident in the availability of enough Raters to serve the expanded market base.

Additionally, this proposed code change would require building developers who previously did not interreact with HERS Raters or the HERS registries to start. Many of the mid-rise multifamily builders this would impact do however have experience with the California HERS process on projects of three stories or fewer, and therefore are unlikely to encounter challenges with hiring HERS raters for their mid-rise projects nor interacting with the registry. Builders that have no experience with the HERS system would face a learning curve to build relationships with HERS Raters, contracting practices, and HERS Registry interactions.

3.1.2.4 Submeasure D: Envelope – Fenestration Properties

Technical Feasibility

For buildings over eight to nine stories, windows must meet higher wind-deflection, rain-penetration load, and similar durability requirements, which often necessitates the use of metal framing. In other situations, designers choose metal framing for aesthetic purpose or to meet local ordinances. Large window expanses are most frequently achieved with metal framing. Metal framing, typically aluminum, has higher conductivity than vinyl or fiberglass, which limits the overall window thermal performance by increasing its U-factor. This is the case even with the use of thermal breaks within the metal framing. This is especially the case for operable windows where there is a higher framing factor to allow for hinges, sliders, and other mechanical methods to allow the windows to operate. Metal framed windows cannot improve above current practice and code without substantial and costly changes in the window assembly.

The Statewide CASE Team explored the appropriateness of applying a less restricted energy efficiency standard for NAFS-2008 Performance Class AW windows. Such windows must fulfill the AAMA/CSA101/I.S.2/A440 test standard to prove durability from wind and water penetration, load deflection, and forced entry. This designation is common for windows in high rise buildings, or similar high-load window situations. The Statewide CASE Team determined that such a designation could be a valuable differentiator to allow for a lesser energy efficiency requirement in situations where aluminum framing is warranted for structural purposes.

This proposal creates a Performance Class AW category to follow a less stringent requirement in the situations where aluminum windows are necessary for durability reasons. For situations that are not covered by the Performance Class AW prescriptive path, the Statewide CASE Team's proposal assumes builders would prioritize their design aesthetics and make other energy improvement elsewhere via the performance route, or they may choose alternative window options that achieve the proposed code requirements at a higher cost. Such options include thermally improved windows with warm edge spacers, wider thermal breaks, additional or improved low-e coatings, smaller windows, or triple pane windows.

Each alternative is technically feasible and readily available in the market. Use of smaller site-built windows would force an adjustment to the designers' preferred aesthetic. Use of thermally improved or triple-pane windows come with a cost premium. Stakeholders speculated that the extra weight inherent in triple pane windows could increase labor costs, though the Statewide CASE Team did not find specific data to support that concern. There is also the option of advanced *skinny triple* windows with a thin pane of glass as the middle pane. These advanced window options are technically feasible, but they come with a cost premium as these are still not widely available on the market. Stakeholders expressed doubt that builders would opt for an aesthetic design change, and they voiced concerns about cost premium for the alternative products. The Statewide CASE Team believes that there are sufficient viable products on the market to meet the U-factor requirements, so builders have options.

Beyond cases where higher window durability is necessary, there is no technical feasibility variance between low-rise and high-rise windows. The current residential standards, and evidence from above code-program data showing use of windows at or better than the proposed thermal performance levels, demonstrate that the proposed products are both technically feasible and market available for most multifamily windows.

The Statewide CASE Team further researched whether it is viable to use the current low-rise prescriptive standard across all multifamily buildings. The biggest challenge will be for large site-built windows and other construction where aluminum framing is common. Interviews with stakeholders revealed that although some manufacturers have found a way to seamlessly reconfigure aluminum windows to be triple pane, this is not the norm. Extrusion designs, dead load capacity, glazing systems, cycle testing, American Disability Act compliance, and supply chain offering would all need to be re-evaluated in order to support this level of flexibility in their manufacturing processes. As many supply chains rely heavily on local fabricators to meet their demands, there is also concern that these manufacturers might not have the technology readily available to transition to lower U-factor requirements. Argon filling, warm edge spacers, and thermally broken frames, are all methods that aluminum framed manufacturers would need to implement to lower their U-factor requirements, but access to the necessary machinery and supplies is not widespread. Therefore, aluminum frame window manufacturers would have a difficult time meeting the 0.30 U-factor requirements. Although vinyl windows would more easily meet these requirements, they would have a difficulty meeting the pressure test standards that architectural windows (AW) meet for buildings above nine stories without sacrificing the aesthetic appeal of the overall building. One stakeholder pointed out that multi-cavity vinyl window frames that may meet AW standards would have much bulkier sightlines than aluminum windows and curtainwall systems. This reduces natural daylighting and views, and would likely not be acceptable to designers, as clear and unobstructed window designs are preferred. Another stakeholder noted that it was more feasible for a vinyl window manufacturer to achieve a commercial window requirement; however, they would face considerable challenges achieving these requirements for large window sizes. Again, this reduction in views would make this window type undesirable to builders and architects of luxury multifamily buildings.

Some stakeholders expressed a preference to maintain different standards between site-built and manufactured window types—allowing for a less stringent U-factor requirement for site-built windows—as a means to allow for larger, metal framed, site-built windows with higher U-factors. The Statewide CASE Team rejected this option. Such a standard would be a backslide reducing energy savings. Current code already contains a prescriptive exception for small quantities of site-built fenestration that would be retained under this proposal. The compliance method which relies on area-weighted average U-factor and SHGC allows for small amounts of worse than code glazing, made up for by improved performance from other windows. Additionally, site-built glazing is nearly indistinguishable visually when in place, which would complicate code inspection and compliance.

Curtain wall glazing at or exceeding the proposed values is similarly technically viable, though it requires maximal application of thermal improvement measures such as warm edge spacers, wider thermal breaks, argon fill, and additional or improved low-e coatings

Market Availability and Current Practices

Multifamily buildings statewide predominately use manufactured window products as shown in the CMFNH data. Within PG&E's above-code multifamily incentive program, CMFNH (CMFNH n.d.), all of 85 unique low-rise buildings (three habitable stories and lower) and 32 of 36 unique high-rise (four habitable stories and higher) buildings sampled report installing manufactured window products. In contrast, roughly 14 percent, or five of 36 high-rise buildings, reported installing site-built windows

There is a large, competitive market of window manufacturers that supply manufactured fenestration to local distributors based on market demand. Window manufacturers have demonstrated a willingness and capacity to increase production of certain products, or to add new product lines, in order to fulfill an enhanced market demand.

Manufactured window products are readily available, and NFRC maintains an online directory of thousands of certified manufactured windows under 29 configurations (NFRC n.d.). Major window manufacturers in North American by sales volume are Anderson Windows & Doors, Jeld-Wen, Marvin Windows and Doors, Masonite, Pella Corp, Ply Gem, Velux USA, and YKK AP America. For larger projects, both curtain wall and manufactured windows from Kawneer, Efco, Wassau, and Old Castle Building Envelope are common. These manufacturers all produce windows that meet or exceed the proposed thermal performance requirements, including aluminum dual pane windows certified as Performance Class AW. Manufacturers and window experts state that vinyl windows that fulfill the proposed requirements are readily available on the market. Local planning ordinances in some cities mandate the use of metal framing, sometimes situationally such as on the road-facing façade, for aesthetic and recycle-ability reasons. These ordinances will force higher window costs for buildings in these municipalities.

In terms of window U-factor performance, CalCERTS (CalCERTS n.d.) registry data indicate that 37 percent of low-rise buildings built under 2013 and 2016 Title 24, Part 6 codes meet or beat the existing 0.30 U-factor requirements as shown in Figure 3. The data represents all low-rise projects submitted under the 2013 and 2016 code cycles and represents a total of over 132,000 dwelling units.

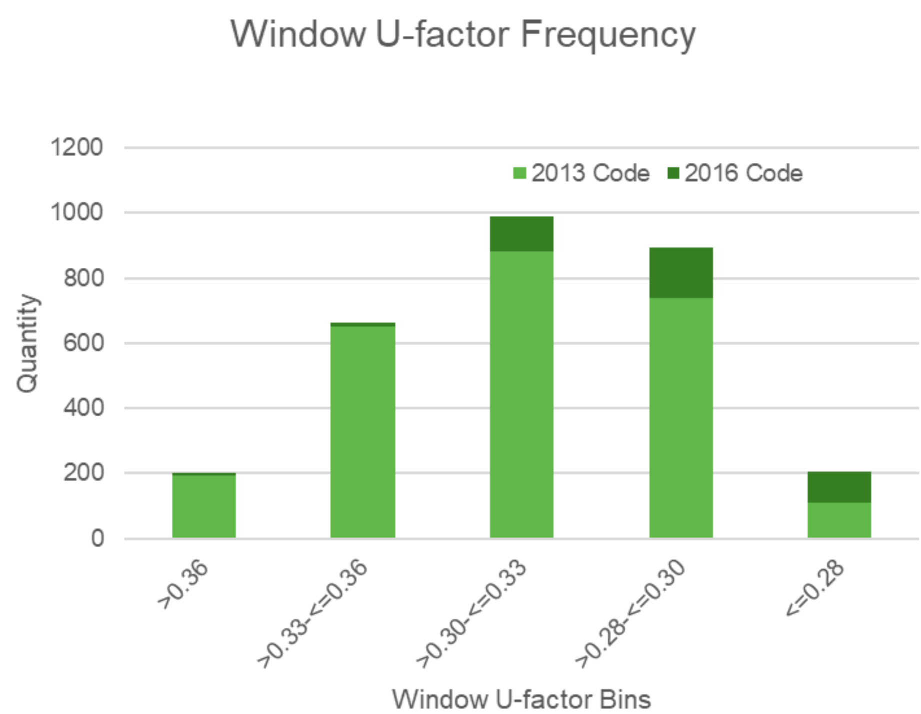

Figure 4: Window U-factor frequency – CalCERTS data.

Source: CalCERTS (CalCERTS n.d.).

While this data is limited to buildings of three or fewer habitable stories, the same window products used in low-rise construction are available to taller buildings. Apart from a slight increase in stringency in Climates Zones 1 and 16, the proposed Class AW category U-factor and SHGC requirements are equivalent to the current nonresidential levels using an area weighted blending method. The same Class AW windows builders are using today remain available. Stakeholders reflected that some window products that meet the Class AW testing requirements are not rated as such due to certification costs. The Statewide CASE team expects that creation of a separate Class AW category, following the example set by Washington State, would push manufacturers to obtain certifications for products that meet the test standards.

3.1.2.5 Submeasure E: Envelope – Fenestration Area

Technical Feasibility

The Statewide CASE Team found no technical issues with this submeasure. Subject matter experts confirmed that window quantity is a planning or design-aesthetic choice. In many instances, local planning department ordinances play a role in determining window fenestration area, but those ordinances do not force builders to put in fenestration above the proposed area limits.

Market Availability and Current Practices

Market availability is not applicable to this submeasure, as it addresses the metric to limit total window area and not products or techniques specifically.

Current market norms, as shown from CMFNH (CMFNH n.d.) data in Figure 5 and Figure 6 below, demonstrate that most multifamily buildings fall within a relatively narrow band of window-to-floor area ratio with a broader band of norms for window to wall ratio. Window-to-floor area ratio, generally, is a more limiting requirement for a broader swath of the market.

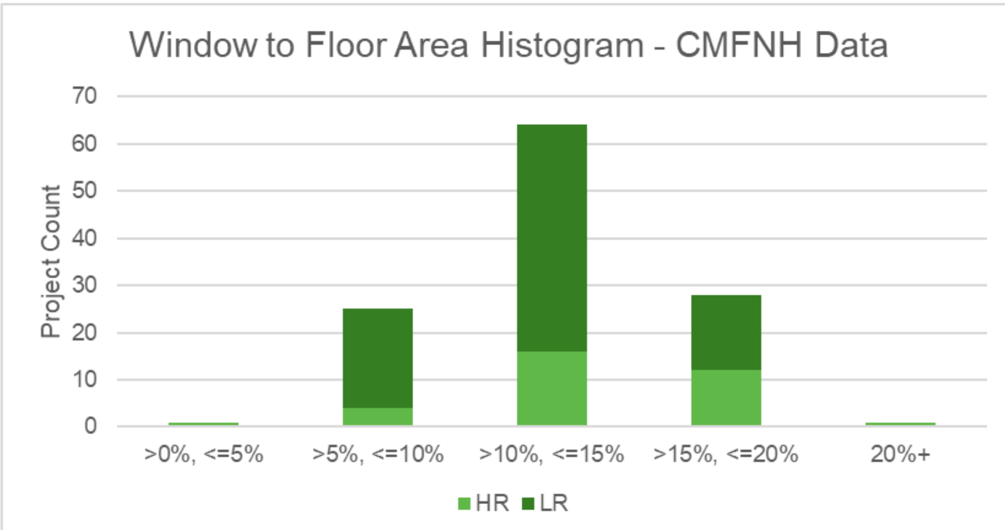

Figure 5: Window-to-floor area histogram – CMFNH data.

Source: PG&E California Multifamily New Homes Program (TRC n.d.).

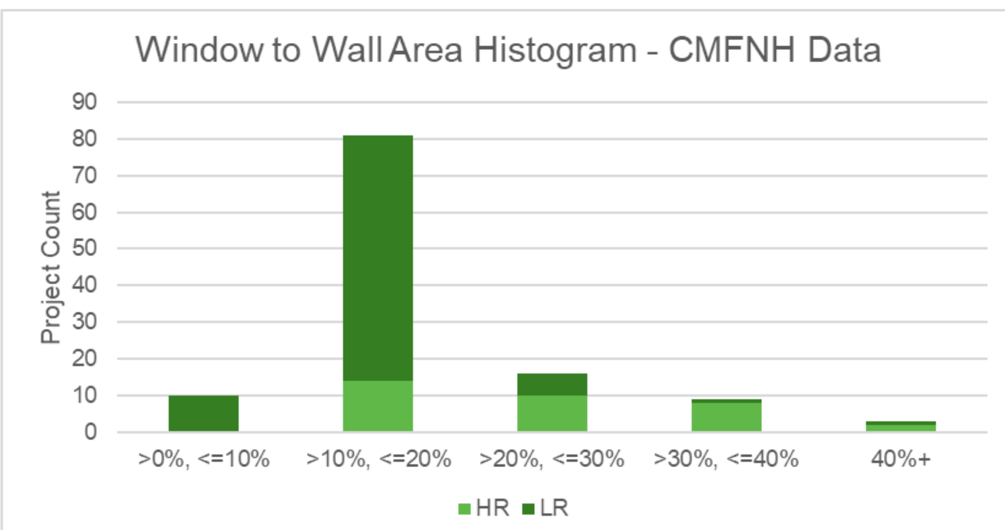

Figure 6: Window to wall area histogram - CMFNH Data.

Source: PG&E California Multifamily New Homes Program (TRC n.d.).

The window area metrics data only includes glazing areas and floor areas from tenant-facing spaces for the proposed window-to-floor ratio. The data includes 34 high-rise projects that met nonresidential code requirements. Those projects' window-to-wall ratio and window-to-floor area ratios are presented arranged by each building's wall area to floor area ratio in Figure 7. The data shows that for the majority of buildings, the window-to-wall ratio fell well below the 40 percent window-to-wall ratio maximum glazing allowed by prescriptive code; therefore, they could increase glazing areas without penalty. In performance modeling, these buildings do not get an extra tradeoff benefit from this choice, as the reference design has the same window area as the proposed design. This self-limiting of glazing quantities reflects that these decisions are driven by costs, aesthetics, or other design considerations.

The Statewide CASE proposes to institute both the 40 percent window-to-wall ratio and 20 percent windows-to-floor ratio thresholds for all multifamily buildings. These two requirements in conjunction provide a unified set of requirements for all multifamily buildings, and they cover the basis for various building wall area to floor area ratios while upholding stringencies from existing requirements.

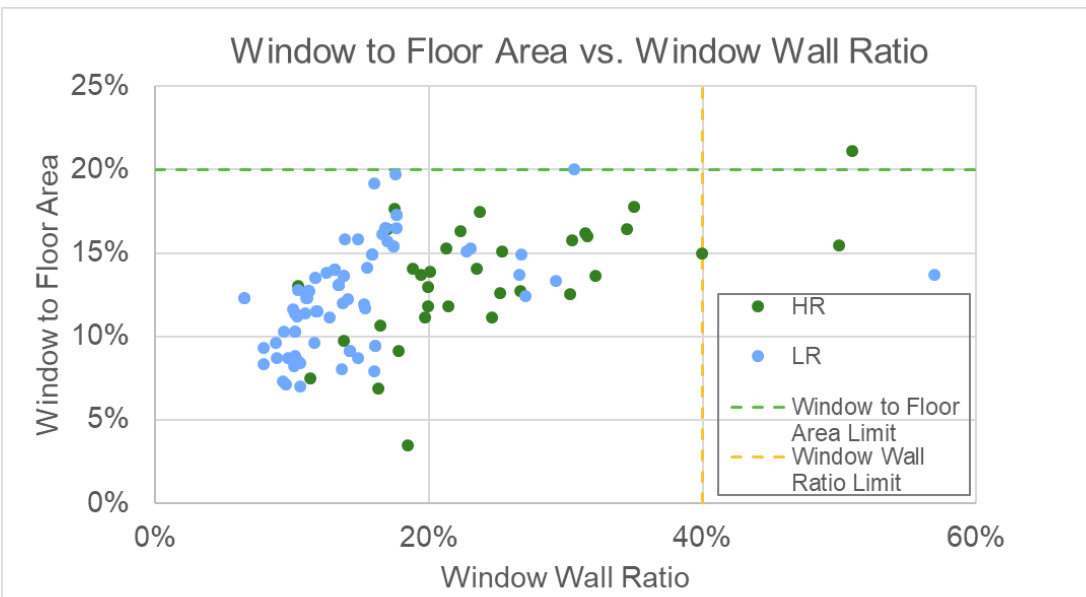

Figure 7: Window area ratios in CMFNH high-rise buildings.

Source: PG&E California Multifamily New Homes Program (TRC n.d.).

The Statewide CASE Team proposal includes maintaining the nonresidential code's method of limiting west-facing glazing—a 40 percent window to wall area limit on the west façade, enforced through performance modeling via the nonresidential ACM. There is no explicit prescriptive requirement. This method was determined to be more appropriately applicable than the residential code's prescriptive restriction of five percent window to total floor area. Infill buildings with large western facades, but no available space for windows on other orientations due to other neighboring buildings will have a reasonable opportunity to place western-facing fenestration balanced with the wall area.

3.2 Space Conditioning

3.2.1 Market Structure

The proposed submeasures all relate to quality installation of space conditioning measures, with the exception of the minor changes to duct insulation requirements. As such, the primary market actors are mechanical designers and mechanical contractors. Other market actors include plans examiners, building inspectors, and building owners.

The HVAC and distribution systems that are installed in multifamily buildings today, to which these new requirements would apply, can meet the performance requirements of this proposal as long as they are adequately considered during the design and installation phases. This includes properly sizing mechanical equipment, ductwork and fan systems. Duct insulation requirements need to be considered during design to ensure there is sufficient space for them where they will be located. The mechanical contractor should seal the ductwork and air handler system during installation when the system is fully accessible, otherwise it can be a challenge to address leaks in the system after ductwork is enclosed in a dropped soffit or other inaccessible location.

The duct insulation and duct leakage testing requirements apply to dwelling units with individual ducted distribution systems. Airflow rate and fan efficacy requirements apply to individual ducted systems with mechanical cooling, and refrigerant charge verification applies to all individual mechanical cooling systems.

There are two broad categories of ductwork: flexible and rigid. Most ducts serving new multifamily units are flexible duct, which are cylindrical tubes comprised of steel wire helixes covered in flexible plastic. Insulation is easily integrated with flexible ducts and is purchased from the manufacturer with specific insulation values, typically R-4.2, R-6, or R-8. Rigid ductwork can be cylindrical or rectangular and is made from different materials, often sheet metal or fiberboard, and are assembled in the field. Sheet metal ducts are insulated in the field by the mechanical contractor. The fiberboard itself is inherently insulating.

Evergreen Economics surveyed 90 multifamily projects across California in 2020 covering 14,673 dwelling units in total. The on-site surveys collected data on at the site, building, and unit level and included information about envelope and mechanical attributes as well as building and site characterization. 127 individual units were surveyed across the 90 projects. Figure 8, Figure 9, and Figure 10 presents results from the survey on HVAC heating system type, the presence of mechanical cooling and, duct type, and location.

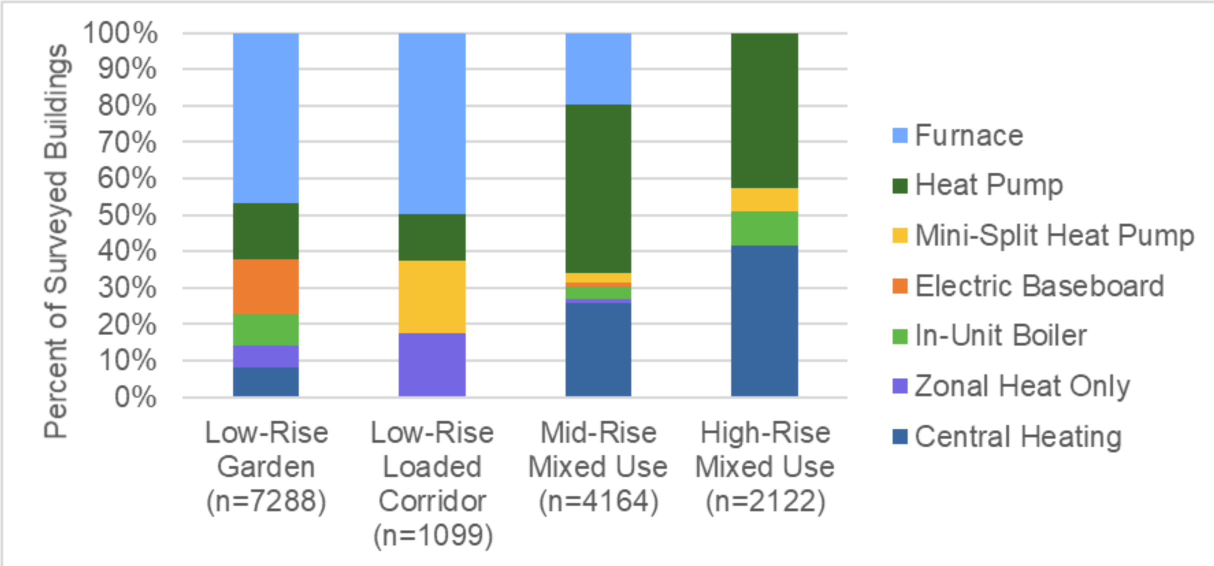

Figure 8: Distribution of HVAC heating system type for sample of California multifamily projects.

Source: Evergreen Economics

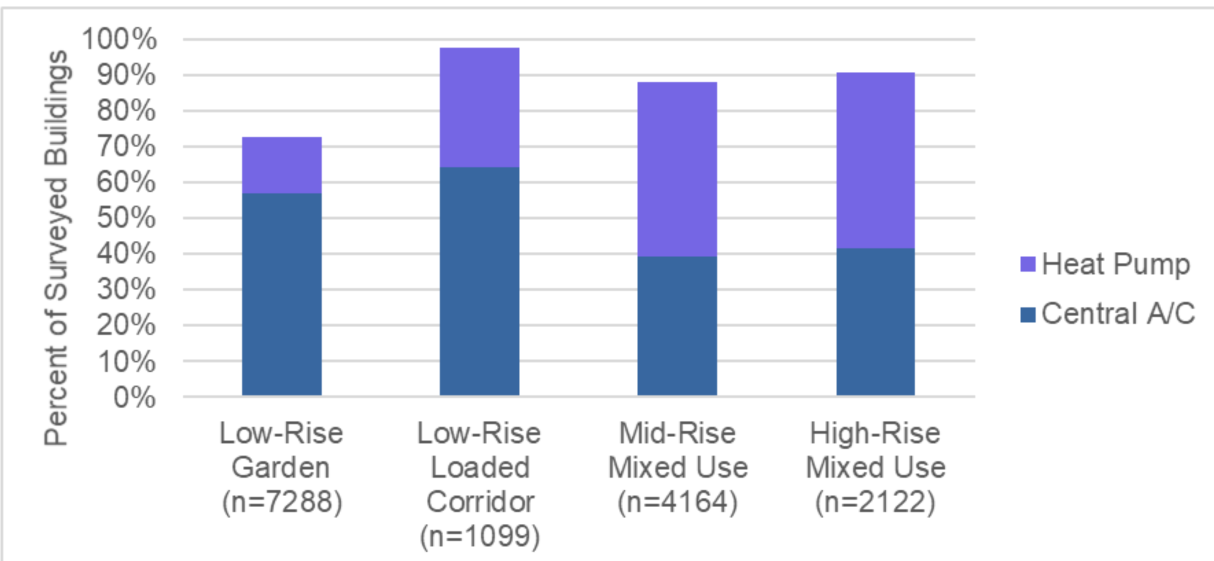

Figure 9: Percent of projects with mechanical cooling for sample of California multifamily projects.

Source: Evergreen Economics.

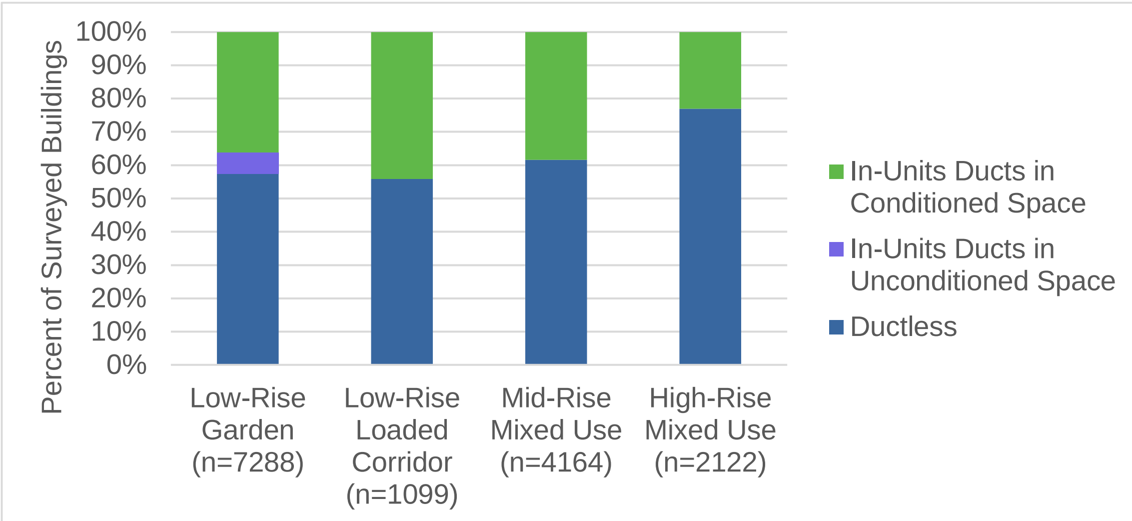

Figure 10: Distribution of duct type and location for sample of California multifamily projects.

Source: Evergreen Economics.

3.2.2 Technical Feasibility, Market Availability, and Current Practices

The Statewide CASE Team collected targeted feedback on the proposed code changes from a varied set of stakeholders specializing in multifamily construction in California. The group included the following industry representation.

- Seven HVAC designers
- Two HERS Raters
- Two HVAC contractors

Most of the stakeholders welcomed the proposed alignment and were supportive of the idea of a unified code, especially considering some of those interviewed have worked on projects that contain both low-rise and mid-rise multifamily buildings at the same site.

Stakeholders indicated that all or most of their multifamily projects contained individual HVAC systems serving dwelling units which is the focus of the proposed code changes. Furthermore, most of these HVAC systems were ducted except affordable housing projects, where packaged terminal air conditioners or packaged terminal heat pumps are more common. It also is challenging in large high-rise projects to install individual HVAC systems, and there is a higher prevalence of central systems. Gas furnaces were less common in multifamily buildings four habitable stories and greater with most stakeholders utilizing split heat pumps for individual dwelling units. Other systems used by stakeholders are hydronic systems and variable refrigerant flow systems. The ducting in almost all cases was placed in a dropped ceiling or soffit, except the units on the top-floor, which may have ducts located in a ventilated attic space. At least one stakeholder indicated that the top-floor unit ducts were sometimes buried within attic insulation.

A few stakeholders indicated that they routinely conduct duct leakage tests on their multifamily projects, either as an internal quality control measure or for other green rating programs. Many of the stakeholders with a portfolio of both low-rise and mid-rise multifamily buildings saw no challenges in applying the proposed verification requirements to multifamily buildings four habitable stories and greater. However, some HERS Raters indicated the possibility of scheduling challenges and urged that sampling be allowed to alleviate the added overhead.

3.2.2.1 Submeasure F: Space Conditioning – Duct Insulation

Figure 11 through Figure 13 present data from CalCERTS for new construction low-rise multifamily projects. The data represents both the 2013 and 2016 Title 24, Part 6 requirements with 57 percent of the units in the dataset under the 2013 code and 43 percent under the 2016 code.

Figure 11 shows that most projects (59 percent) locate ductwork in conditioned space. When ducts are in unconditioned space, it is almost always within an unconditioned attic space.

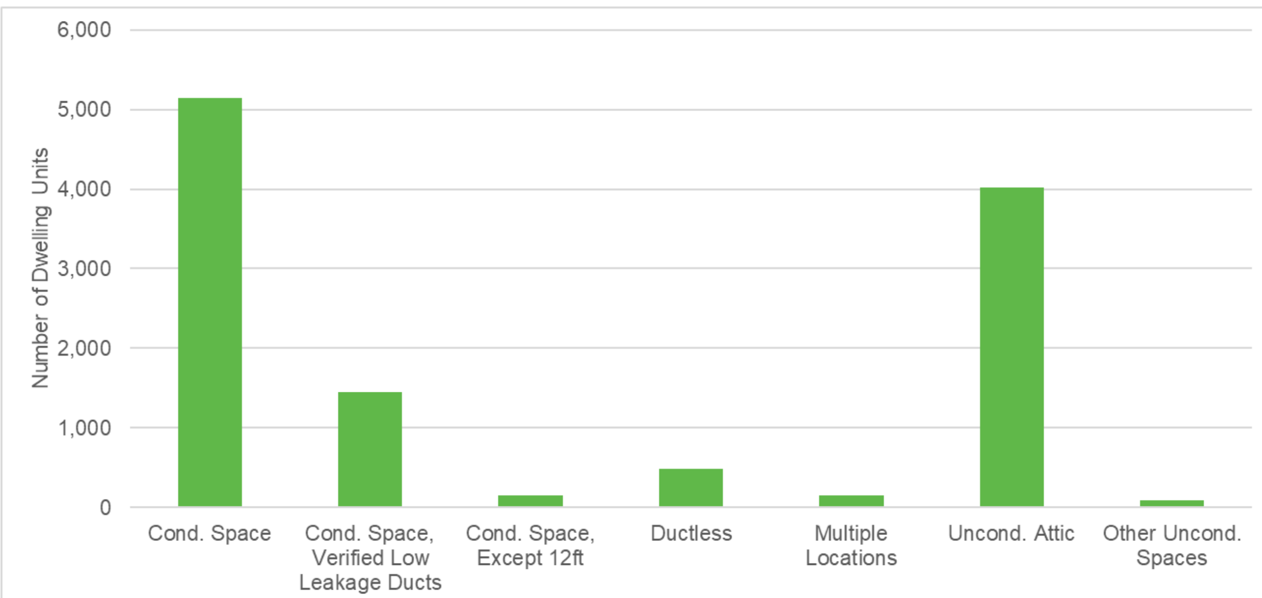

Figure 11: Distribution of HVAC system duct location for multifamily projects up to three habitable stories.

Source: CalCERTS (CalCERTS n.d.).

Ducts in Unconditioned Space

Figure 12 shows the distribution of duct insulation levels across all climate zones. 63 percent of ducts have R-6 insulation and 35 percent have R-8 insulation. The percentage of dwelling units with R-8 duct insulation is lower in Climate Zones 3 through 6.

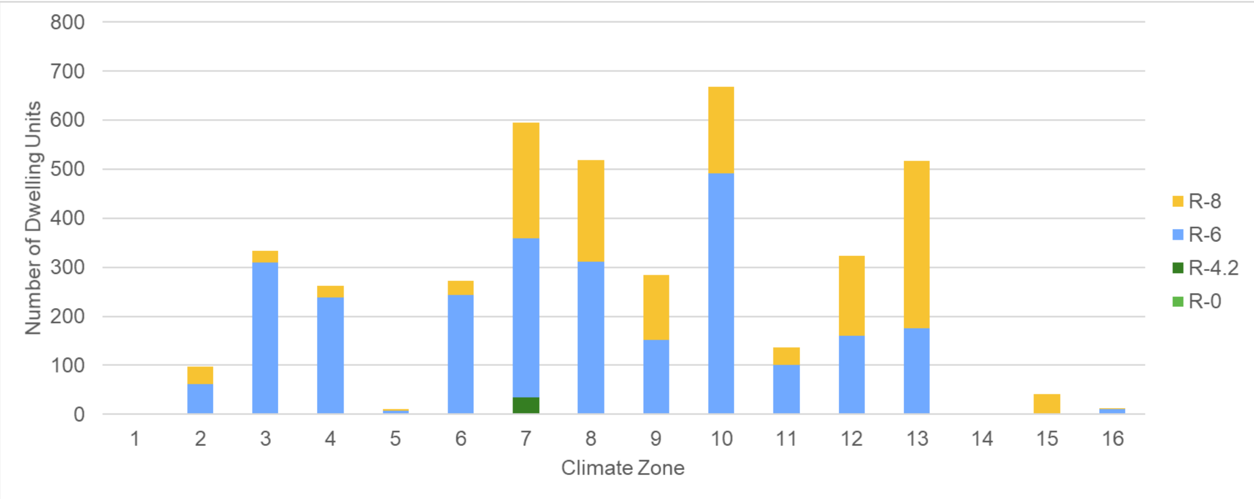

Figure 12: Distribution of duct insulation R-value by climate zone for ducts in unconditioned space in multifamily projects up to three habitable stories.

Source: CalCERTS (CalCERTS n.d.).
Note: No or limited data available for Climate Zones 1 and 14.

R-8 is already prescriptively required in many climate zones under the current low-rise residential code and is mandatory under the nonresidential code for ducts in unconditioned space; therefore, there is an existing market for it and the industry is familiar with installing it. There are typically not space limitations with fitting R-8 ducts in unconditioned spaces since they are often larger and more accessible than conditioned space locations.

Ducts in Conditioned Space

Data was not available for multifamily buildings four habitable stories and greater; however, the CalCERTS data in Figure 13 for multifamily projects up to three habitable stories is relevant to understand how multifamily projects with ducts in conditioned space (without low leakage verified by a HERS Rater) are insulating the ducts. 63 percent of dwelling units in the dataset installed R-4.2 or had uninsulated ductwork, even though current mandatory requirements require R-6 unless the ductwork is directly exposed to conditioned space or is within wall cavities inside the thermal envelope. 21 and 15 percent of projects installed R-6 and R-8 insulation, respectively.

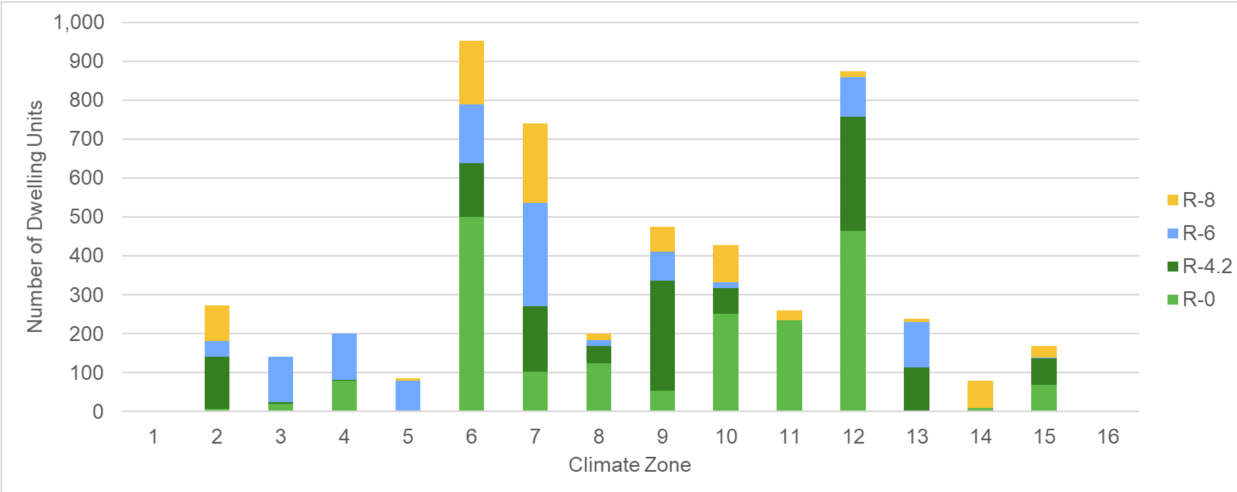

Figure 13: Distribution of duct insulation R-value by climate zone for ducts in conditioned space in multifamily projects up to three habitable stories.

Source: CalCERTS (CalCERTS n.d.).
Note: No or limited data available for Climate Zones 1 and 16.

Stakeholders feedback has indicated that there may be space limitations with fitting R-6 ducts located in conditioned spaces such as in soffits or between floors, which is a very common duct configuration in multifamily buildings. R-4.2 duct insulation adds about two and a half inches to the outside diameter of an uninsulated duct, and R-6 adds one to one and a half inches relative to R-4.2 flexible ducts. If this additional thickness is considered during the design phase, it can often be accommodated. If not, there may be tight spaces that do not have the dimensions to fit R-6 ductwork.

3.2.2.2 Submeasure G: Space Conditioning – Duct Leakage Testing

Most dwelling units in multifamily buildings four habitable stories and greater are either ductless or have ductwork located within conditioned space (see Figure 10).

Duct leakage reduces the operational performance of distribution systems resulting in conditioned supply air loss and a subsequent loss in system capacity. While the impact is reduced if ducts are located within conditioned space, even when ductwork is within conditioned space such as a soffit, duct leakage has an energy penalty since less conditioned air is directed to the registers as designed. Return leaks may introduce unfiltered air to the system depending on where the leak is in relation to the system air filter. If the distribution system is not completely within the pressure boundary of the dwelling units, an imbalance between supply and return leaks can cause additional unit infiltration (California Energy Commission 2011).

Duct leakage can occur in a distribution system wherever there are seams or connections as well as at the air handler. Duct sealing of a new distribution system is conducted by the mechanical contractor using Title 24, Part 6 approved tapes and sealants. All accessible joints, seams, and connections must be inspected and sealed as necessary. The air handler is also a source of leakage and must also be inspected and sealed. The mechanical contractor will test the duct system and verify that the maximum leakage criteria are met. The HERS Rater then conducts the third-party verification and submits the results to the HERS Registry.

Data was not available for multifamily buildings four habitable stories and greater; however, the Efficiency Characteristics and Opportunities for New California Homes study (California Energy Commission 2011) surveyed multifamily units in building up to three habitable stories and provides valuable information on total duct leakage and leakage to outside for ductwork located within conditioned space. Figure 14 presents duct leakage data from 17 multifamily units from the 2011 report (California Energy Commission 2011). Most of the units in the sample had ductwork within a soffit (61 percent). Only two units had ductwork in the attic. There is a wide range of leakage results with total leakage ranging from 5 to almost 45 percent and leakage to outside ranging from two percent to over 15 percent. Many of these projects would not meet the current low-rise residential requirement for 12 percent total leakage or 6 percent leakage to outside.

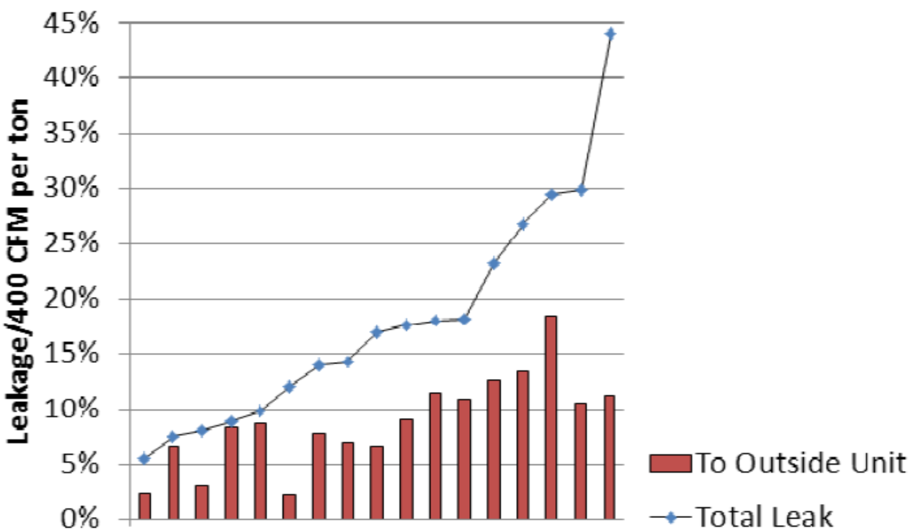

Figure 14: Duct leakage for a sample of multifamily projects one to three habitable stories built under the 2005 Title 24, Part 6 code.

Source: Figure 22 in ECO Report (California Energy Commission 2011).

The stakeholders interviewed were split on their perceptions of the challenges of this submeasure. Some are already conducting duct leakage testing to comply with other green programs or for their own quality control and see no challenges with meeting the proposed requirements. Others do not currently test their systems and expressed concerns about the value and additional costs of testing low pressure ducts, which are most typically located within conditioned space.

3.2.2.3 Submeasure H: Space Conditioning – Space Cooling Airflow Rate and Fan Efficacy

All stakeholders interviewed specialized in multifamily building construction and are very familiar with the requirements that currently apply to low-rise multifamily buildings. Many stakeholders saw no additional challenges with meeting these verification requirements for their multifamily projects four habitable stories and greater. However, one stakeholder described the difficulty of meeting the airflow requirement with inverter driven compressors which switch to low flow, and low capacity, when loads are low. This can be resolved in most cases by setting the system to maximum speed as is specified in the Title 24, Part 6 language and confirmed by other stakeholders. A second stakeholder expressed concerns for certain duct configurations where meeting the supply airflow requirement at the same time would invariably result in a failure to meet the fan watt draw requirement. Because most multifamily duct systems are typically compact in nature, it is likely that this concern would apply to a smaller subset and can be addressed adequately if considered early in the design stage. Design strategies are addressed in Table 150.0-B and Table 150.0-C of the 2019 standards and are also included in the proposed language for the new multifamily chapter.

There are some HVAC systems where it is challenging to accurately measure fan power, specifically mini-split heat pumps[2], which are powered directly from the outdoor condensing unit. This makes it challenging or impossible to isolate the fan power from the system power. Based on conversations with CalCERTS these types of systems are considered to be exempt from the fan efficacy testing for practical reasons. However, the Reference Appendices do not formally identify any exemptions and adding specificity to the document would provide clarity to practitioners when and when not, this requirement should apply.

3.2.2.4 Submeasure I: Space Conditioning – Refrigerant Charge Verification

Figure 15 presents refrigerant charge test data from CalCERTS for new construction low-rise multifamily projects. The data represents all projects submitted under the 2016 code cycle and represents a total of over 132,000 dwelling units. Over 50 percent of projects apply HERS verified refrigerant charge in Climate Zones 8 through 15 where it is currently prescriptively required. It is also prescriptively required in Climate Zone 2, but the testing is applied less often in this region, closer to 25 percent.

[2] Fan efficacy testing is only required for ducted systems; therefore, this is only relevant for ducted mini-split heat pumps.

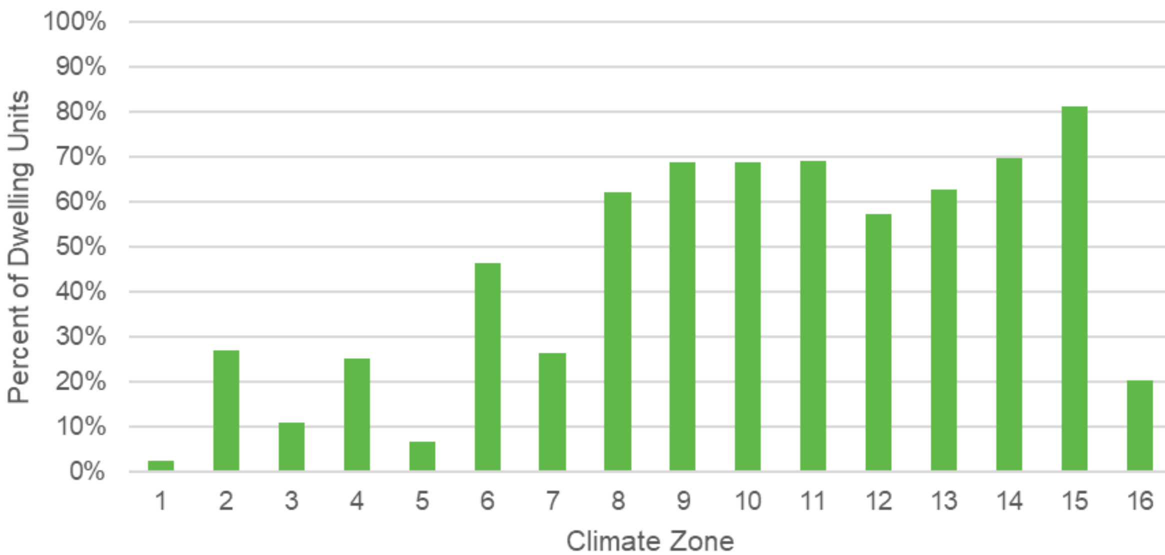

Figure 15: Percent of new construction multifamily projects up to three habitable stories with refrigerant charge verification.

Source: CalCERTS (CalCERTS 2020).

Stakeholders provided feedback that while some projects apply this prescriptive requirement for low-rise projects, many do not. However, they all generally agreed that meeting this requirement for most system types would be straightforward, except for mini-splits, which require a more coordinated weigh-in test method. For these, some stakeholders suggested allowing sampling to help reduce the scheduling effort required.

3.3 Market Impacts and Economic Assessments

Sections 3.3.1 through 3.4.7 apply to all submeasures unless otherwise specified.

3.3.1 Impact on Builders

Builders of residential and commercial structures are directly impacted by many of the measures proposed by the Statewide CASE Team for the 2022 code cycle. It is within the normal practices of these businesses to adjust their building practices to changes in building codes. When necessary, builders engage in continuing education and training in order to remain compliant with changes to design practices and building codes.

California's construction industry is comprised of about 80,000 business establishments and 860,000 employees (see Table 15).[3] In 2018, total payroll was $80 billion. Nearly 60,000 of these business establishments and 420,000 employees are engaged in the

[3] Average total monthly employment in California in 2018 was 18.6 million; the construction industry represented 4.5 percent of 2018 employment.

residential building sector. The remainder of establishments and employees work in industrial, utilities, infrastructure, and other heavy construction (industrial sector).

Table 15: California Construction Industry, Establishments, Employment, and Payroll

Construction Sectors	Establishments	Employment	Annual Payroll (billions $)
Residential	**59,287**	**420,216**	**$23.3**
Residential Building Construction Contractors	22,676	115,777	$7.4
Foundation, Structure, & Building Exterior	6,623	75,220	$3.6
Building Equipment Contractors	14,444	105,441	$6.0
Building Finishing Contractors	15,544	123,778	$6.2

Source: (State of California, Employment Development Department n.d.)

The proposed changes would likely affect residential builders but would not impact firms that focus on construction and retrofit of industrial buildings, utility systems, public infrastructure, or other heavy construction. The effects on the residential and commercial building industry would not be felt by all firms and workers, but rather would be concentrated in specific industry subsectors. Table 16 shows the residential building subsectors. The Statewide CASE Team's estimates of the magnitude of these impacts are shown in Section 3.4 Economic Impacts.

Table 16: Size of the California Residential Building Industry by Subsector

Residential Building Subsector	Establishments	Employment	Annual Payroll (billions $)
New multifamily general contractors	406	5,333	$0.5
New housing for-sale builders	180	2,719	$0.3
Residential Remodelers	11,122	52,133	$3.0
Residential glass and glazing contractors	577	3,660	$0.2
Residential Roofing Contractors	2,208	16,814	$0.8
Residential Siding Contractors	208	1,894	$0.1
Other Residential Exterior Contractors	465	2,666	$0.2
Residential Electrical Contractors	6,095	37,933	$2.2
Residential plumbing and HVAC contractors	8,086	66,177	$3.8
Other Residential Equipment Contractors	263	1,331	$0.2
All other residential trade contractors	2,356	21,280	$1.2

Source: (State of California, Employment Development Department n.d.)

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 Energy Code) are typically updated on a three-year revision cycle and building designers and energy consultants engage in continuing education and training in order to remain compliant with changes to design practices and building codes.

Businesses that focus on residential, commercial, institutional, and industrial building design are contained within the Architectural Services sector. (North American Industry Classification System 541310) Table 17 shows the number of establishments, employment, and total annual payroll for Building Architectural Services. The proposed code changes would potentially impact all firms within the Architectural Services sector. The Statewide CASE Team anticipates the impacts for multifamily restructuring to affect firms that focus on multifamily construction.

There is not a North American Industry Classification System (NAICS)[4] code specific for energy consultants. Instead, businesses that focus on consulting related to building energy efficiency are contained in the Building Inspection Services sector (NAICS 541350), which is comprised of firms primarily engaged in the physical inspection of residential and nonresidential buildings.[5] It is not possible to determine which business establishments within the Building Inspection Services sector are focused on energy efficiency consulting. The information shown in Table 17 provides an upper bound indication of the size of this sector in California.

[4] NAICS is the standard used by federal statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. business economy. NAICS was development jointly by the U.S. Economic Classification Policy Committee (ECPC), Statistics Canada, and Mexico's Instituto Nacional de Estadistica y Geografia, to allow for a high level of comparability in business statistics among the North American countries. NAICS replaced the Standard Industrial Classification (SIC) system in 1997.

[5] Establishments in this sector include businesses primarily engaged in evaluating a building's structure and component systems and includes energy efficiency inspection services and home inspection services. This sector does not include establishments primarily engaged in providing inspections for pests, hazardous wastes or other environmental contaminates, nor does it include state and local government entities that focus on building or energy code compliance/enforcement of building codes and regulations.

Table 17: California Building Designer and Energy Consultant Sectors

Sector	Establishments	Employment	Annual Payroll (billions $)
Architectural Services [a]	3,704	29,611	$2.9
Building Inspection Services [b]	824	3,145	$0.2

Source: (State of California, Employment Development Department n.d.)

a. Architectural Services (NAICS 541310) comprises private-sector establishments primarily engaged in planning and designing residential, institutional, leisure, commercial, and industrial buildings and structures;

b. Building Inspection Services (NAICS 541350) comprises private-sector establishments primarily engaged in providing building (residential & nonresidential) inspection services encompassing all aspects of the building structure and component systems, including energy efficiency inspection services.

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)

3.3.4.1 Residential Buildings

According to data from the United States (U.S) Census, American Community Survey, there were nearly 14.3 million housing units in California in 2018 and nearly 13.1 million were occupied (see Table 18). Most housing units (nearly 9.2 million were single family homes, either detached or attached), while about 2 million homes were in building containing two to nine units and 2.5 million were in multifamily building containing 10 or more units. The U.S. Census reported that 59,200 single family and 50,700 multifamily homes were constructed in 2019.

Table 18: California Housing Characteristics

	Housing Characteristic	Estimate
Housing Measure	Total housing units	14,277,867
	Occupied housing units	13,072,122
	Vacant housing units	1,205,745
	Homeowner vacancy rate	1.2%
	Rental vacancy rate	4.0%
Units in Structure	1-unit, detached	8,177,141
	1-unit, attached	1,014,941
	2 units	358,619
	3 or 4 units	783,963
	5 to 9 units	874,649
	10 to 19 units	742,139
	20 or more units	1,787,812
	Mobile home, RV, etc.	538,603

Source: (2018 American Community Survey n.d.)

Table 19 shows the distribution of California homes by vintage. About 15 percent of California homes were built in 2000 or later, and another 11 percent built between 1990 and 1999. The majority of California's existing housing stock (8.5 million homes—59 percent of the total) were built between 1950 and 1989, a period of rapid population and economic growth in California. Finally, about 2.1 million homes in California were built before 1950. According to Kenney et al, 2019, more than half of California's existing multifamily buildings (those with five or more units) were constructed before 1978 when there no building energy efficiency standards (Kenney 2019).

Table 19: Distribution of California Housing by Vintage

Home Vintage	Units	Percent	Cumulative Percent
Built 2014 or later	343,448	2.4%	2.4%
Built 2010 to 2013	248,659	1.7%	4.1%
Built 2000 to 2009	1,553,769	10.9%	15.0%
Built 1990 to 1999	1,561,579	10.9%	26.0%
Built 1980 to 1989	2,118,545	14.8%	40.8%
Built 1970 to 1979	2,512,178	17.6%	58.4%
Built 1960 to 1969	1,925,945	13.5%	71.9%
Built 1950 to 1959	1,896,629	13.3%	85.2%
Built 1940 to 1949	817,270	5.7%	90.9%
Built 1939 or earlier	1,299,845	9.1%	100.0%
Total housing units	14,277,867	100%	

Source: (2018 American Community Survey n.d.)

Table 20 shows the distribution of owner- and renter-occupied housing by household income. Overall, about 55 percent of California housing is owner-occupied, and the rate of owner-occupancy generally increases with household income. The owner-occupancy rate for households with income below $50,000 is only 37 percent, whereas the owner occupancy rate is 72 percent for households earning $100,000 or more.

Table 20: Owner- and Renter-Occupied Housing Units in California by Income

Household Income	Total	Owner Occupied	Renter Occupied
Less than $5,000	391,235	129,078	262,157
$5,000 to $9,999	279,442	86,334	193,108
$10,000 to $14,999	515,804	143,001	372,803
$15,000 to $19,999	456,076	156,790	299,286
$20,000 to $24,999	520,133	187,578	332,555
$25,000 to $34,999	943,783	370,939	572,844
$35,000 to $49,999	1,362,459	590,325	772,134
$50,000 to $74,999	2,044,663	1,018,107	1,026,556
$75,000 to $99,999	1,601,641	922,609	679,032
$100,000 to $149,999	2,176,125	1,429,227	746,898
$150,000 or more	2,780,761	2,131,676	649,085
Total Housing Units	13,072,122	7,165,664	5,906,458
Median household income	$75,277	$99,245	$52,348

Source: (2018 American Community Survey n.d.)

Understanding the distribution of California residents by home type, home vintage, and household income is critical for developing meaningful estimates of the economic impacts associated with proposed code changes affecting residents. Many proposed code changes specifically target single family or multifamily residences, so the counts of housing units by building type shown in Table 18 provides the information necessary to quantify the magnitude of potential impacts. Likewise, impacts may differ for owners and renters, by home vintage, and by household income, information provided in Table 19 and Table 20.

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

The Statewide CASE Team anticipates the proposed change will have no material impact on California component retailers.

3.3.6 Impact on Building Inspectors

Table 21 shows employment and payroll information for state and local government agencies, in which many inspectors of residential and commercial buildings are employed. Building inspectors participate in continuing training to stay current on all aspects of building regulations, including energy efficiency. The Statewide CASE Team, therefore, anticipates the proposed change would have no impact on employment of building inspectors or the scope of their role conducting energy efficiency inspections.

Table 21: Employment in California State and Government Agencies with Building Inspectors

Sector	Govt.	Establishments	Employment	Annual Payroll (millions $)
Administration of Housing Programs	State	17	283	$29.0
	Local	36	2,882	$205.7
Urban and Rural Development Admin[b]	State	35	552	$48.2
	Local	52	2,446	$186.6

Source: (State of California, Employment Development Department n.d.).

a. Administration of Housing Programs (NAICS 925110) comprises government establishments primarily engaged in the administration and planning of housing programs, including building codes and standards, housing authorities, and housing programs, planning, and development.

b. Urban and Rural Development Administration (NAICS 925120) comprises government establishments primarily engaged in the administration and planning of the development of urban and rural areas. Included in this industry are government zoning boards and commissions.

3.3.7 Impact on Statewide Employment

As described in Sections 3.3.1 through 3.3.6, the Statewide CASE Team does not anticipate significant employment or financial impacts to any particular sector of the California economy. This is not to say that the proposed change would not have modest impacts on employment in California. In Section 3.4, the Statewide CASE Team estimated the proposed change would affect statewide employment and economic output directly and indirectly through its impact on builders, designers and energy consultants, and building inspectors. In addition, the Statewide CASE Team estimated how energy savings associated with the proposed change would lead to modest ongoing financial savings for California residents, which would then be available for other economic activities.

3.4 Economic Impacts

For the 2022 code cycle, the Statewide CASE Team used the IMPLAN model software, along with economic information from published sources and professional judgement, to develop estimates of the economic impacts associated with each of the proposed code changes.[6] While this is the first code cycle in which the Statewide CASE Team develops estimates of economic impacts using IMPLAN, it is important to note that the economic impacts developed for this report are only estimates and are based on limited and to some extent speculative information. In addition, the IMPLAN model provides a relatively simple representation of the California economy and, though the Statewide CASE Team is confident that direction and approximate magnitude of the estimated economic impacts are reasonable, it is important to understand that the IMPLAN model is a simplification of extremely complex actions and interactions of individual, businesses, and other organizations as they respond to changes in energy efficiency codes. In all aspect of this economic analysis, the CASE Authors rely on conservative assumptions regarding the likely economic benefits associated with the proposed code change. By following this approach, the Statewide CASE Team believes the economic impacts presented below represent lower bound estimates of the actual impacts associated with this proposed code change.

Adoption of this code change proposal would result in relatively modest economic impacts through the additional direct spending by those in the multifamily building and remodeling industry, architects, energy consultants, and building inspectors, as well as indirectly as residents spend all or some of the money saved through lower utility bills on other economic activities. There may also be some nonresidential customers that are impacted by this proposed code change; however, the Statewide CASE Team does not anticipate such impacts to be materially important to the building owner and would have measurable economic impacts.

3.4.1 Estimated Economic Impacts

Table 22 through Table 28 present the estimated impact of the adoption of proposed measures. Submeasures not listed are assumed to have no economic impact.

3.4.1.1 Building Envelope

Submeasure A: Envelope – Roof Products

There are no costs associated with this measure.

[6] IMPLAN (Impact Analysis for Planning) software is an input-output model used to estimate the economic effects of proposed policies and projects. IMPLAN is the most commonly used economic impact model due to its ease of use and extensive detailed information on output, employment, and wage information.

Submeasure B: Envelope – Wall U-Factor

Table 22: Estimated Impact that Adoption of the Proposed Measure would have on the California Residential Construction Sector

Type of Economic Impact	Employment (jobs)	Labor Income	Total Value Added	Output
Direct Effects (Additional spending by Residential Builders)	2.4	$150,886	$254,297	$412,938
Indirect Effect (Additional spending by firms supporting Residential Builders)	0.9	$58,234	$90,769	$161,191
Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects)	1.1	$62,164	$111,241	$181,590
Total Economic Impacts	4.4	$271,284	$456,308	$755,719

Source: Analysis by Evergreen Economics of data from the IMPLAN V3.1 modeling software.

Submeasure C: Envelope – Quality Insulation Installation

Table 23: Estimated Impact that Adoption of the Proposed Measure would have on the California Residential Construction Sector

Type of Economic Impact	Employment (jobs)	Labor Income	Total Value Added	Output
Direct Effects (Additional spending by Residential Builders)	1	$106,532	$105,256	$187,230
Indirect Effect (Additional spending by firms supporting Residential Builders)	1	$43,879	$59,283	$94,240
Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects)	1	$44,942	$80,413	$131,285
Total Economic Impacts	3	$195,353	$244,952	$412,756

Source: Analysis by Evergreen Economics of data from the IMPLAN V3.1 modeling software.

Submeasure D: Envelope – Fenestration Properties

Table 24: Estimated Impact that Adoption of the Proposed Measure would have on the California Residential Construction Sector

Type of Economic Impact	Employment (jobs)	Labor Income	Total Value Added	Output
Direct Effects (Additional spending by Residential Builders)	96	$6,175,608	$10,408,143	$16,901,138
Indirect Effect (Additional spending by firms supporting Residential Builders)	37	$2,383,466	$3,715,107	$6,597,410
Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects)	46	$2,544,297	$4,552,981	$7,432,292
Total Economic Impacts	179	$11,103,372	$18,676,231	$30,930,840

Source: Analysis by Evergreen Economics of data from the IMPLAN V3.1 modeling software.

3.4.1.2 Space Conditioning

Submeasure G: Space Conditioning – Duct Leakage Testing

Table 25: Estimated Impact that Adoption of the Proposed Measure would have on the California Residential Construction Sector

Type of Economic Impact	Employment (jobs)	Labor Income	Total Value Added	Output
Direct Effects (Additional spending by Residential Builders)	17	$1,114,173	$1,877,787	$3,049,221
Indirect Effect (Additional spending by firms supporting Residential Builders)	7	$430,013	$670,261	$1,190,273
Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects)	8	$459,030	$821,427	$1,340,898
Total Economic Impacts	32	$2,003,216	$3,369,475	$5,580,392

Source: Analysis by Evergreen Economics of data from the IMPLAN V3.1 modeling software.

Table 26: Estimated Impact that Adoption of the Proposed Measure would have on the California Building Designers and Energy Consultants Sectors

Type of Economic Impact	Employment (jobs)	Labor Income	Total Value Added	Output
Direct Effects (Additional spending by Building Designers & Energy Consultants)	16	$1,692,028	$1,671,762	$2,973,745
Indirect Effect (Additional spending by firms supporting Bldg. Designers & Energy Consult.)	10	$696,927	$941,583	$1,496,805
Induced Effect (Spending by employees of firms experiencing "direct" or "indirect" effects)	13	$713,809	$1,277,191	$2,085,184
Total Economic Impacts	39	$3,102,764	$3,890,536	$6,555,735

Source: Analysis by Evergreen Economics of data from the IMPLAN V3.1 modeling software.

Submeasure H: Space Conditioning – Space Cooling Airflow Rate and Fan Efficacy

Table 27: Estimated Impact that Adoption of the Proposed Measure would have on the California Residential Construction Sector

Type of Economic Impact	Employment (jobs)	Labor Income	Total Value Added	Output
Direct Effects (Additional spending by Residential Builders)	21	$1,347,662	$2,271,301	$3,688,224
Indirect Effect (Additional spending by firms supporting Residential Builders)	8	$520,128	$810,723	$1,439,709
Induced Effect (Spending by employees of firms experiencing "direct" or "indirect" effects)	10	$555,225	$993,567	$1,621,900
Total Economic Impacts	39	$2,423,016	$4,075,591	$6,749,833

Source: Analysis by Evergreen Economics of data from the IMPLAN V3.1 modeling software.

Submeasure I: Space Conditioning – Refrigerant Charge Verification

Table 28: Estimated Impact that Adoption of the Proposed Measure would have on the California Building Designers and Energy Consultants Sectors

Type of Economic Impact	Employment (jobs)	Labor Income	Total Value Added	Output
Direct Effects (Additional spending by Building Designers & Energy Consultants)	14	$885,209	$1,491,899	$2,422,602
Indirect Effect (Additional spending by firms supporting Bldg. Designers & Energy Consult.)	5	$341,645	$532,522	$945,670
Induced Effect (Spending by employees of firms experiencing "direct" or "indirect" effects)	7	$364,699	$652,622	$1,065,342
Total Economic Impacts	26	$1,591,553	$2,677,043	$4,433,614

Source: Analysis by Evergreen Economics of data from the IMPLAN V3.1 modeling software.

3.4.2 Creation or Elimination of Jobs

The Statewide CASE Team does not anticipate that the measures proposed for the 2022 code cycle regulation would lead to the creation of new *types* of jobs or the elimination of *existing* types of jobs. In other words, the Statewide CASE Team's proposed change would not result in economic disruption to any sector of the California economy. Rather, the estimates of economic impacts discussed in Section 3.4 would lead to modest changes in employment of existing jobs.

3.4.3 Creation or Elimination of Businesses in California

As stated in Section 3.4.1, the Statewide CASE Team's proposed change would not result in economic disruption to any sector of the California economy. The proposed change would not excessively burden or competitively disadvantage California businesses, nor would it necessarily lead to a competitive advantage for California businesses. Therefore, the Statewide CASE Team does not foresee any new businesses being created, nor does the Statewide CASE Team think any existing businesses would be eliminated due to the proposed code changes.

3.4.4 Competitive Advantages or Disadvantages for Businesses in California

The proposed code changes would apply to all businesses incorporated in California, regardless of whether the business is located inside or outside of the state.[7] Therefore,

[7] Gov. Code, §§ 11346.3(c)(1)(C), 11346.3(a)(2); 1 CCR § 2003(a)(3) Competitive advantages or disadvantages for California businesses currently doing business in the state.

the Statewide CASE Team does not anticipate that these measures proposed for the 2022 code cycle regulation would have an adverse effect on the competitiveness of California businesses. Likewise, the Statewide CASE Team does not anticipate businesses located outside of California would be advantaged or disadvantaged.

3.4.5 Increase or Decrease of Investments in the State of California

The Statewide CASE Team does not anticipate that the economic impacts associated with the proposed measure would lead to significant change (increase or decrease) in investment in any directly or indirectly affected sectors of California's economy.

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

The Statewide CASE Team does not expect the proposed code changes would have a measurable impact on the California's General Fund, any state special funds, or local government funds.

3.4.7 Impacts on Specific Groups of Californians

While the objective of any of the Statewide CASE Team's proposal is to promote energy efficiency, the Statewide CASE Team recognizes that there is the potential that a proposed code change may result in unintended consequences. However, the Statewide CASE Team does not anticipate that the proposed code change will have impacts on specific groups of Californians.

4. Energy Savings

4.1 Key Assumptions for Energy Savings Analysis

The Statewide CASE Team made key assumptions across all submeasures for the purpose of evaluating energy savings equitably and accurately across the CBECC-Res and CBECC-Com software and across multifamily buildings of all sizes.

- **Infiltration schedule of 1.0. CBECC-Com assumes a 0.25 infiltration schedule by default.** The Statewide CASE Team proposes this be changed to 1.0 for all multifamily buildings and has assumed this base and proposed case analysis in CBECC-Com. No change was required for CBECC-Res modeling.
- **Internal heat gains consistent with residential algorithms.** The Statewide CASE Team proposes the internal heat gain assumptions for residential buildings be used for all multifamily buildings. The Statewide CASE Team has calculated internal heat gains for the mid-rise and high-rise prototypes using the residential assumptions and used those in energy analysis in CBECC-Com. The Statewide CASE Team did not make any changes to internal heat gain assumptions in CBECC-Res.
- **Baseline HVAC system aligned with proposed 2019 ACM mapping.** The Standard Design HVAC system for all multifamily buildings is a ducted gas forced air furnace and a split system air conditioner for each dwelling unit. The Statewide CASE Team used this system type in energy simulations used to calculate per-unit energy savings, statewide energy savings, and cost benefits. Recent multifamily construction trends demonstrate preference for heat pumps in multifamily buildings. Because this system type is not used in our calculations, natural gas therm usage and/or savings may be overestimated at a statewide level.

4.2 Energy Savings Methodology

4.2.1 Energy Savings Methodology per Prototypical Building

The Energy Commission directed the Statewide CASE Team to model the energy impacts using specific prototypical building models that represent typical building geometries for different types of buildings. The prototype buildings that the Statewide CASE Team used in the analysis are presented in Table 29 and Table 30.

Table 29: New Construction Prototype Buildings Used for Energy, Demand, Cost, and Environmental Impacts Analysis

Prototype Name	Number of Stories	Floor Area (ft^2)	Description
2-Story Garden Style	2	7,680	8-unit residential building with slab on-grade foundation, wood framed wall construction and a sloped roof. Individual space conditioning and domestic hot water systems serving each unit. Window to Wall Ratio 0.15
3-Story Loaded Corridor	3	40,000	36-unit residential building with slab on-grade foundation, wood framed wall construction, and a flat roof. Window to Wall Ratio 0.25. Dwelling units flank and central corridor and common area spaces included on bottom floor. Individual space conditioning systems and shared domestic hot water system.
5-Story Mixed Use	5	113,100	88-unit building with 4-story residential plus 1-story commercial. Concrete podium construction with underground parking, wood framed wall construction, and flat roof. Window to Wall Ratio-0.10 (ground floor) 0.25 (residential floors). Individual space conditioning systems and a central domestic hot water system.
10-Story Mixed Use	10	125,400	117-unit building with 9-story residential + 1-story commercial. Concrete podium construction with underground parking, steel framed wall construction, and a flat roof. Window to Wall Ratio-0.10 (ground floor) 0.40 (residential floors). Individual space conditioning systems and a central domestic hot water system.

Table 30: Additions and Alterations Prototype Buildings Used for Energy, Demand, Cost, and Environmental Impacts Analysis for Fenestration Properties

Prototype Name	Number of Stories	Floor Area (ft^2)	Description
Prototype D Existing	2	6,960	8-unit residential building with slab on-grade foundation, wood framed wall construction and a steep-sloped roof with attic. Individual space conditioning and domestic hot water systems serving each unit.
High-Rise Existing	10	125,400	117-unit building with 9-story residential + 1-story commercial. Concrete podium construction with underground parking, steel framed wall construction, and a flat roof. Window to Wall Ratio-0.10 (ground floor) 0.40 (residential floors). Individual space conditioning systems.

The Statewide CASE Team estimated energy and demand impacts by simulating the proposed code change using the 2022 Research Version of the CBECC software for multifamily buildings (CBECC-Com for buildings four habitable stories and taller and CBECC-Res for buildings three habitable stories and fewer).

CBECC-Com and CBECC-Res generate two models based on user inputs: the Standard Design and the Proposed Design.[8] The Standard Design represents the geometry of the design that the builder would like to build and inserts a defined set of features that result in an energy budget that is minimally compliant with 2019 Title 24, Part 6 code requirements. Features used in the Standard Design are described in the 2019 Residential and Nonresidential ACM Reference Manuals. The Proposed Design represents the same geometry as the Standard Design, but it assumes the energy features that the software user describes with user inputs. To develop savings estimates for the proposed code changes, the Statewide CASE Team created a Standard Design and Proposed Design for each prototypical building The Proposed Design was identical to the Standard Design in all ways except for the revisions that represent the proposed changes to the code. Comparing the energy impacts of the Standard Design to the Proposed Design reveals the impacts of the proposed code change relative to a building that is minimally compliant with the 2019 Title 24, Part 6 requirements.

The two existing building prototypes, Prototype D for low rise and High-Rise Existing for high rise, are set up using building characteristics and efficiency specifications common to a 1990s building. They are similar to new construction prototypes in size and geometry but include 1990s vintage assumptions for envelope and mechanical equipment measures. These prototypes better represent the energy use profile, and therefore savings potential, of buildings that would replace windows during the upcoming code cycle than the new construction prototypes based on 2019 code energy measures.

CBECC-Com and CBECC-Res calculate whole-building energy consumption for every hour of the year measured in kilowatt-hours per year (kWh/yr) and therms per year (therms/yr). It then applies the 2022 TDV factors to calculate annual energy use in kilo British thermal units per year (TDV kBtu/yr) and annual peak electricity demand reductions measured in kilowatts (kW). CBECC-Com/Res also generates TDV energy cost savings values measured in 2023 present value dollars (2023 PV$).

The energy impacts of the proposed code change vary by climate zone. The Statewide CASE Team simulated the energy impacts in every climate zone and applied the climate-zone specific TDV factors when calculating energy and energy cost impacts.

Per-unit energy impacts for multifamily buildings are presented in savings per dwelling unit. Annual energy and peak demand impacts for each prototype building were

[8] CBECC-Res creates a third model, the Reference Design, that represents a building similar to the Proposed Design, but with construction and equipment parameters that are minimally compliant with the 2006 International Energy Conservation Code (IECC). The Statewide CASE Team did not use the Reference Design for energy impacts evaluations.

translated into impacts per dwelling unit by dividing by the number of dwelling units in the prototype building. This step enables a calculation of statewide savings using the construction forecast that is published in terms of number of multifamily dwelling units by climate zone.

Subsections 4.2.1.1 and 4.2.1.2 describe Standard and Proposed Design conditions per submeasure.

4.2.1.1 Building Envelope

Submeasure A: Envelope – Roof Assemblies

There are existing Title 24, Part 6 requirements that cover roofing product and roof and ceiling insulations and applies to new construction, so the Standard Design is minimally compliant with the 2019 Title 24, Part 6 requirements. The baseline attic roof is modeled with cavity insulation and radiant barrier option per Option C in Table 150.1-B in 2019 Title 24, Part 6 with no insulation above or below deck. The ducts are placed in conditioned space. The roofing products assumed in the baseline have 0.63 ASR in Climate Zones 13 and 15 for low-rise buildings (with three habitable stories and fewer) and 0.55 ASR for high-rise buildings in Climate Zones 9 through 11 and 13 through 15. In all other Climate Zones, where this is no prescriptive roofing product requirement, the assumed ASR is 0.10 and matches the mandatory requirement. Thermal emittance of 0.75 was modeled in all models.

Table 31 presents precisely which parameters were modified and what values were used in the Standard Design and Proposed Design.

Table 31: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change - Roof Option A

Prototype ID	Climate Zone	Parameter Name	Standard Design Parameter Value	Proposed Design Parameter Value
2-Story Garden Style, 3-Story Loaded Corridor	1,16	Ceiling cavity insulation	R-38	0.028 U- factor
		ASR/Thermal Emittance	0.10 / 0.75	0.10 / 0.75
		Radiant barrier	No	No
	2,4,8	Ceiling cavity insulation	R-30	0.028 U- factor
		ASR/Thermal Emittance	0.10 / 0.75	0.10 / 0.75
		Radiant barrier	Yes	No
	3,5,6	Ceiling cavity insulation	R-30	0.034 U- factor
		ASR/Thermal Emittance	0.10 / 0.75	0.10 / 0.75
		Radiant barrier	Yes	No
	7	Ceiling cavity insulation	R-30	0.039 U- factor
		ASR/Thermal Emittance	0.10 / 0.75	0.10 / 0.75
		Radiant barrier	Yes	No
	9,10	Ceiling cavity insulation	R-30	0.028 U- factor
		ASR/Thermal Emittance	0.10 / 0.75	0.63 / 0.75
		Radiant barrier	Yes	No
	11-15	Ceiling cavity insulation	R-38	0.028 U- factor
		ASR/Thermal Emittance	0.10 / 0.75	0.63 / 0.75
		Radiant barrier	Yes	No
	12	Ceiling cavity insulation	R-38	0.028 U- factor
		ASR/Thermal Emittance	0.10 / 0.75	0.10 / 0.75
		Radiant barrier	Yes	No
5-Story Mixed Use, 10-Story Mixed Use	9-11,13-15	Ceiling cavity insulation	0.028 U- factor	0.028 U- factor
		ASR/Thermal Emittance	0.55 / 0.75	0.63 / 0.75

Submeasure B: Envelope – Wall U-Factor

There is an existing Title 24, Part 6 requirement that covers the wall assembly U-factors and applies to new construction, so the Standard Design is minimally compliant with the 2019 Title 24, Part 6 requirements.

Table 32 presents precisely which parameters were modified and what values were used in the Standard Design and Proposed Design. Specifically, the proposed conditions assume wall assembly U-factor matching levels matching the existing wall categories for the prototype buildings. The top two rows in the table provide parameters for high fire rating walls in a three-story prototype switching from existing residential to the proposed high fire rating U-factor requirements, and the reverse scenario of a five-story prototype switching from existing nonresidential to the proposed low fire rating U-factor requirements. The bottom row provides parameters for the five-story and ten-story prototype buildings unifying into a high fire-rating requirement by changing from existing nonresidential to the proposed high fire rating U-factor requirements.

Table 32: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change - Wall U-Factor

Prototype ID Proposed category: Application scenario	Climate Zone	Parameter Name	Standard Design Parameter Value	Proposed Design Parameter Value
3-Story Loaded Corridor Framed construction; High 2- or 3-hr fire rating: Residential to HR wood-framed*	1-5, 8-10, 12, 13	Wall Assembly U-Factor	0.051	0.059*
5-Story Mixed Use Framed construction; Low 0- or 1-hr fire rating: HR wood-framed to residential	1-5, 8-10, 12, 13	Wall Assembly U-Factor	0.059	0.051
	6, 7		0.059	0.065*
	11, 14-16		0.042	0.051*
5-Story Mixed Use, 10-Story Mixed Use Framed construction; High 2- or 3-hr fire rating: HR wood framed to residential*	6, 7	Wall Assembly U-Factor	0.059	0.065*
	11, 14-16		0.042	0.051*

* Will result in increased energy use. Proposed to allow for appropriate unification between divergent 2019 nonresidential and residential code requirements, where unification at higher stringency is not cost-effective.

Submeasure C: Envelope – Quality Insulation Installation

There are no existing requirements in Title 24, Part 6 that covers the QII requirement for mid-rise and high-rise residential buildings. The Statewide CASE Team kept the Standard Design such that the calculated energy use of the wood framed building accounts for no cavity insulation deration. The Proposed Design assumes a cavity insulation derated by 30 percent. This is done for all climate zones except Climate Zone 7 where QII is not required.

Submeasure D: Envelope – Fenestration Properties

There are existing Title 24, Part 6 requirements that cover fenestration properties and apply to new construction, so the Standard Design is minimally compliant with the 2019 Title 24, Part 6 requirements.

Table 33 presents precisely which parameters were modified to analyze new construction fenestration properties and what values were used in the Standard Design and Proposed Design. Existing residential and nonresidential U-factor requirements have different fenestration categories and variations between climate zones. The top three rows (by Prototype ID) provide parameters for buildings four habitable stories or more for the three proposed new construction window categories; curtainwalls and storefronts, Performance Class AW, and all-other windows.

For the second and third row (by Prototype ID) the standard design parameter value 0.40/0.24 represents current nonresidential prescriptive requirements with an area-weighted average across 59 percent fixed windows at 0.36/0.25, 39 percent operable windows at 0.46/0.22, and two percent glazed doors at 0.45/0.23. This ratio comes from subject matter expert interviews as well as review of CMNFH program participating buildings.

Table 33: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change – Fenestration Properties – New Construction

Prototype ID Proposed category: Application scenario	Climate Zone	Parameter Name	Standard Design Parameter Value	Proposed Design Parameter Value
5-Story Mixed Use, 10-Story Mixed Use Curtainwall/Store Fronts	1	U-Factor/SHGC*	0.41/0.26	0.38/0.35
	16			0.38/0.25
5-Story Mixed Use, 10-Story Mixed Use NAFS Class AW	1	U-Factor/SHGC*	0.40/0.24	0.38/0.35
	16			0.38/0.24
5-Story Mixed Use, 10-Story Mixed Use All Others: Blended Nonresidential to “All Others”	1	U-Factor/SHGC*	0.40/0.24	0.30/0.35
	2-5, 8-16			0.30/0.23
	7			0.34/0.23
3-Story Loaded Corridor	CZ 6, 7	U-Factor/SHGC*	0.30/0.23	0.34/0.23
2-Story Garden	CZ 6, 7	U-Factor/SHGC*	0.30/0.23	0.34/0.23

* Default VT values were used for the simulation runs. The simulation results are not dependent on VT values since CBECC-Com does not calculate VT driven lighting savings in residential spaces.
** No Requirement SHGC is modeled as 0.35 as per the residential ACM.

Table 34 presents which parameters were modified to analyze fenestration properties in alterations and what values were used in the Standard Design and Proposed Design. These prototypes are based on 1990 vintage energy measures for the envelope and mechanical equipment. This better represents the energy use profile from a typical building undergoing a window replacement retrofit. For all measures, the energy savings per dwelling unit are estimated presuming replacement of all the building’s fenestration at once. For fixed and operable Performance Class AW windows, this presumption is conservative. Each additional upgraded window adds smaller marginal savings per dwelling unit to the overall building. Assuming replacement of all fenestration will therefore have lower per-dwelling unit savings than assuming replacement of only a portion of windows that match the fixed, or operable, category under consideration.

The “Prototype D Existing” row isolates the energy impact of changing the U-factor requirement from 0.30 to 0.34. The last four rows (by Prototype ID) show the proposed alterations modeling parameters requirements for existing high-rise buildings.

Table 34: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change – Fenestration Properties – Alterations

Prototype ID Proposed category: Application scenario	Climate Zone	Parameter Name	Standard Design Parameter Value	Proposed Design Parameter Value
Low Rise Prototype D Existing	6, 7	U-Factor/SHGC	0.30/0.23	0.34/0.23
High-Rise Existing Curtainwall/Store Fronts/Glazed Doors	1	U-Factor/SHGC*	0.47/0.41	0.38/0.35
	2, 4, 6-15		0.47/0.31	0.41/0.26
	3, 5		0.58/0.41	0.41/0.26
	16		0.47/0.41	0.38/0.25
High-Rise Existing NAFS Class AW - Fixed	1	U-Factor/SHGC*	0.47/0.41	0.38/0.35
	2, 4, 9-15		0.47/0.31	0.38/0.25
	3, 5		0.58/0.41	0.38/0.25
	6-8		0.47/0.31	0.41/0.26
	16		0.47/0.41	0.38/0.25
High-Rise Existing NAFS Class AW - Operable	1	U-Factor/SHGC*	0.47/0.41	0.43/0.35
	2, 4, 6-15		0.47/0.31	0.43/0.24
	3, 5		0.58/0.41	0.43/0.24
	16		0.47/0.41	0.43/0.24
High-Rise Existing All Others: Blended NR to "All Others"	1	U-Factor/SHGC*	0.47/0.41	0.30/0.35
	2, 4, 8-15		0.47/0.31	0.30/0.23
	3, 5		0.58/0.41	0.30/0.23
	6, 7		0.47/0.31	0.34/0.23
	16		0.47/0.41	0.30/0.23

* Default VT values were used for the simulation runs. The simulation results are not dependent on VT values since CBECC-Com does not calculate VT driven lighting savings in residential spaces.

Submeasure E: Envelope – Fenestration Area

No energy simulation was performed for this submeasure.

4.2.1.2 Space Conditioning

Submeasure F: Space Conditioning – Duct Insulation

There is an existing Title 24, Part 6 requirement that covers ductwork installed in all multifamily buildings and applies to both new construction and alterations, so the Standard Design is minimally compliant with the 2019 Title 24, Part 6 requirements. For ductwork in unconditioned space for multifamily buildings four habitable stories and higher, the current mandatory requirement is R-8 duct insulation in all climate zones. If the current requirements for multifamily building three habitable stories and fewer is adopted for all multifamily buildings, the requirement will be reduced to R-6 duct insulation in Climate Zones 3 and 5 through 7 for new construction and in Climate Zones 1 through 10, 12, and 13 for new or replacement ducts.

For ductwork in conditioned space for multifamily buildings three habitable stories and fewer the current mandatory requirement is R-6 duct insulation unless the HERS low leakage verified duct credit is taken or the ducts are directly exposed to conditioned space. If the current requirements for multifamily buildings four habitable stories and higher is adopted for all multifamily buildings, the requirement will be reduced to R-4.2 supply duct insulation in all climate zones with no insulation requirement for return duct insulation.

Table 35 presents the parameters which were modified and what values were used in the Standard Design and Proposed Design. Specifically, for the component of this submeasure that impacts ducts in unconditioned space, the proposed conditions assume R-6 ductwork in a vented attic in Climate Zones 3 and 5 through 7. The energy impacts cannot be directly modeled in CBECC-Com using the 5-story and 10-story prototypes because CBECC-Com does not currently include a duct model and neither thermal nor leakage impacts of ducts are considered. CBECC-Res has a detailed duct system model and was used to estimate impacts for the 5-story and 10-story prototypes using the 3-story loaded corridor prototype. The new construction prototypes were used to evaluate savings for both the new construction and alteration scenarios. Existing buildings, with less insulation and poorer performing assemblies and systems, typically will experience a greater energy impact savings from these measures than a new construction building, but the impact will be small and varied across the building stock.

For the component of this submeasure that impacts ducts in conditioned space, the energy impacts of duct insulation cannot be directly modeled in CBECC-Res. CBECC-Res has a detailed duct system model; however, it does not evaluate thermal losses of ductwork within conditioned space. To simulate the conditions of an indirectly conditioned dropped soffit, where ducts are typically located in multifamily buildings, the used the unvented attic model. To isolate the unvented attic from exterior conditions, the Statewide CASE team added high levels of insulation at the roof level, removed insulation at the ceiling level, and modeled the roof with perfect solar reflectance and emissivity. The Statewide CASE Team reviewed temperature conditions within the unvented attic for the base model in Climate Zone 12. The Statewide CASE team found that the maximum temperature difference between the unvented attic and the zone below was 6°F and the average temperature difference was less than 1°F. Based on these results, the Statewide CASE Team concluded this was a reasonable approach to modeling this scenario. Since the majority of the thermal losses are from supply ductwork and it is not straightforward in CBECC-Res to evaluate distinct insulation values for supply and return ductwork, the Statewide CASE Team applied the same insulation value on both the supply and return side.

The impacts of the proposed submeasures are climate-specific; therefore, the Statewide CASE Team evaluated energy savings in each applicable climate zone.

Table 35: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change for Duct Insulation

Measure	Prototype ID	Climate Zone	Software	Parameter Name	Standard Design Parameter Value	Proposed Design Parameter Value
Ducts in unconditioned space	3-story loaded corridor (with vented attic) as proxy for 5-story & 10-story mixed-use	1-10, 12, 13	CBECC-Res	3rd Floor - Distribution System - Type	Ducts located in attic (Ventilated)	Ducts located in attic (Ventilated)
				3rd Floor - Distribution System - Duct Insulation R-value	R-8	R-6
Ducts in conditioned space	3-story loaded corridor	All	CBECC-Res	Distribution System - Type	Ducts located in attic (Unventilated)	Ducts located in attic (Unventilated)
				Distribution System - Duct Insulation R-value	R-6	R-4.2
				Attic – Sol. Reflectance	1	1
				Attic – IR Emittance	1	1
				Attic Roof Cons. U-factor (cavity R-value)	0.029 (R-60)	0.029 (R-60)

Submeasure G: Space Conditioning – Duct Leakage Testing

There are no existing requirements in Title 24, Part 6 that cover duct leakage testing for multifamily buildings four habitable stories and greater with ductwork directly or indirectly within conditioned space. The Statewide CASE Team modified the Standard Design to calculate energy impacts of the most common current design practice based on limited available data. The Standard Design duct leakage is based on the 2013 CASE Report for the 2013 code cycle when the mandatory requirement for low-rise residential buildings was proposed (Statewide CASE Team 2011). Feedback provided to the Statewide CASE Team was that in absence of a testing requirement, contractors do not necessarily take the time to seal ductwork. The Statewide CASE Team assumed that the existing condition for low-rise residential buildings prior to the current testing requirements apply to multifamily buildings four habitable stories and greater. The 2013 CASE Report used a basecase of 22 percent total leakage, which is based on the default assumptions in the 2008 Residential ACM Manual for untested duct systems built after June 1, 2001 (California Energy Commission 2008). A leakage to outside value of 12 percent was applied in this evaluation as equivalent to the 22 percent total leakage. This correlates with the ratio of total leakage to leakage to outside of the current low-rise residential code requirements of 12 percent total and six percent leakage to outside as well as test data from multifamily buildings up to three habitable stories in the Efficiency Characteristics and Opportunities for New California Homes study (California Energy Commission 2011).

Table 36 presents the parameters which were modified and what values were used in the Standard Design and Proposed Design. Specifically, the proposed conditions assume six percent leakage to outside and the basecase assumes 12 percent leakage to outside. The energy impacts cannot be directly modeled in CBECC-Com using the 5-story and 10-story prototypes because CBECC-Com does not currently include a duct model and neither thermal nor leakage impacts of ducts are considered. The Statewide CASE Team evaluated impacts of leakage to outside by adjusting heating and cooling system efficiencies according to seasonal distribution system efficiencies (DSEs) estimated from the ASHRAE Standard 152 Spreadsheet to represent typical duct losses (Lawrence Berkeley National Laboratory 2003). The Statewide CASE Team calculated DSE assuming all ductwork located in conditioned space, 40,000 Btu/h heating capacity, 24,000 Btu/h cooling capacity, 21.7 cfm per Btu/h heating fan flow, and 300 cfm per nominal ton. The Statewide CASE Team used an average across all 11 of the available California locations in the spreadsheet; variation by location was minimal (less than one percent). The Statewide CASE Team evaluated both the new construction and existing building prototypes.

The Statewide CASE Team compared the results using this approach to results from CBECC-Res' detailed duct model with the 3-story loaded corridor prototype. In CBECC-

Res when ducts are located in conditioned space the leakage rate to outside can be altered directly in the underlying CSE engine. The Statewide CASE Team evaluated six percent and 12 percent leakage. Comparing percent heating and cooling savings, the CBECC-Com results using the DSE approach align reasonably well for cooling energy use in most climate zones. In the mildest climates with low cooling loads the estimated cooling loads are higher in CBECC-Com than CBECC-Res and subsequently the cooling savings in those climates are higher. Heating savings are underestimated in CBCC-Com relative to CBECC-Res' duct model results.

Table 36: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change for Duct Leakage Testing

Prototype ID	Climate Zone	Software	Parameter Name	Standard Design Parameter Value	Proposed Design Parameter Value
5-story & 10-story (new construction & 10-story (existing)	All	CBECC-Com	Residential - Zone System - Cooling Coil - EER & SEER	12% leakage (multiply by factor of 0.8992)	6% leakage (multiply by factor of 0.9342)
			Residential - Zone System - Heating Coil - AFUE / HSPF	12% leakage (multiply by factor of 0.9260)	6% leakage (multiply by factor of 0.9633)

Submeasure H: Space Conditioning – Space Cooling Airflow Rate and Fan Efficacy

There are no existing requirements in Title 24, Part 6 that cover airflow and fan efficacy testing for multifamily buildings four habitable stories and greater. The Statewide CASE Team modified the Standard Design to calculate energy impacts of the most common current design practice based on limited available data. The Standard Design values are based on the 2013 CASE Report for the 2013 code cycle when the mandatory requirements for airflow and fan efficacy testing for low-rise residential buildings were proposed (Statewide CASE Team 2011). The 2013 CASE Report used a basecase of 300 cfm per ton of cooling capacity and 0.80 watts per cfm, which are based on the default assumptions in the 2008 Residential ACM Manual for untested cooling systems (California Energy Commission 2008).

Table 37 presents the parameters which were modified and what values were used in the Standard Design and Proposed Design. Specifically, the proposed conditions assume 350 cfm per ton and 0.45 watts per cfm. The 5-story and 10-story prototype buildings use gas furnaces for space heating, which under the current low-rise residential requirement triggers a lower threshold for fan efficacy of 0.45 watts per cfm. All other air handlers including heat pumps only required 0.58 watts per cfm. Where the proposed new construction requirements apply to entirely new or complete replacement space conditioning systems, the Statewide CASE Team used the new construction prototypes to evaluate savings for the alteration scenarios. Existing buildings, with less insulation and poorer performing assemblies and systems, typically result in greater energy impact savings from these measures than a new construction building, but the impact will be small and varied across the building stock.

The impacts of the proposed submeasures are climate-specific; therefore, the Statewide CASE Team evaluated energy savings in each applicable climate zone.

Table 37: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change for Space Cooling Airflow Rate and Fan Efficacy

Prototype ID	Climate Zone	Software	Parameter Name	Standard Design Parameter Value	Proposed Design Parameter Value
5-story & 10-story	All	CBECC-Com	Residential - Zone System - Fan – Flow Capacity	300 cfm/ton	350 cfm/ton
5-story & 10-story	All	CBECC-Com	Residential - Zone System - Fan – Power Per Flow	0.80 W/cfm	0.45 W/cfm

Submeasure I: Space Conditioning – Refrigerant Charge Verification

There are no existing requirements in Title 24, Part 6 that cover refrigerant charge verification for multifamily buildings four habitable stories and greater. The Statewide CASE Team modified the Standard Design to calculate energy impacts of the most common current design practice based on limited available data. The approach to evaluating the impact of refrigerant charge verification is based on the current approach for low-rise residential buildings as defined in the Residential ACM Reference Manual (California Energy Commission 2019). The Residential ACM Reference Manual describes that the software applies a factor to the cooling system compressor efficiency using a multiplier of 0.90 to account for the effect of improper refrigerant charge and 0.96 for proper charge. In CBECC-Res these factors are applied to the air conditioner compressor energy efficiency ratio (EER) without fan energy included. The EER that is directly input into CBECC-Com is the system EER, which includes fan energy. The factors that need to be applied to the system EER were calculated using the CBECC-Com assumptions as described in the Nonresidential ACM Reference Manual

(California Energy Commission 2019b) for how system EER is translated to compressor EER.[9]

Table 38 presents the parameters which were modified and what values were used in the Standard Design and Proposed Design. Specifically, the proposed conditions assume a factor of 0.965 applied to the system EER entered in CBECC-Com, which is equivalent to a factor of 0.96 applied to compressor EER. Similarly, the basecase conditions assume a factor of 0.913 applied to the system EER entered in CBECC-Com, which is equivalent to a factor of 0.90 applied to compressor EER. The Statewide CASE Team evaluated both the new construction and existing building prototypes.

The impacts of the proposed submeasures are climate-specific; therefore, The Statewide CASE Team evaluated energy savings in each applicable climate zone.

Table 38: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change for Refrigerant Charge Verification

Prototype ID	Climate Zone	Software	Parameter Name	Standard Design Parameter Value	Proposed Design Parameter Value
5-story & 10-story (new construction) & 10-story (existing)	All	CBECC-Com	Residential - Zone System - Cooling Coil – EER & SEER	No refrigerant charge verification (multiply by factor of 0.913)	Refrigerant charge verification (multiply by factor of 0.965)

4.2.2 Statewide Energy Savings Methodology

The per-unit energy impacts were extrapolated to statewide impacts using the Statewide Construction Forecasts that the Energy Commission provided. The Statewide Construction Forecasts estimate new construction that will occur in 2023, the first year that the 2022 Title 24, Part 6 requirements are in effect. It also estimates the size of the total existing building stock in 2023 that the Statewide CASE Team used to approximate savings from building alterations. The construction forecast provides construction (new construction and existing building stock) by building type and climate zone. The building types used in the construction forecast, Building Type ID, are not identical to the prototypical building types available in CBECC-Com and CBECC-Res, so the Energy Commission provided guidance on which prototypical buildings to use for each Building Type ID when calculating statewide energy impacts. Table 39 presents the prototypical

[9] Compressor EER is referred to as EER_{adj} in the Nonresidential ACM Reference Manual and is described in Section 5.7.5.2.

buildings and weighting factors that the Energy Commission requested the Statewide CASE Team use for each Building Type ID in the Statewide Construction Forecast.

Appendix A presents additional information about the methodology and assumptions used to calculate statewide energy impacts.

Table 39: Multifamily Building Types and Associated Prototype Weighting

Building Type ID from Statewide Construction Forecast	Building Prototype for Energy Modeling	Weighting Factors for Statewide New Construction Impacts Analysis	Weighting Factors for Statewide Existing Building Impact Analysis
Multifamily	2-Story	4%	40%
	3-Story	33%	18%
	5-Story	58%	18%
	10-Story	5%	24%

4.3 Per-Unit Energy Impacts Results

Energy savings and peak demand reductions per unit are presented by Submeasure in the subsections below. Because the Standard Design includes a gas forced air furnace and does not account for heat pump installation in a portion of the market, natural gas therm usage and/or savings may be overestimated. Based on project data from Gabel-Associates, Frontier Energy, and the California Multifamily New Homes program, 92 percent of recent multifamily new construction use heat pump space conditioning.

4.3.1 Building Envelope

4.3.1.1 Submeasure A: Envelope – Roof Assemblies

Energy savings and peak demand reduction per unit are presented in Table 40 through Table 43 for newly constructed buildings. The per-unit energy savings figures do not account for naturally occurring market adoption or compliance rates.

The results tables are presented in the following order:

- Non-Attic Option A for low-sloped roofs, including of 0.63 ASR and insulation values by climate zone, for two-story and three-story prototypes.
- Low-sloped roofs, increase to 0.63 ASR, for five-story and ten-story prototypes

The results in Table 40 apply to roughly 15 percent of garden style dwelling units. The majority of garden style dwelling units are built with an attic roof and therefore Option A is not applicable. per-unit electricity use for the first year is expected to range from an increase of 39.89 to a decrease of 78.86 kWh/yr, and natural gas use is expected to range from an increase of 3.68 to a decrease of 0.49 therms/yr depending upon climate zone. Demand is expected to range from an increase of 0.03 to a decrease of 0.05 kW depending upon climate zone. The statewide weighted average, based on projected construction volume, shows TDV savings.

Table 40: First-Year Energy Impacts Per Dwelling Unit– Low-Slope New Requirement of Insulation plus 0.63 ASR, 2-Story Prototype Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	(0.40)	(0.00)	(0.59)	(230)
2	2.07	0.00	0.04	29
3	(1.23)	(0.00)	(0.16)	(394)
4	(0.76)	(0.01)	0.49	(307)
5	(0.98)	(0.00)	(0.31)	(240)
6	(9.27)	(0.01)	(0.05)	(586)
7	(11.07)	(0.02)	(0.20)	(749)
8	7.69	0.00	0.04	557
9	67.71	0.05	(1.13)	2,515
10	78.86	0.05	(1.43)	2,294
11	75.75	0.04	(2.91)	2,554
12	4.53	(0.00)	(0.73)	10
13	(15.35)	(0.01)	(0.90)	(1,066)
14	51.34	0.04	(3.68)	1,286
15	(39.89)	(0.03)	(0.13)	(1,574)
16	0.96	(0.00)	(0.70)	(221)
Statewide Weighted Average	**21.65**	**0.01**	**(0.60)**	**609**

The results in Table 41 apply to roughly 56 percent of loaded corridor dwelling units. Many buildings for which this prototype is representative are built with an attic roof. Option A is not applicable across the entire population of loaded corridor buildings. Per-unit electricity use for the first year is expected to range from an increase of 65.07 to a decrease of 80.39 kWh/yr, and natural gas use increases are expected to range from 0.07 to 4.83 therms/yr depending upon climate zone. Demand is expected to range between an increase of 0.040 and a decrease of 0.04 kW depending upon climate zone. The statewide weighted average, based on projected construction volume, shows TDV savings.

Table 41: First-Year Energy Impacts Per Dwelling Unit– Low-Slope New Requirement of Insulation plus 0.63 ASR, 3-Story Prototype Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	(6.54)	0.00	(3.81)	(1,522)
2	6.01	0.00	(2.20)	(200)
3	(3.33)	(0.00)	(1.02)	(522)
4	2.26	(0.00)	(0.76)	(478)
5	(4.35)	(0.00)	(1.09)	(578)
6	(10.54)	(0.01)	(0.19)	(467)
7	(13.76)	(0.02)	(0.07)	(689)
8	15.89	0.00	(0.11)	1,078
9	68.38	0.04	(0.73)	2,511
10	80.39	0.04	(1.27)	2,311
11	65.53	0.03	(3.42)	1,856
12	13.36	0.00	(2.38)	(133)
13	(23.53)	(0.02)	(2.40)	(1,989)
14	37.20	0.03	(3.80)	744
15	(65.07)	(0.04)	(0.11)	(2,378)
16	(3.58)	(0.00)	(4.83)	(1,833)
Statewide Weighted Average	**22.40**	**0.01**	**(1.13)**	**525**

The results in Table 42 represent an estimated 35 percent of dwelling units in mid-rise buildings impacted by this submeasure. Per-unit electricity savings for the first year are expected to range from 6.99 to 11.36 kWh/yr, and natural gas is expected to increase very slightly, ranging from 0.04 to 0.21 therms/yr, depending upon climate zone. Demand is not expected to change for the mid-rise prototype.

Table 42: First-Year Energy Impacts Per Dwelling Unit– Low-Slope Increase to 0.63 ASR, 5-Story Prototype Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	N/A	N/A	N/A	N/A
2	N/A	N/A	N/A	N/A
3	N/A	N/A	N/A	N/A
4	N/A	N/A	N/A	N/A
5	N/A	N/A	N/A	N/A
6	N/A	N/A	N/A	N/A
7	N/A	N/A	N/A	N/A

8	N/A	N/A	N/A	N/A
9	8.82	0.00	(0.08)	240
10	9.01	0.00	(0.10)	225
11	6.99	0.00	(0.15)	181
12	N/A	N/A	N/A	N/A
13	8.78	0.00	(0.17)	182
14	7.05	0.00	(0.21)	172
15	11.36	0.00	(0.04)	291
16	N/A	N/A	N/A	N/A
Statewide Weighted Average	**3.27**	**0.00**	**(0.04)**	**85**

The results in Table 43 apply to high-rise dwelling units. Only 37 percent would be impacted by the change to select climate zones. Per-unit electricity savings for the first year are expected to range from 2.82 to 4.62 kWh/yr, and natural gas is expected to increase very slightly, ranging from 0.02 to 0.07 therms/yr, depending upon climate zone. Demand is not expected to change for the high-rise prototype.

Table 43: First-Year Energy Impacts Per Dwelling Unit– Low-Slope Increase to 0.63 ASR, 10-Story Prototype Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	N/A	N/A	N/A	N/A
2	N/A	N/A	N/A	N/A
3	N/A	N/A	N/A	N/A
4	N/A	N/A	N/A	N/A
5	N/A	N/A	N/A	N/A
6	N/A	N/A	N/A	N/A
7	N/A	N/A	N/A	N/A
8	N/A	N/A	N/A	N/A
9	3.63	0.00	(0.04)	98
10	3.76	0.00	(0.04)	94
11	2.83	0.00	(0.06)	71
12	N/A	N/A	N/A	N/A
13	3.64	0.00	(0.06)	78
14	2.97	0.00	(0.07)	78
15	4.62	0.00	(0.02)	114
16	N/A	N/A	N/A	N/A
Statewide Weighted Average	**1.35**	**0.00**	**(0.02)**	**35**

4.3.1.2 Submeasure B: Envelope – Wall U-Factor

Energy savings and peak demand reduction per unit are presented in Table 44 through Table 47 for newly constructed buildings. The per-unit energy savings figures do not account for naturally occurring market adoption or compliance rates.

The results tables are presented in the following order, in the “proposed category: application scenario, prototype” format:

- Framed, high fire rating (two- and three-hour) in low-rise: from adhering to residential to adhering to high-rise wood-framed requirements in select climate zones, three-story prototype (increased energy use)
- Framed, low fire rating (zero- and one-hour) in high-rise: from adhering to high-rise wood-framed to adhering to residential requirements in all climate zones, five-story prototype (some climate zones with decreased energy use, others with increased energy use)
- Framed, high fire rating (two- and three-hr) in high-rise: from adhering to residential to adhering to high-rise wood-framed requirements in select climate zones, five-story and ten-story prototype (increased energy use)

The Statewide CASE Team expects Increased energy use for some results. In these instances, the proposal’s purpose is to allow for appropriate unification between divergent 2019 nonresidential and residential code requirements.

Table 44 represents only three percent of low-rise loaded corridor buildings estimated to have high fire rating wood framing. The remaining 97 percent of low-rise loaded corridor will have no change in requirement. In Table 44, per-unit electricity use for the first year are expected to increase between 0.32 to 6.62 kWh/yr and natural gas use to increase between 0.07 and 1.72 therms/yr depending upon climate zone. No demand reduction is expected.

Table 44: First-Year Energy Impacts Per Dwelling Unit – Framed, High Fire Rating (2- and 3-hr), 3-Story Prototype Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	(3.57)	(0.00)	(1.72)	(689)
2	(2.04)	0.00	(0.92)	(400)
3	(1.83)	0.00	(0.58)	(278)
4	(0.80)	0.00	(0.52)	(233)
5	(1.74)	0.00	(0.52)	(222)
6	N/A	N/A	N/A	N/A
7	N/A	N/A	N/A	N/A
8	(0.32)	(0.00)	(0.07)	(89)
9	(0.64)	(0.00)	(0.21)	(167)
10	(1.90)	(0.00)	(0.35)	(244)
11	N/A	N/A	N/A	N/A
12	(2.11)	0.00	(0.83)	(444)
13	(6.62)	(0.00)	(0.70)	(533)
14	N/A	N/A	N/A	N/A
15	N/A	N/A	N/A	N/A
16	N/A	N/A	N/A	N/A
Statewide Weighted Average	**(1.24)**	**(0.00)**	**(0.37)**	**(213)**

In Table 45 represents the 39 percent of newly constructed mid-rise dwelling units expected to have low fire-rated, wood framed walls. Per-unit electricity use for the first year is expected to range from an increase of 21.76 to a decrease of 12.10 kWh/yr and natural gas use is expected to range from an increase of 3.30 to a decrease of 1.96 therms/yr depending upon climate zone. Demand is expected to increase up to 0.01 kW. The statewide weighted average, based on projected construction volume, shows electricity, natural gas, and TDV savings.

Table 45: First-Year Energy Impacts Per Dwelling Unit– Framed, Low Fire Rating (0- or 1- hour), 5-Story Prototype Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	4.00	(0.00)	1.96	825
2	7.85	(0.00)	1.32	729
3	2.93	(0.00)	0.87	347
4	4.70	(0.00)	0.77	447
5	3.98	(0.00)	0.88	312
6	1.34	(0.00)	(0.12)	(246)
7	1.55	(0.00)	(0.09)	(191)
8	4.95	(0.00)	0.32	262
9	5.66	0.00	0.43	322
10	7.99	0.00	0.61	393
11	(12.78)	(0.01)	(1.56)	(1,891)
12	9.70	0.00	1.47	915
13	12.10	0.00	0.94	711
14	(11.11)	(0.01)	(1.51)	(1,827)
15	(21.76)	(0.01)	(0.23)	(1,318)
16	(7.78)	(0.01)	(3.30)	(2,188)
Statewide Weighted Average	**4.44**	**(0.00)**	**0.53**	**340**

Table 46 represents the 55 percent of mid-rise multifamily buildings expected to have high fire-rated, wood framed walls. Because the proposed change will impact only a portion of climate zones with combined construction volume less than 19 percent of multifamily new construction, the wall U-factor changes will impact only ten percent of multifamily mid-rise dwelling units. Per-unit electricity use for the first year is expected to range from an increase of 21.76 to a decrease of 1.55 kWh/yr and natural gas use is expected increase, ranging from 0.09 to 3.30 therms/yr depending upon climate zone. Demand is expected to increase up to 0.01 kW.

Table 46: First-Year Energy Impacts Per Dwelling Unit– Framed, High Fire Rating, 5-Story Prototype Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	N/A	N/A	N/A	N/A
2	N/A	N/A	N/A	N/A
3	N/A	N/A	N/A	N/A
4	N/A	N/A	N/A	N/A
5	N/A	N/A	N/A	N/A
6	1.34	(0.00)	(0.12)	(246)
7	1.55	(0.00)	(0.09)	(191)
8	N/A	N/A	N/A	N/A
9	N/A	N/A	N/A	N/A
10	N/A	N/A	N/A	N/A
11	(12.78)	(0.01)	(1.56)	(1,891)
12	N/A	N/A	N/A	N/A
13	N/A	N/A	N/A	N/A
14	(11.11)	(0.01)	(1.51)	(1,827)
15	(21.76)	(0.01)	(0.23)	(1,318)
16	(7.78)	(0.01)	(3.30)	(2,188)
Statewide Weighted Average	**(0.54)**	**(0.00)**	**(0.10)**	**(128)**

Table 47 represents the 30 percent of high-rise dwelling units estimated to have framed walls. Because the proposed change will impact only a portion of climate zones with combined construction volume less than 19 percent of multifamily new construction, the wall U-factor changes will impact only six percent of multifamily high-rise dwelling units. Per-unit electricity use for the first year is expected to range from an increase of 32.93 to a decrease of 1.51 kWh/yr and natural gas use is expected increase, ranging from 0.07 to 4.93 therms/yr depending upon climate zone. Demand is expected to increase up to 0.02 kW.

Table 47: First-Year Energy Impacts Per Dwelling Unit– Framed, High Fire Rating, 10-Story Prototype Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	N/A	N/A	N/A	N/A
2	N/A	N/A	N/A	N/A
3	N/A	N/A	N/A	N/A
4	N/A	N/A	N/A	N/A
5	N/A	N/A	N/A	N/A
6	1.30	(0.00)	(0.11)	(35)
7	1.51	(0.00)	(0.07)	(9)
8	N/A	N/A	N/A	N/A
9	N/A	N/A	N/A	N/A
10	N/A	N/A	N/A	N/A
11	(20.88)	(0.02)	(2.57)	(1,752)
12	N/A	N/A	N/A	N/A
13	N/A	N/A	N/A	N/A
14	(18.74)	(0.01)	(2.42)	(1,620)
15	(32.93)	(0.02)	(0.42)	(1,457)
16	(12.35)	(0.01)	(4.93)	(1,644)
Statewide Weighted Average	**(0.99)**	**(0.00)**	**(0.14)**	**(93)**

4.3.1.3 Submeasure C: Envelope – Quality Insulation Installation

Energy use and peak demand change per unit for the 5-story and 3-story prototypes are presented in Table 48, Table 49, and Table 50. An estimated eight percent of total new multifamily construction occurs in buildings up to three habitable stories and greater than 40,000 ft^2 and would not be required to comply with QII. The savings losses per unit for the 3-story prototype are shown in Table 50. Per-unit electricity use for the first year are expected to range from an increase of 3.43 kWh/yr to 45.43 kWh/yr and natural gas use from an increase of 0.07 therms/yr to 4.92 therms/yr depending upon climate zone. Demand reduction impacts are negligible

Roughly 30 percent of all multifamily new construction occurs in buildings four or greater habitable stories with less than 40,000 ft^2 of conditioned floor area. Savings per dwelling unit for QII in the 5-story prototype are shown in Table 48. Per-unit electricity savings for the first year are expected to range from 10.40 kWh/yr to 30.85 kWh/yr and natural gas savings are expected to range from of 0.93 therms/yr to 6.47 therms/yr depending upon climate zone. Demand reduction impacts are negligible. Climate zones with large space cooling and/or space heating loads have the largest TDV energy savings. The proposed code change does not include Climate Zone 7.

Table 48: First-Year Energy Impacts Per Dwelling Unit– 5-Story Prototype Building – QII

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	10.40	0.00	6.47	1,900
2	19.43	0.00	4.72	1,905
3	15.92	0.00	4.91	1,698
4	15.90	0.00	3.25	1,478
5	18.44	0.00	5.09	1,711
6	27.61	0.00	3.72	1,707
7	N/A	N/A	N/A	N/A
8	18.15	0.01	2.01	1,200
9	18.59	0.01	2.27	1,286
10	21.64	0.01	2.53	1,400
11	19.17	0.01	2.82	1,482
12	21.80	0.01	3.96	1,869
13	29.22	0.01	3.09	1,855
14	18.45	0.01	2.74	1,431
15	30.85	0.01	0.93	1,295
16	14.17	0.00	4.83	1,652

Table 49: First-Year Energy Impacts Per Dwelling Unit– 3-Story Prototype Building – QII

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	(8.22)	0.00	(3.94)	(1,616)
2	(10.48)	0.00	(2.55)	(1,585)
3	(5.32)	0.00	(1.55)	(945)
4	(11.10)	0.00	(1.58)	(1,161)
5	(5.09)	0.00	(1.42)	(721)
6	(3.43)	0.00	(0.40)	(444)
7	N/A	N/A	N/A	N/A
8	(13.38)	0.00	(0.25)	(909)
9	(13.31)	0.00	(0.66)	(1,032)
10	(18.39)	0.00	(1.04)	(1,318)
11	(24.24)	0.00	(2.36)	(2,088)
12	(15.98)	0.00	(2.15)	(1,701)
13	(30.57)	0.00	(1.74)	(2,011)
14	(22.89)	0.00	(2.43)	(1,996)
15	(45.43)	0.00	(0.07)	(1,896)
16	(12.54)	0.00	(4.92)	(2,139)

4.3.1.4 Submeasure D: Envelope – Fenestration Properties

Energy savings and peak demand reduction per unit are presented Table 50 through Table 62 for new construction buildings and alterations. The per-unit energy savings figures do not account for naturally occurring market adoption or compliance rates. The results tables are presented in the following order:

- New Construction:
  - Curtainwall/ Storefronts category: 5-story and 10-story prototypes
  - NAFS Performance Class AW: 5-story and 10-story prototypes
  - A combined category *All Others* for Fixed, Operable Fenestrations, and Glazed Doors: 2-story, 3-story, 5-story, and 10-story prototypes
- Alterations:
  - Curtainwall/storefronts and glazed doors: high rise existing prototype
  - NAFS Performance Class AW: high rise existing prototype
  - Combined fixed and operable all others: high rise and low-rise existing prototypes

Table 50 and Table 51 show savings for curtainwall and storefront windows in newly constructed buildings. The change in Climate Zones 1 and 16 is estimated to impact 0.1 percent of all multifamily buildings. Per-unit electricity use for the first year are expected to range between an increase of 3.77 kWh/yr to a savings of 61.51 kWh/yr and natural gas savings from 3.22 to 8.47 therms/yr, depending upon prototype building and climate zone. Demand changes are expected to range between an increase of 0.02 kW and savings of 0 kW.

Table 50: First-Year Energy Impacts Per Dwelling Unit – Curtainwall/Storefronts, 5-Story Prototype Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	(26.14)	(0.02)	5.86	1,240
2	N/A	N/A	N/A	N/A
3	N/A	N/A	N/A	N/A
4	N/A	N/A	N/A	N/A
5	N/A	N/A	N/A	N/A
6	N/A	N/A	N/A	N/A
7	N/A	N/A	N/A	N/A
8	N/A	N/A	N/A	N/A
9	N/A	N/A	N/A	N/A
10	N/A	N/A	N/A	N/A
11	N/A	N/A	N/A	N/A
12	N/A	N/A	N/A	N/A
13	N/A	N/A	N/A	N/A
14	N/A	N/A	N/A	N/A
15	N/A	N/A	N/A	N/A
16	(3.77)	(0.00)	3.22	995

Table 51: First-Year Energy Impacts Per Dwelling Unit – Curtainwall/Storefronts, 10-Story Prototype Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	(61.51)	(0.02)	8.47	1,241
2	N/A	N/A	N/A	N/A
3	N/A	N/A	N/A	N/A
4	N/A	N/A	N/A	N/A
5	N/A	N/A	N/A	N/A
6	N/A	N/A	N/A	N/A
7	N/A	N/A	N/A	N/A
8	N/A	N/A	N/A	N/A
9	N/A	N/A	N/A	N/A
10	N/A	N/A	N/A	N/A
11	N/A	N/A	N/A	N/A
12	N/A	N/A	N/A	N/A
13	N/A	N/A	N/A	N/A
14	N/A	N/A	N/A	N/A
15	N/A	N/A	N/A	N/A
16	(14.67)	(0.00)	4.82	1,245

Table 52 and Table 53 show savings for Class AW windows in newly constructed buildings. The change in Climate Zones 1 and 16 is estimated to impact 0.1 percent of all multifamily buildings. Per-unit electricity use for the first year is expected to increase, in the range of 0.93 to 66.37 kWh/yr. Natural gas use savings are expected to range from 2.19 to 8.21 therms/yr depending upon prototype building and climate zone. Demand is expected to increase up to 0.03 kW depending on prototype building and climate zone.

Table 52: First-Year Energy Impacts Per Dwelling Unit – Combined Category *Performance Class AW*, 5-Story Prototype Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	(25.93)	(0.02)	5.99	1,626
2	N/A	N/A	N/A	N/A
3	N/A	N/A	N/A	N/A
4	N/A	N/A	N/A	N/A
5	N/A	N/A	N/A	N/A
6	N/A	N/A	N/A	N/A
7	N/A	N/A	N/A	N/A
8	N/A	N/A	N/A	N/A
9	N/A	N/A	N/A	N/A
10	N/A	N/A	N/A	N/A
11	N/A	N/A	N/A	N/A
12	N/A	N/A	N/A	N/A
13	N/A	N/A	N/A	N/A
14	N/A	N/A	N/A	N/A
15	N/A	N/A	N/A	N/A
16	(0.93)	(0.00)	2.19	833

Table 53: First-Year Energy Impacts Per Dwelling Unit – Combined Category *Performance Class AW* 10-Story Prototype Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	(66.37)	(0.03)	8.21	1,526
2	N/A	N/A	N/A	N/A
3	N/A	N/A	N/A	N/A
4	N/A	N/A	N/A	N/A
5	N/A	N/A	N/A	N/A
6	N/A	N/A	N/A	N/A
7	N/A	N/A	N/A	N/A
8	N/A	N/A	N/A	N/A
9	N/A	N/A	N/A	N/A
10	N/A	N/A	N/A	N/A
11	N/A	N/A	N/A	N/A
12	N/A	N/A	N/A	N/A
13	N/A	N/A	N/A	N/A
14	N/A	N/A	N/A	N/A
15	N/A	N/A	N/A	N/A
16	(5.48)	(0.00)	3.19	1,091

Table 54 and Table 55 show the energy impact per dwelling unit in Climate Zones 6 and 7 for an increase in U-factor for the combined all-others window category in new construction. When construction-weighted across prototypes and climate zones, this change is TDV positive. Per-unit electricity use for the first year are expected to decrease, with savings ranging from 3.87 to 7.82 kWh/yr. Natural gas use is expected to increase between 0.17 and 0.82 therms/yr depending upon prototype building and climate zone. Demand is expected to decrease up to 0.01 kW.

Table 54: First-Year Energy Impacts Per Dwelling Unit – Combined Category *All Others*, 2-Story Prototype Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	N/A	N/A	N/A	N/A
2	N/A	N/A	N/A	N/A
3	N/A	N/A	N/A	N/A
4	N/A	N/A	N/A	N/A
5	N/A	N/A	N/A	N/A
6	3.87	0.01	(0.82)	(105.6)
7	4.83	0.00	(0.45)	105.6
8	N/A	N/A	N/A	N/A
9	N/A	N/A	N/A	N/A
10	N/A	N/A	N/A	N/A
11	N/A	N/A	N/A	N/A
12	N/A	N/A	N/A	N/A
13	N/A	N/A	N/A	N/A
14	N/A	N/A	N/A	N/A
15	N/A	N/A	N/A	N/A
16	N/A	N/A	N/A	N/A

Table 55: First-Year Energy Impacts Per Dwelling Unit – Combined Category *All Others*, 3-Story Prototype Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	N/A	N/A	N/A	N/A
2	N/A	N/A	N/A	N/A
3	N/A	N/A	N/A	N/A
4	N/A	N/A	N/A	N/A
5	N/A	N/A	N/A	N/A
6	7.68	0.01	(0.44)	15.38
7	7.82	0.01	(0.17)	40.37
8	N/A	N/A	N/A	N/A
9	N/A	N/A	N/A	N/A
10	N/A	N/A	N/A	N/A
11	N/A	N/A	N/A	N/A
12	N/A	N/A	N/A	N/A
13	N/A	N/A	N/A	N/A
14	N/A	N/A	N/A	N/A
15	N/A	N/A	N/A	N/A
16	N/A	N/A	N/A	N/A

Table 56 represents an estimated 77 percent of mid-rise dwelling units with windows that are neither curtain wall nor Class AW windows.

Table 56: First-Year Energy Impacts Per Dwelling Unit – Combined Category *All Others*, 5-Story Prototype Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	(30.36)	(0.03)	11.74	3,696
2	(1.95)	(0.00)	4.06	1,701
3	(9.70)	(0.01)	2.91	914
4	(7.48)	(0.00)	2.24	960
5	(11.74)	(0.01)	2.49	600
6	(4.25)	(0.00)	0.47	105
7	(6.00)	(0.00)	0.36	(42)
8	(12.24)	(0.00)	0.86	234
9	(9.36)	0.00	1.25	505
10	(2.57)	0.00	1.72	804
11	12.73	0.01	4.38	2,417
12	1.31	0.00	3.63	1,740
13	12.80	0.01	3.09	1,937
14	8.80	0.01	3.88	2,073
15	28.07	0.01	0.59	1,389
16	3.85	(0.00)	9.91	3,930
Statewide Weighted Average	**(5.03)**	**(0.00)**	**2.13**	**887**

Table 57 represents the estimated 2 percent of high-rise dwelling units that have windows that are neither curtain wall nor Class AW windows.

Table 57: First-Year Energy Impacts Per Dwelling Unit – Combined Category *All Others* 10-Story Prototype Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	(91.82)	(0.04)	16.61	4,081
2	(16.45)	(0.01)	6.17	2,341
3	(28.85)	(0.01)	4.53	1,154
4	(22.91)	(0.00)	3.35	1,220
5	(32.02)	(0.01)	3.77	592
6	(10.97)	(0.00)	0.73	82
7	(11.78)	(0.00)	0.64	(81)
8	(28.50)	0.00	1.22	120
9	(24.22)	0.00	1.89	582
10	(14.59)	0.01	2.47	979
11	11.44	0.01	7.11	3,693
12	(9.79)	0.00	5.67	2,491
13	10.15	0.01	4.76	2,822
14	1.31	0.01	5.73	2,868
15	37.32	0.02	0.80	2,001
16	(11.16)	(0.01)	14.91	5,414
Statewide Weighted Average	**(18.05)**	**(0.00)**	**3.25**	**1,158**

For window alterations, the proposed measure achieves energy savings in high rise buildings for curtainwall/storefront, Class AW, and other windows (manufactured or site built). In low-rise buildings, the proposed unified multifamily requirements are less stringent than current code in Climate Zones 6 and 7 leading to overall energy losses only in Climate Zone 6.

In Table 58, representing curtain wall window replacements in high rise buildings, per-unit electricity savings for the first year are expected to range from 36.10 to 313.15 kWh/yr and natural gas use savings from 0.82 to 5.86 therms/yr depending upon prototype building and climate zone. Demand is expected to range between a 0.01 and 0.07 kW depending on prototype building and climate zone.

Table 58: First-Year Energy Impacts Per Dwelling Unit – Curtainwall/Storefronts, High-Rise Existing Prototype Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	81.67	0.01	5.86	3,984
2	43.69	0.01	3.62	2,986
3	273.04	0.04	4.31	8,510
4	43.95	0.01	2.07	2,509
5	306.21	0.04	4.21	8,290
6	41.74	0.01	1.03	1,577
7	36.10	0.01	0.82	1,179
8	47.50	0.01	1.14	2,022
9	53.32	0.01	1.39	2,400
10	61.44	0.02	1.73	2,619
11	66.19	0.03	3.49	3,801
12	50.26	0.02	2.99	3,062
13	64.94	0.03	2.44	3,429
14	76.33	0.02	3.36	3,876
15	109.99	0.03	0.84	3,889
16	313.15	0.07	1.97	7,476

Table 58 and Table 59 show per-unit electricity savings for replacement of Class AW windows. First year electricity savings are expected to range from 22.34 to 346.92 kWh/yr. Natural gas use is expected to range from an increase of 6.8 therms/yr to a decrease of 6.25 therms/yr depending upon prototype building and climate zone. Demand is expected to range between a 0.01 and 0.08 kW depending on prototype building and climate zone.

Table 59: First-Year Energy Impacts Per Dwelling Unit – Class AW Fixed, High-Rise Existing Prototype Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	81.67	0.01	5.86	3,984
2	27.55	0.01	6.17	3,754
3	255.81	0.04	6.25	8,915
4	22.34	0.01	3.58	2,812
5	288.69	0.03	6.09	8,604
6	41.74	0.01	1.03	2,617
7	36.10	0.01	0.82	2,123
8	47.50	0.01	1.14	2,979
9	29.89	0.01	2.36	2,442
10	41.34	0.02	2.92	2,822
11	53.20	0.03	5.88	4,788
12	31.24	0.02	5.09	3,712
13	50.86	0.03	4.22	4,183
14	65.26	0.02	5.79	4,867
15	105.24	0.04	1.37	4,446
16	313.15	0.07	1.97	7,476

Table 60: First-Year Energy Impacts Per Dwelling Unit – Class AW Operable, High-Rise Existing Prototype Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	82.51	0.02	(0.59)	1,565
2	66.74	0.02	1.46	2,778
3	299.15	0.05	2.53	8,501
4	74.46	0.02	0.73	2,743
5	336.13	0.05	2.60	8,412
6	85.88	0.02	0.41	2,401
7	80.64	0.01	0.32	2,063
8	87.32	0.02	0.51	2,708
9	92.48	0.02	0.55	3,014
10	98.36	0.02	0.73	3,089
11	88.45	0.03	1.39	3,502
12	76.08	0.02	1.17	2,970
13	88.66	0.03	0.84	3,325
14	107.50	0.03	1.20	3,773
15	141.56	0.03	0.38	4,334
16	346.92	0.08	(6.85)	4,777

Table 61: First-Year Energy Impacts Per Dwelling Unit – Combined All-Others, High-Rise Existing Prototype Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	73.51	0.00	16.16	7,718
2	68.79	0.01	11.79	7,350
3	277.91	0.04	10.29	11,100
4	57.80	0.02	6.87	5,551
5	315.06	0.03	9.97	10,567
6	66.00	0.01	2.34	2,804
7	53.84	0.01	1.87	1,946
8	57.04	0.02	3.51	3,774
9	71.44	0.02	4.43	4,804
10	95.23	0.03	5.51	5,559
11	125.21	0.05	11.39	9,477
12	80.59	0.03	9.78	7,367
13	123.09	0.05	8.06	8,322
14	137.40	0.04	10.96	9,330
15	226.50	0.07	2.54	8,792
16	352.52	0.07	12.48	12,411

Table 62, representing window replacements of manufactured or site built glazing in low rise buildings, per-unit electricity savings (from an increase in U-factor) for the first year are expected to range from of 6.16 to 6.88 kWh/yr. Natural gas use is estimated to increase in the range of 0.80 to 1.27 therms/yr. Demand is expected to increase by 0.01 kW.

Table 62: First-Year Energy Impacts Per Dwelling Unit – Combined All-Others, Prototype D Existing Low-Rise Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	N/A	N/A	N/A	N/A
2	N/A	N/A	N/A	N/A
3	N/A	N/A	N/A	N/A
4	N/A	N/A	N/A	N/A
5	N/A	N/A	N/A	N/A
6	6.16	0.01	(1.27)	(182.40)
7	6.88	0.01	(0.80)	67.20
8	N/A	N/A	N/A	N/A
9	N/A	N/A	N/A	N/A
10	N/A	N/A	N/A	N/A
11	N/A	N/A	N/A	N/A
12	N/A	N/A	N/A	N/A
13	N/A	N/A	N/A	N/A
14	N/A	N/A	N/A	N/A
15	N/A	N/A	N/A	N/A
16	N/A	N/A	N/A	N/A

4.3.1.5 Submeasure E: Envelope – Fenestration Area

No energy simulation was performed for this submeasure.

4.3.2 Space Conditioning

4.3.2.1 Submeasure F: Space Conditioning – Duct Insulation

This submeasure is not increasing stringency but does result in reduced stringency in certain situations. The energy and peak demand impacts per unit are presented in Table 63 through Table 65.

The change to duct insulation for ducts in unconditioned space impacts multifamily buildings four habitable stories and greater; however, because there is no duct model within CBECC-Com energy impacts the Statewide CASE Team evaluated the three-story loaded corridor prototype in CBECC-Res. Results per dwelling unit are presented in Table 63 for new construction and Table 64 for alterations. The energy impacts are expected to be similar for both the five-story and ten-story mixed use prototypes; the average dwelling unit size across all three prototypes is very similar but there are differences in envelope characteristics and modeling algorithms. Per-unit increase in energy use for the first year are expected to range from 2 to 11 kWh/yr and 0 to 0.5 therms/yr depending upon climate zone. Demand is expected to increase between 0 kW and 0.015 kW depending on climate zone.

Table 65 presents impacts for the change to duct insulation for ducts in conditioned space for the three-story loaded corridor prototype. Per-unit increase in energy use for the first year are expected up to 8 kWh/yr and up to 1.6 therms/yr depending upon climate zone. Demand is expected to increase between 0 kW and 0.007 kW depending on climate zone.

Table 63: First-Year Energy Impacts Per Dwelling Unit – Three-Story Loaded Corridor Prototype Building New Construction – Duct Insulation for Ducts in Unconditioned Space

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	N/A	N/A	N/A	N/A
2	N/A	N/A	N/A	N/A
3	(2)	(0.001)	(0.1)	(340)
4	N/A	N/A	N/A	N/A
5	(2)	(0.001)	(0.1)	(188)
6	(9)	(0.010)	(0.0)	(521)
7	N/A	N/A	N/A	N/A
8	N/A	N/A	N/A	N/A
9	N/A	N/A	N/A	N/A
10	N/A	N/A	N/A	N/A
11	N/A	N/A	N/A	N/A
12	N/A	N/A	N/A	N/A
13	N/A	N/A	N/A	N/A
14	N/A	N/A	N/A	N/A
15	N/A	N/A	N/A	N/A
16	N/A	N/A	N/A	N/A

Table 64: First-Year Energy Impacts Per Dwelling Unit – Three-Story Loaded Corridor Prototype Building Alteration – Duct Insulation for Ducts in Unconditioned Space

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	(5)	0.000	(0.5)	(295)
2	(6)	(0.004)	(0.3)	(787)
3	(2)	(0.001)	(0.1)	(340)
4	(7)	(0.008)	(0.1)	(400)
5	(2)	(0.001)	(0.1)	(188)
6	(9)	(0.010)	(0.0)	(521)
7	(10)	(0.015)	0.0	(552)
8	(9)	(0.010)	(0.0)	(430)
9	(9)	(0.010)	(0.0)	(424)
10	(10)	(0.011)	(0.1)	(491)
11	N/A	N/A	N/A	N/A
12	(8)	(0.007)	(0.2)	(515)
13	(11)	(0.009)	(0.2)	(575)
14	N/A	N/A	N/A	N/A
15	N/A	N/A	N/A	N/A
16	N/A	N/A	N/A	N/A

Table 65: First-Year Energy Impacts Per Dwelling Unit – Three-Story Loaded Corridor Prototype Building – Duct Insulation for Ducts in Conditioned Space

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	2	0.000	(1.6)	(492)
2	0	(0.001)	(0.8)	(339)
3	(0)	0.000	(0.5)	(208)
4	(2)	(0.003)	(0.4)	(394)
5	0	0.000	(0.4)	(186)
6	(2)	(0.004)	(0.1)	(175)
7	(2)	(0.004)	(0.0)	(153)
8	(3)	(0.004)	(0.1)	(186)
9	(3)	(0.005)	(0.2)	(230)
10	(3)	(0.005)	(0.3)	(284)
11	(3)	(0.006)	(0.7)	(459)
12	(1)	(0.004)	(0.7)	(383)
13	(4)	(0.007)	(0.5)	(416)
14	(5)	(0.006)	(0.7)	(481)
15	(8)	(0.006)	(0.0)	(317)
16	2	(0.003)	(1.5)	(470)

4.3.2.2 Submeasure G: Space Conditioning – Duct Leakage Testing

Energy savings and peak demand reduction per unit are presented in Table 66 through Table 67 for the five-story and ten-story mixed use new construction prototypes, respectively. Per-unit savings for the first year are expected to range from 4 to 92 kWh/yr and 0 to 1 therms/yr depending upon climate zone. Demand reduction/increase is expected to range between 0.001 kW and 0.021 kW depending on climate zone.

Energy savings and peak demand reduction per unit are presented in Table 68 for the ten-story mixed use existing building prototype. Per-unit savings for the first year are expected to range from 9 to 98 kWh/yr and 0 to 3 therms/yr depending upon climate zone. Demand reduction/increase is expected to range between 0.002 kW and 0.022 kW depending on climate zone.

The per-unit energy savings figures do not account for naturally occurring market adoption or compliance rates.

Table 66: First-Year Energy Impacts Per Dwelling Unit – 5-Story Mixed-Use Prototype Building New Construction – Duct Leakage Testing

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	4.3	0.002	0.6	307
2	23.0	0.008	0.4	1,054
3	14.5	0.004	0.2	620
4	30.0	0.010	0.2	1,176
5	16.0	0.004	0.2	481
6	33.1	0.008	0.1	955
7	30.6	0.008	0.0	820
8	41.9	0.011	0.0	1,304
9	41.3	0.012	0.1	1,344
10	46.0	0.013	0.1	1,423
11	46.8	0.016	0.4	1,795
12	36.2	0.012	0.4	1,443
13	54.6	0.017	0.3	1,958
14	46.4	0.014	0.3	1,677
15	86.8	0.021	0.0	2,599
16	25.3	0.008	1.0	944

Table 67: First-Year Energy Impacts Per Dwelling Unit – 10-Story Mixed-Use Prototype Building New Construction – Duct Leakage Testing

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	4.7	0.001	0.7	343
2	23.3	0.008	0.4	1,078
3	15.0	0.004	0.2	653
4	30.9	0.010	0.2	1,208
5	16.7	0.004	0.2	512
6	34.6	0.009	0.0	1,003
7	31.8	0.008	0.0	869
8	43.3	0.011	0.0	1,341
9	43.0	0.012	0.1	1,397
10	47.8	0.013	0.1	1,483
11	50.0	0.017	0.5	1,929
12	36.7	0.012	0.4	1,475
13	56.0	0.017	0.3	2,020
14	49.6	0.014	0.4	1,801
15	92.0	0.021	0.0	2,733
16	25.7	0.008	1.3	1,027

Table 68: First-Year Energy Impacts Per Dwelling Unit – 10-Story Mixed-Use Prototype Building Alteration– Duct Leakage Testing

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	9.2	0.002	2.1	849
2	25.2	0.007	1.7	1,603
3	20.9	0.004	1.2	1,106
4	31.3	0.009	0.9	1,555
5	23.6	0.004	1.1	940
6	32.7	0.008	0.3	1,131
7	29.3	0.007	0.2	916
8	43.5	0.010	0.4	1,595
9	43.5	0.012	0.5	1,690
10	49.5	0.013	0.7	1,849
11	52.2	0.018	1.9	2,526
12	38.2	0.013	1.5	1,975
13	58.5	0.018	1.3	2,531
14	51.5	0.014	1.6	2,339
15	97.7	0.022	0.3	3,226
16	32.9	0.008	3.4	1,855

4.3.2.3 Submeasure H: Space Conditioning – Space Cooling Airflow Rate and Fan Efficacy

Energy savings and peak demand reduction per unit are presented in Table 69 through Table 70 for the five-story and ten-story mixed use new construction prototypes, respectively. The per-unit energy savings figures do not account for naturally occurring market adoption or compliance rates. Per-unit savings for the first year are expected to range from 30 to 283 kWh/yr depending on climate zone. Per-unit gas use is expected to increase from zero to two therms/yr depending upon climate zone. Demand reduction/increase is expected to range between 0.012 kW and 0.073 kW depending on climate zone.

There is electricity, demand, and TDV savings in every climate zone. Natural gas use increases in all climate zones. This is a result of the lower fan power which reduces heat from fan operation that transfers to the supply air stream, subsequently increasing heating energy use.

Table 69: First-Year Energy Impacts Per Dwelling Unit – 5-Story Mixed-Use Prototype Building – Cooling Coil Airflow and Fan Efficacy

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	31.4	0.013	(0.7)	672
2	105.9	0.040	(0.6)	3,884
3	80.1	0.027	(0.3)	2,902
4	133.4	0.046	(0.2)	4,797
5	84.5	0.026	(0.2)	2,399
6	148.9	0.040	(0.1)	4,444
7	141.0	0.037	(0.0)	4,090
8	173.7	0.050	(0.1)	5,500
9	168.1	0.052	(0.1)	5,431
10	182.1	0.058	(0.2)	5,726
11	176.6	0.063	(0.7)	5,801
12	153.4	0.054	(0.6)	5,362
13	211.1	0.068	(0.5)	6,963
14	169.9	0.054	(0.5)	5,454
15	283.1	0.073	(0.0)	8,530
16	122.5	0.037	(1.8)	2,855

Table 70: First-Year Energy Impacts Per Dwelling Unit – 10-Story Mixed-Use Prototype Building – Cooling Coil Airflow and Fan Efficacy

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	30.4	0.012	(0.5)	658
2	96.2	0.036	(0.4)	3,404
3	78.7	0.025	(0.2)	2,772
4	123.8	0.042	(0.2)	4,267
5	82.1	0.025	(0.2)	2,393
6	144.7	0.038	(0.0)	4,238
7	137.6	0.036	(0.0)	3,989
8	161.8	0.044	(0.0)	4,967
9	154.8	0.045	(0.1)	4,825
10	164.7	0.050	(0.1)	5,070
11	158.6	0.053	(0.6)	4,996
12	136.2	0.046	(0.5)	4,594
13	184.1	0.055	(0.4)	5,898
14	152.1	0.046	(0.4)	4,737
15	238.9	0.056	(0.0)	6,984
16	111.3	0.033	(1.5)	2,544

4.3.2.4 Submeasure I: Space Conditioning – Refrigerant Charge Verification

Energy savings and peak demand reduction per unit are presented in Table 71 through Table 72 for the five-story and -story mixed use new construction prototypes, respectively. The per-unit energy savings figures do not account for naturally occurring market adoption or compliance rates. Per-unit savings for the first year are expected to range from 6 to 107 kWh/yr depending upon climate zone. There are no natural gas savings for this submeasure. Demand reduction/increase is expected to range between 0 kW and 0.022 kW depending on climate zone. While this measure is only proposed in Climate Zones 2 and 8 through 15, there are savings in all climate zones even where cooling loads are low.

Energy savings and peak demand reductions per unit are presented in Table 73 for the ten-story mixed use existing building prototype. Per-unit savings for the first year are expected to range from 11 to 133 kWh/yr depending upon climate zone. There are no natural gas savings for this submeasure. Demand reduction/increase is expected to range between 0.004 kW and 0.037 kW depending on climate zone.

While this measure is only proposed in Climate Zones 2 and 8 through 15, there are savings in all climate zones even where cooling loads are low. The per-unit energy savings figures do not account for naturally occurring market adoption or compliance rates.

Table 71: First-Year Energy Impacts Per Dwelling Unit – 5-Story Mixed-Use Prototype Building New Construction – Refrigerant Charge

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	5.6	0.004	0.0	146
2	30.1	0.013	0.0	1,251
3	22.9	0.008	0.0	876
4	40.3	0.015	0.0	1,525
5	24.6	0.008	0.0	724
6	47.5	0.013	0.0	1,432
7	44.7	0.012	0.0	1,317
8	55.7	0.016	0.0	1,785
9	54.9	0.017	0.0	1,815
10	58.8	0.019	0.0	1,879
11	57.3	0.023	0.0	2,180
12	45.4	0.018	0.0	1,750
13	66.2	0.024	0.0	2,399
14	58.9	0.020	0.0	2,068
15	106.7	0.029	0.0	3,430
16	30.4	0.013	0.0	753

Table 72: First-Year Energy Impacts Per Dwelling Unit – 10-Story Mixed-Use Prototype Building New Construction – Refrigerant Charge

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	6.8	0.004	0.0	176
2	29.1	0.012	0.0	1,121
3	23.9	0.008	0.0	865
4	38.8	0.014	0.0	1,373
5	25.8	0.008	0.0	764
6	47.4	0.013	0.0	1,391
7	45.2	0.012	0.0	1,324
8	53.1	0.014	0.0	1,637
9	51.9	0.015	0.0	1,631
10	54.4	0.016	0.0	1,684
11	51.9	0.019	0.0	1,869
12	41.7	0.016	0.0	1,510
13	58.6	0.019	0.0	2,022
14	54.4	0.017	0.0	1,820
15	90.5	0.022	0.0	2,797
16	30.3	0.012	0.0	736

Table 73: First-Year Energy Impacts Per Dwelling Unit – 10-Story Mixed-Use Prototype Building Alterations – Refrigerant Charge

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	10.7	0.004	0.0	231
2	32.0	0.012	0.0	1,475
3	28.3	0.007	0.0	1,037
4	41.2	0.015	0.0	1,770
5	32.5	0.007	0.0	824
6	43.6	0.013	0.0	1,388
7	39.1	0.011	0.0	1,117
8	58.4	0.017	0.0	2,029
9	58.0	0.019	0.0	2,095
10	66.2	0.023	0.0	2,210
11	67.9	0.030	0.0	2,619
12	49.5	0.021	0.0	2,047
13	77.5	0.030	0.0	2,918
14	67.4	0.024	0.0	2,479
15	133.0	0.037	0.0	4,328
16	39.3	0.013	0.0	885

5. Cost and Cost Effectiveness

5.1 Building Envelope

5.1.1 Energy Cost Savings Methodology

Energy cost savings were calculated by applying the TDV energy cost factors to the energy savings estimates that were derived using the methodology described in Section 4.2. TDV is a normalized metric to calculate energy cost savings that accounts for the variable cost of electricity and natural gas for each hour of the year, along with how costs are expected to change over the period of analysis (30 years for 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 across all submeasures and multifamily building prototypes. The TDV cost impacts are presented in 2023 present value dollars and represent the energy cost savings realized over 30 years. The TDV methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods. There are minimal peak savings attributed to the code change.

The alterations proposal for fenestration properties differs from the new construction requirements. The energy cost savings results are derived from prototype modeling with vintage building prototypes.

5.1.2 Energy Cost Savings Results

Per-unit energy cost savings for newly constructed buildings and alterations realized over the 30-year period of analysis are presented in 2023 dollars in Table 74 through

Table 89. Per-unit energy cost savings results in nominal collars are presented in Appendix H.

5.1.2.1 Submeasure A: Envelope – Roof Assemblies

Table 74: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit– New Construction – Roof Assembly Change, 2-Story Prototype Building

Climate Zone	30-Year TDV Electricity Cost Savings (2023 PV$)	30-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 30-Year TDV Energy Cost Savings (2023 PV$)
1	($1.66)	($38.20)	($39.86)
2	$3.32	$1.66	$4.98
3	($56.47)	($11.63)	($68.09)
4	($83.04)	$29.89	($53.15)
5	($21.59)	($19.93)	($41.52)
6	($97.99)	($3.32)	($101.31)
7	($116.26)	($13.29)	($129.54)
8	$93.00	$3.32	$96.33
9	$506.54	($71.41)	$435.13
10	$488.28	($91.34)	$396.93
11	$624.46	($182.69)	$441.77
12	$49.82	($48.16)	$1.66
13	($126.22)	($58.13)	($184.35)
14	$456.72	($234.17)	$222.55
15	($264.07)	($8.30)	($272.37)
16	$4.98	($43.18)	($38.20)
Statewide Weighted Average	**$144**	**-$39**	**$105**

Table 75: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit– New Construction – Roof Assembly Change, 3-Story Prototype Building

Climate Zone	30-Year TDV Electricity Cost Savings (2023 PV$)	30-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 30-Year TDV Energy Cost Savings (2023 PV$)
1	($34.60)	($228.74)	($263.34)
2	$99.96	($134.56)	($34.60)
3	($26.91)	($63.43)	($90.34)
4	($34.60)	($48.06)	($82.66)
5	($32.68)	($67.28)	($99.96)
6	($69.20)	($11.53)	($80.73)
7	($113.41)	($5.77)	($119.18)
8	$194.14	($7.69)	$186.46
9	$478.63	($44.21)	$434.42
10	$478.63	($78.81)	$399.82
11	$532.46	($211.44)	$321.01
12	$124.94	($148.01)	($23.07)
13	($196.07)	($148.01)	($344.08)
14	$363.30	($234.51)	$128.79
15	($403.67)	($7.69)	($411.36)
16	($24.99)	($292.18)	($317.17)
Statewide Weighted Average	**$161**	**-$70**	**$91**

Table 76: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit– New Construction – Low-Slope Roof Products, 5-Story Prototype Building

Climate Zone	30-Year TDV Electricity Cost Savings (2023 PV$)	30-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 30-Year TDV Energy Cost Savings (2023 PV$)
1	N/A	N/A	N/A
2	N/A	N/A	N/A
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	N/A	N/A	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	N/A	N/A	N/A
9	$45.36	($3.89)	$41.47
10	$43.80	($4.80)	$39.00
11	$38.47	($7.12)	$31.35
12	N/A	N/A	N/A
13	$42.50	($10.96)	$31.54
14	$39.58	($9.89)	$29.68
15	$53.14	($2.85)	$50.29
16	N/A	N/A	N/A

Table 77: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit– New Construction – Low-Slope Roof Products, 10-Story Prototype Building

Climate Zone	30-Year TDV Electricity Cost Savings (2023 PV$)	30-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 30-Year TDV Energy Cost Savings (2023 PV$)
1	N/A	N/A	N/A
2	N/A	N/A	N/A
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	N/A	N/A	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	N/A	N/A	N/A
9	$18.54	($1.67)	$16.87
10	$18.17	($1.91)	$16.26
11	$15.02	($2.65)	$12.37
12	N/A	N/A	N/A
13	$17.57	($4.16)	$13.42
14	$16.69	($3.13)	$13.55
15	$21.01	($1.21)	$19.80
16	N/A	N/A	N/A

5.1.2.2 Submeasure B: Envelope – Wall U-Factor

Table 78: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit– New Construction – Framed (Wood or Metal) and Others, ≤ 1 hr Fire Rating, 5-Story Prototype Building

Climate Zone	30-Year TDV Electricity Cost Savings (2023 PV$)	30-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 30-Year TDV Energy Cost Savings (2023 PV$)
1	$18.98	$102.86	$121.84
2	$41.60	$71.13	$112.74
3	$3.03	$47.20	$50.22
4	$28.35	$41.81	$70.16
5	($4.44)	$47.42	$42.99 $
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	$25.25	$17.60	$42.85
9	$28.30	$23.84	$52.14
10	$27.96	$33.94	$61.89
11	N/A	N/A	N/A
12	$64.99	$79.98	$144.97
13	$62.92	$51.29	$114.21
14	N/A	N/A	N/A
15	N/A	N/A	N/A
16	N/A	N/A	N/A

5.1.2.3 Submeasure C: Envelope – Quality Insulation Installation

Table 79: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit– New Construction - 5-Story Prototype Building – QII

Climate Zone	30-Year TDV Electricity Cost Savings (2023 PV$)	30-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 30-Year TDV Energy Cost Savings (2023 PV$)
1	$51.81	$276.97	$328.78
2	$123.62	$206.00	$329.63
3	$80.04	$213.74	$293.78
4	$110.73	$145.01	$255.74
5	$75.82	$220.10	$295.92
6	$127.40	$167.98	$295.38
7	N/A	N/A	N/A
8	$115.40	$92.25	$207.65
9	$119.18	$103.32	$222.50
10	$126.51	$115.69	$242.20
11	$128.29	$128.11	$256.41
12	$146.08	$177.30	$323.38
13	$179.65	$141.21	$320.87
14	$122.29	$125.34	$247.62
15	$180.10	$43.96	$224.06
16	$70.26	$215.59	$285.85

5.1.2.4 Submeasure D: Envelope – Fenestration Properties

Table 80: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit – New Construction - Curtainwall/Storefronts, 5-Story Prototype Building

Climate Zone	30-Year TDV Electricity Cost Savings (2023 PV$)	30-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 30-Year TDV Energy Cost Savings (2023 PV$)
1	($90.07)	$304.55	$214.48
2	N/A	N/A	N/A
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	N/A	N/A	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	N/A	N/A	N/A
12	N/A	N/A	N/A
13	N/A	N/A	N/A
14	N/A	N/A	N/A
15	N/A	N/A	N/A
16	$0.65	$171.46	$172.11

Table 81: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit – New Construction - Curtainwall/Storefronts, 10-Story Prototype Building

Climate Zone	30-Year TDV Electricity Cost Savings (2023 PV$)	30-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 30-Year TDV Energy Cost Savings (2023 PV$)
1	($224.12)	$438.74	$214.62
2	N/A	N/A	N/A
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	N/A	N/A	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	N/A	N/A	N/A
12	N/A	N/A	N/A
13	N/A	N/A	N/A
14	N/A	N/A	N/A
15	N/A	N/A	N/A
16	($39.75)	$255.08	$215.33

Table 82: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit – New Construction - Combined Category *Performance Class AW*, 5-Story Prototype Building

Climate Zone	30-Year TDV Electricity Cost Savings (2023 PV$)	30-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 30-Year TDV Energy Cost Savings (2023 PV$)
1	($93.16)	$374.51	$281.35
2	N/A	N/A	N/A
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	N/A	N/A	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	N/A	N/A	N/A
12	N/A	N/A	N/A
13	N/A	N/A	N/A
14	N/A	N/A	N/A
15	N/A	N/A	N/A
16	$5.01	$139.14	$144.16

Table 83: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit – New Construction - Combined Category *Performance Class AW*, 10-Story Prototype Building

Climate Zone	30-Year TDV Electricity Cost Savings (2023 PV$)	30-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 30-Year TDV Energy Cost Savings (2023 PV$)
1	($249.05)	$513.06	$264.00
2	N/A	N/A	N/A
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	N/A	N/A	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	N/A	N/A	N/A
12	N/A	N/A	N/A
13	N/A	N/A	N/A
14	N/A	N/A	N/A
15	N/A	N/A	N/A
16	($13.51)	$202.29	$188.78

Table 84: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit – New Construction - Combined Category *All Others*, 5-Story Prototype Building

Climate Zone	30-Year TDV Electricity Cost Savings (2023 PV$)	30-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 30-Year TDV Energy Cost Savings (2023 PV$)
1	($99.23)	$738.67	$639.45
2	$32.70	$261.59	$294.29
3	($29.77)	$187.84	$158.07
4	$21.03	$145.10	$166.14
5	($55.96)	$159.82	$103.86
6	($12.79)	$30.88	$18.09
7	($30.75)	$23.47	($7.28)
8	($15.89)	$56.41	$40.52
9	$6.13	$81.18	$87.31
10	$27.28	$111.77	$139.06
11	$134.20	$284.00	$418.19
12	$65.90	$235.07	$300.96
13	$134.59	$200.47	$335.06
14	$106.86	$251.79	$358.65
15	$201.49	$38.75	$240.24
16	$48.51	$631.33	$679.84

Table 85: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit – New Construction - Combined Category *All Others*, 10-Story Prototype Building

Climate Zone	30-Year TDV Electricity Cost Savings (2023 PV$)	30-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 30-Year TDV Energy Cost Savings (2023 PV$)
1	($339.43)	$1,045.43	$706.00
2	$6.76	$398.23	$405.00
3	($92.48)	$292.16	$199.68
4	($6.06)	$217.04	$210.98
5	($139.52)	$241.93	$102.42
6	($68.81)	$97.46	$28.65
7	($114.22)	$84.97	($29.25)
8	($58.53)	$79.36	$20.83
9	($22.20)	$122.95	$100.75
10	$8.59	$160.79	$169.38
11	$178.20	$460.71	$638.91
12	$63.12	$367.78	$430.90
13	$178.78	$309.38	$488.16
14	$124.02	$372.12	$496.14
15	$293.88	$52.29	$346.17
16	($10.36)	$946.96	$936.60

Table 86: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit – Alterations - Curtainwall/Storefronts, High-Rise Existing Prototype Building

Climate Zone	30-Year TDV Electricity Cost Savings (2023 PV$)	30-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 30-Year TDV Energy Cost Savings (2023 PV$)
1	$318.67	$370.63	$689.30
2	$287.06	$229.45	$516.50
3	$1,197.23	$274.92	$1,472.15
4	$301.18	$132.86	$434.04
5	$1,165.84	$268.36	$1,434.20
6	$206.17	$66.59	$272.76
7	$150.36	$53.69	$204.05
8	$275.99	$73.89	$349.88
9	$325.51	$89.67	$415.18
10	$341.12	$111.91	$453.04
11	$433.01	$224.50	$657.50
12	$337.86	$191.85	$529.70
13	$435.88	$157.41	$593.29
14	$454.43	$216.06	$670.49
15	$618.30	$54.55	$672.85
16	$1,163.18	$130.16	$1,293.34

Table 87: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit– Alterations Class AW Fixed, High-Rise Existing Prototype Building

Climate Zone	30-Year TDV Electricity Cost Savings (2023 PV$)	30-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 30-Year TDV Energy Cost Savings (2023 PV$)
1	$318.67	$370.63	$689.30
2	$258.43	$391.10	$649.53
3	$1,143.64	$398.71	$1,542.35
4	$256.87	$229.68	$486.56
5	$1,101.60	$386.90	$1,488.51
6	$248.10	$204.65	$452.76
7	$188.74	$178.47	$367.20
8	$312.95	$202.46	$515.41
9	$270.06	$152.37	$422.42
10	$298.96	$189.32	$488.28
11	$450.09	$378.17	$828.26
12	$315.99	$326.25	$642.23
13	$451.37	$272.22	$723.59
14	$469.50	$372.57	$842.07
15	$679.82	$89.30	$769.13
16	$1,163.18	$130.16	$1,293.34

Table 88: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit– Alterations Class AW Operable, High-Rise Existing Prototype Building

Climate Zone	30-Year TDV Electricity Cost Savings (2023 PV$)	30-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 30-Year TDV Energy Cost Savings (2023 PV$)
1	$302.41	($31.61)	$270.81
2	$388.26	$92.29	$480.55
3	$1,308.93	$161.82	$1,470.75
4	$427.80	$46.65	$474.45
5	$1,289.23	$165.96	$1,455.19
6	$388.67	$26.74	$415.42
7	$335.63	$21.25	$356.88
8	$435.56	$32.86	$468.42
9	$485.59	$35.81	$521.39
10	$487.12	$47.24	$534.36
11	$516.44	$89.34	$605.79
12	$439.16	$74.58	$513.74
13	$521.35	$53.81	$575.15
14	$575.67	$77.12	$652.80
15	$724.64	$25.13	$749.77
16	$1,253.34	($426.97)	$826.37

Table 89: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit– Alterations - Combined All Others, High-Rise Existing Prototype Building

Climate Zone	30-Year TDV Electricity Cost Savings (2023 PV$)	30-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 30-Year TDV Energy Cost Savings (2023 PV$)
1	$320.16	$1,015.00	$1,335.16
2	$523.38	$748.22	$1,271.60
3	$1,263.70	$656.67	$1,920.38
4	$519.06	$441.25	$960.31
5	$1,194.24	$633.89	$1,828.13
6	$333.52	$151.61	$485.13
7	$214.80	$121.85	$336.64
8	$424.66	$228.20	$652.86
9	$544.49	$286.68	$831.17
10	$604.22	$357.43	$961.65
11	$906.01	$733.53	$1,639.55
12	$646.25	$628.29	$1,274.53
13	$919.57	$520.22	$1,439.79
14	$907.94	$706.23	$1,614.17
15	$1,355.04	$166.02	$1,521.06
16	$1,350.83	$796.28	$2,147.11

5.1.2.5 Submeasure E: Envelope – Fenestration Area

The Statewide CASE Team did not calculate energy cost savings for this submeasure because it has no energy savings impact.

5.1.3 Incremental First Cost

Incremental first cost is the initial cost to adopt more efficient equipment or building practices when compared to the cost of an equivalent baseline project. Therefore, it was important that the Statewide CASE Team consider first costs in evaluating overall measure cost effectiveness. Incremental first costs are based on data available today and can change over time as markets evolve and professionals become familiar with new technology and building practices.

5.1.3.1 Submeasure A: Envelope – Roof Assembles

The Statewide CASE Team assessed roofing product incremental costs for buildings up to four habitable stories by comparing the costs of roofing products that achieve the proposed and baseline aged solar reflectance levels. Market study results from the companion Nonresidential High Performance Envelope CASE Report (California Codes and Standards Enhancement (CASE) initiative 2020) indicate that installation costs of the same type of roofing were the same regardless of the reflective level of the products.

A 2015-16 National Roofing Contractor Association survey indicates that at 40 percent, Thermoplastic olefin (TPO) has the highest market share for low-sloped roof applications (International Institute of Building Enclosure Consultants n.d.). Raising the ASR level from 0.55 to 0.63 involves choosing TPO roofing products of different colors. There are no incremental costs for raising the ASR from 0.55 to 0.63 (for select climate zones) because multiple TPO materials available in the RS Means database achieve the proposed 0.63 level with no pricing difference associated with the product colors.

Because Option A adds a prescriptive compliance option for non-attic roofs and does not increase stringency for buildings up to three habitable stories, costs and cost-effectiveness analysis are not presented.

5.1.3.2 Submeasure B: Envelope – Wall U-Factor

The Statewide CASE Team assessed the incremental cost of different wall assembly U-factors by calculating the change in wall construction costs of assemblies to meet the proposed requirements. The proposed stringency change is in Climate Zones 1 through 5, 8 through 10, 12, and 13, from an assembly U-factor of 0.059 to a U-factor of 0.051 for low-fire rated wood-framed walls in buildings with four or more habitable stories. Assuming the most common wood framing methods, achieving either assembly U-factor requires some level of continuous rigid external insulation regardless of the external cladding methodology. A builder can accomplish the proposed change entirely through an increase in rigid external continuous insulation thickness. A construction assembly that uses 2x6 walls at 16 inches on center, and employing R-19 cavity fill achieves an assembly u-factor of 0.059 with a 3/8" extruded polystyrene (EPS) rigid external layer at 1.5 pounds per cubic foot density, constituting an external insulation level of R-1.635. To achieve assembly U-factor of 0.059 assumes a cladding method that is at least R-0.18, which is the R-value of one-coat stucco. Though stucco is not viable above five stories, all other cladding materials have at least R-0.18. An otherwise similar wall with a 1-inch thick 1.5 lbs/cf EPS of R-4.35 achieves a U-factor of 0.050. The Statewide CASE Team determined the incremental cost by consulting with a major EPS manufacturer in California and confirmed the cost sales sheet data from other manufacturers. The incremental cost difference between these EPS layers is estimated at \$0.15 per ft^2.

There is no additional labor cost between installation of 3/8" thick EPS and 1" thick EPS. The same common fasteners and installation methods apply to both products.

For the purpose of cost-effectiveness calculations, the Statewide CASE Team converted the per square foot wall assembly incremental measure costs to a per dwelling unit cost based on the prototype's features.

5.1.3.3 Submeasure C: Envelope – Quality Insulation Installation

The incremental first cost of the QII measure is equal to the verification cost of HERS rating. There are no additional material costs or installation costs. The Statewide CASE Team derived verification costs by estimating the time it would take to conduct the verification protocol on larger multifamily buildings, priced at HERS Rater labor rates with appropriate markups for profit and overhead. The Statewide CASE Team accounted for the additional costs for vehicular travel to and from the work site for each visit using the reimbursement rates of $0.55 per mile traveled.

For each data point in the cost estimation – labor rates, verification time, travel distance, and surface area coverage – the Statewide CASE Team chose conservative values (i.e. leaning towards the higher end of potential the cost spectrum). The estimates and their methodology were informed by interviews and email correspondence with multiple HERS Raters, energy consultants, HERS Providers, and by the 2019 CASE Report on QII (Dakin and German 2017). The Statewide CASE Team received cost method input from a total of seven SMEs. The cost estimate uses the following assumptions:

1. A HERS Rater's field time would be billed at $80 per hour.
    a. The Statewide CASE Team developed and applied the climate zone labor rate adjustment based on RSMeans data across CASE topics.
2. The HERS Rater would verify 100 percent of the wall area.
3. The air sealing verification would take 20 minutes for a 500 ft^2 of wall area (the approximate average wall area of a typical multifamily dwelling unit).
4. The insulation installation verification would take 30 minutes for a 500 ft^2 of wall area.
    a. These time estimations encompass the average time to conduct wall inspections, attic/roof inspections, floor-over-unconditioned space inspections, documentation of findings, transition between spaces, and communication of verification-revealed failures with installing trades to allow for mitigation.
5. An average 100-mile round trip travel distance per site visit.
6. A maximum site visit time of five hours.

The Statewide CASE Team accounted for an additional trip per every two otherwise required site visits. This is to account for the extra trips necessary to manage staged construction timing considerations, such as seeing wall areas before bathtubs or cabinetry are installed. The Statewide CASE Team did not create an estimate for QII on the 10-Story Mixed Use prototype based on the assumption that negligible instances of high-rise buildings would be under 40,000 ft^2.

The method results in the following QII inspection costs per dwelling unit, by climate zone:

Table 90: Incremental Costs for Full QII Inspection per Dwelling Unit

Climate Zone	5-Story Mixed Use
1	$79
2	$87
3	$89
4	$90
5	$74
6	$76
7	$72
8	$74
9	$76
10	$74
11	$77
12	$78
13	$76
14	$73
15	$74
16	$77

5.1.3.4 Submeasure D: Envelope – Fenestration Properties

The Statewide CASE Team derived window costs from several factors. Some cost factors are directly correlated with thermal performance such as argon fill, use of low-e coatings, warm edge spacers, and the use of thermal breaks. Other cost factors, like the percentage of surface area that is framing or sash and the framing material, indirectly impact U-factor and SHGC, even though the design choice is driven by aesthetic, functionality, or window durability reasons. The technology improvements that impact thermal properties have intertwined and inconsistent impact from window to window. The Statewide CASE Team's proposed use of an area-weighted blend across fixed and operable window types for all new construction and additions give designers flexibility to meet prescriptive code across the spectrum of aesthetic, functional, and durability requirements. Designers will use different strategies to meet these requirements while considering overall lowest cost. The area-weighted average and associated costs are a blend of fixed and operable window costs. Costs may be considered at top-down aggregate level across a range of window products employing various blends of technology improvements, or by looking at specific technology improvements.

To derive incremental cost changes, the Statewide CASE Team leveraged cost data compiled by the ASHRAE 90.1 committee from their 2016 and 2019 updates, previous

Title 24 CASE research data, and information from SMEs. The ASHRAE data evaluated the incremental technical improvement cost for 27 specific technical window improvements that impact U-factor and SHGC such as use of argon fill, extra low-e coating layers, and warm edge spacers. The data is presented as per ft^2 of window area, and itself references three different cost studies: the 2013 Title 24, Part 6 CASE research, ASHRAE's 2008 cost analysis, and manufacturer supplied cost data from F&G Windows. The ASHRAE committee came to consensus opinion across these sources. The committee also compiled window costs and technology measures used for 319 window-wall product options.

The AHSRAE data was from window-walls only, which have minimal thermal bridging. The Statewide CASE Team shifted U-factor performance level downward in using the data to represent other window types. For example, an operable aluminum framed Performance Class AW window will perform at a U-factor approximately 0.12 lower than the same glazing product in the window wall-data. SMEs supported the shift methodology and scale. Therefore, to asses operable Performance Class AW change from U-factor of 0.46 to 0.44, the Statewide CASE Team looked at incremental costs of products from U-factor of 0.34 to 0.32 within the ASHRAE data.

From the available data, the Statewide CASE Team assessed incremental measures costs using these two methodologies:

- Market-Minimum: This method compared the lowest cost product available at each of the assessed U-factor points to determine the incremental cost.
- Aggregate technical measure: This method looked at the costs of specific technical measures that achieve the proposed U-factor and SHGC shift from a baseline window assumption.

New Construction

For curtain walls the market-minimum method yielded a cost of $0.24 and the aggregated technical measure cost yielded a total of $1.00. To be conservative and consistent with the nonresidential Statewide CASE approach, the Statewide CASE Team applied a cost of $1.00 per square foot. For Climate Zone 1, the Statewide CASE Team did not assess a cost savings relative to the shift from 0.26 to 0.35.

For Performance Class AW windows, the Statewide CASE Team looked at incremental costs for operable and fixed windows independently, and then blended the costs together for a typical weighted area average. For the proposed shift from a weighted average U-factor of 0.40 and SHGC of 0.24 to U-factor 0.38 and SHGC 0.24 the market minimum method yielded a cost of $1.09, and aggregate technical measure costs were $1.00. To be conservative, the Statewide CASE Team applied a cost of $1.09 per square foot.

The ASHRAE data is not applicable for the All Others window category. The framing material and available technological improvement presumptions represented in data specific to curtainwall windows cannot be correlated consistently to vinyl framed windows. The lowest cost punched window products on the market that achieve current U-factor and SHGC standards are vinyl framed, dual-pane, with a triple-silver low-e coating, aluminum spacers and air fill. Such a window has a U-factor of 0.34 and SHGC of 0.23. Adding a warm-edge spacer improves the window’s U-factor to the proposed value of 0.30. The estimated cost of a warm edge spacer in a typical multifamily window according 2013 Title 24, Part 6 CASE research is $0.36 per square foot.

This data only includes product costs, as there are no labor impacts. For the purpose of cost-effectiveness calculations, the Statewide CASE Team converted the per square foot window area incremental measure costs to a per dwelling unit cost based on each prototype’s features.

Alterations and Additions

For curtainwall and Performance Class AW window types, the Statewide CASE Team exclusively used the market-minimum method. The windows that meet the proposed values are well within the range of normal, ubiquitously available products and do not push the technical limitations for dual pane glazing. The market minimum approach is most appropriate for alterations to reflect the costs a builder will face to achieve the proposed values. Selection of higher priced windows would be driven by aesthetic or other functional choices, and not energy code compliance.

The proposed change in SHGC goes beyond what would occur as a second order impact from the same U-factor reduction technologies. In Climate Zone 12 for example, current code has a SHGC requirement of 0.31. A reduction to 0.26 for curtainwall windows would not occur based on the proposed U-factor change from 0.47 to 0.41. The Statewide CASE Team created a scatter plot of SHGC values against incremental costs and created a power function trendline through them. The scatter plot only included windows with U-factors in the proposed U-factor ranges to accentuate costs specific to the SHGC change itself, rather than secondarily from U-factor improvements. This power function served as the basis for a concurrent SHGC cost shift. This method is likely double counting costs to some degree, as many of the same technologies that yield lower U-factors result in lower SHGC. By summing them, the incremental cost estimates are conservative in nature.

Table 91 presents the resultant incremental measure cost for window alterations for curtain walls and Performance Class AW window categories.

Table 91: Incremental Measure Costs for Proposed Fenestration Thermal Properties, Alterations

		Baseline		Proposed		
Window Type	**Climate Zones**	**U-Factor (maximum)**	**SHGC (maximum)**	**U-Factor (maximum)**	**SHGC (maximum)**	**IMC**
Curtainwall/ storefront/ glazed doors	CZ 1	0.47	0.41	0.38	0.35	$2.08
	CZ 2, 4 6- 15	0.47	0.41	0.41	0.26	$2.06
	CZ 3 & 5	0.58	0.41	0.41	0.26	$4.16
	CZ 16	0.47	0.41	0.38	0.25	$4.03
Performance Class AW – Fixed Window	CZ 1	0.47	0.41	0.38	0.35	$1.24
	CZ 2, 4, 9-15	0.47	0.31	0.38	0.25	$2.41
	CZ 3 & 5	0.58	0.41	0.38	0.25	$5.35
	CZ 6-8	0.47	0.41	0.41	0.26	$1.98
	CZ 16	0.47	0.41	0.38	0.25	$3.19
Performance Class AW – Operable Window	CZ 1	0.47	0.41	0.43	0.35	$1.00
	CZ 2, 4, 6-15	0.47	0.31	0.43	0.24	$1.78
	CZ 3 & 5	0.58	0.41	0.43	0.24	$5.93
	CZ 16	0.47	0.41	0.43	0.24	$2.56

Incremental costs for the All Others window category follow the same methodology and results as used for new-construction all-other windows. The Statewide CASE Team estimated an incremental measure cost of $0.36 in Climate Zones 1 through 5 and 8 through 16 to account for the addition of warm edges spacers, improving on the lowest cost products available on the market for this window category. There is no incremental cost for Climate Zones 6 and 7.

This data only includes product costs, as there are no labor impacts. For the purpose of cost-effectiveness calculations, the Statewide CASE Team converted the per square foot window area incremental measure costs to a per dwelling unit cost based on each prototype's features.

5.1.3.5 Submeasure E: Envelope – Fenestration Area

The submeasure does not increase stringency, and therefore costs and cost-effectiveness analysis are not presented.

5.1.4 Incremental Maintenance and Replacement Costs

Incremental maintenance cost is the incremental cost of replacing the equipment or parts of the equipment, as well as periodic maintenance required to keep the equipment operating relative to current practices over the 30-year period of analysis. The present value of equipment maintenance costs (savings) was calculated using a three percent discount rate (d), which is consistent with the discount rate used when developing the 2022 TDV. The present value of maintenance costs that occurs in the n^{th} year is calculated as follows:

$$\text{Present Value of Maintenance Cost} = \text{Maintenance Cost} \times \left\lfloor \frac{1}{1+d} \right\rfloor^{n}$$

5.1.4.1 Submeasure A: Envelope – Roof Assemblies

This measure proposes a new prescriptive option for buildings up to three habitable stories. As such, no cost analysis is required to demonstrate that the measure is cost effective over the 30-year period of analysis.

For buildings four habitable stories or greater, the measure requires cost effectiveness and introduces an increase in stringency. Research and interviews with stakeholders from the companion Single Family Additions and Alterations CASE (California Codes and Standards Enhancement (CASE) initiative 2020) proposal indicate that that the life of a low-slope roof depends on the installation quality. Various industry sources references lifetimes of up to 20 years for roof installations. The Statewide CASE Team determined that the submeasure incurs no incremental costs for new construction. As a result, this analysis did not quantify replacement costs as they will be the same between the baseline and proposed scenarios also.

5.1.4.2 Submeasure B: Envelope – Wall U-Factor

The expected useful life of this submeasure is 30 years (California Utilities Statewide Codes and Standards Team 2011). No additional maintenance or replacement costs are anticipated for this submeasure.

5.1.4.3 Submeasure C: Envelope – Quality Insulation Installation

The expected useful life of this submeasure is 30 years (California Utilities Statewide Codes and Standards Team 2011). No additional maintenance or replacement costs are anticipated for this submeasure.

5.1.4.4 Submeasure D: Envelope – Fenestration Properties

The expected useful life of this submeasure is 30 years (California Utilities Statewide Codes and Standards Team 2011). No additional maintenance or replacement costs are anticipated for this submeasure.

5.1.4.5 Submeasure E: Envelope – Fenestration Area

The submeasure does not increase stringency; therefore, costs and cost effectiveness analyses are not presented.

5.1.5 Cost Effectiveness

The Energy Commission establishes the procedures for calculating 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. The 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 were the incremental costs of code compliance verification.

According to the Energy Commission's definitions, a measure is cost effective if the benefit-to-cost (B/C) ratio 1.0 or greater. The B/C ratio is calculated by dividing the cost benefits realized over 30 years by the total incremental costs, which includes maintenance costs for 30 years. The B/C ratio was calculated using 2023 PV costs and cost savings.

5.1.5.1 Submeasure A: Envelope – Roof Assemblies

This measure proposes a new prescriptive option for buildings up to three habitable stories. Because it does not replace the prescriptive requirement, cost-effectiveness analysis is not required.

For buildings four habitable stories or greater, the measure introduces a no cost increase in stringency.

Results of the per-unit cost-effectiveness analyses for increased stringency for buildings four habitable stories and greater are presented in Table 92 and Table 93 for new construction for the five-story and ten-story prototype buildings.

The proposed measure saves money over the 30-year period of analysis relative to the existing conditions. The proposed code change is cost effective in every climate zone where changes are proposed.

Table 92: 30-Year Cost-Effectiveness Summary Per Dwelling Unit – New Construction, Additions & Alterations – Low-Slope Increase to 0.63 ASR, 5-Story Prototype Building

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	N/A	N/A	N/A
2	N/A	N/A	N/A
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	N/A	N/A	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	N/A	N/A	N/A
9	$41.47	$0.00	Undefined
10	$39.00	$0.00	Undefined
11	$31.35	$0.00	Undefined
12	N/A	N/A	N/A
13	$31.54	$0.00	Undefined
14	$29.68	$0.00	Undefined
15	$50.29	$0.00	Undefined
16	N/A	N/A	N/A

Table 93: 30-Year Cost-Effectiveness Summary Per Dwelling Unit – New Construction, Additions & Alterations – Low-Slope Increase to 0.63 ASR, 10-Story Prototype Building

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	N/A	N/A	N/A
2	N/A	N/A	N/A
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	N/A	N/A	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	N/A	N/A	N/A
9	$16.87	$0.00	Undefined
10	$16.26	$0.00	Undefined
11	$12.37	$0.00	Undefined
12	N/A	N/A	N/A
13	$13.42	$0.00	Undefined
14	$13.55	$0.00	Undefined
15	$19.80	$0.00	Undefined
16	N/A	N/A	N/A

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 PV maintenance cost savings if PV of proposed maintenance costs is less than 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 and if PV of proposed maintenance costs is greater than 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.

5.1.5.2 Submeasure B: Envelope – Wall U-Factor

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

Results of the per-unit cost-effectiveness analyses are presented in Table 94 for new construction. The submeasure is not applicable to additions or alterations.

Table 94: 30-Year Cost-Effectiveness Summary Per Dwelling Unit – New Construction – Framed (Wood or Metal) and Others, ≤ 1 hr Fire Rating, 5-Story Prototype Building

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$121.84	$41.61	3.43
2	$112.74	$41.61	3.03
3	$50.22	$41.61	1.44
4	$70.16	$41.61	1.86
5	$42.99 $	$41.61	1.30
6	N/A	N/A	3.43
7	N/A	N/A	N/A
8	$42.85	$41.61	1.09
9	$52.14	$41.61	1.34
10	$61.89	$41.61	1.63
11	N/A	N/A	N/A
12	$144.97	$41.61	3.80
13	$114.21	$41.61	2.96
14	N/A	N/A	N/A
15	N/A	N/A	N/A
16	N/A	N/A	N/A

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 PV maintenance cost savings if PV of proposed maintenance costs is less than 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 and if PV of proposed maintenance costs is greater than 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.

5.1.5.3 Submeasure C: Envelope – Quality Insulation Installation

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

Results of the per-unit cost-effectiveness analyses are presented in Table 95.

Table 95: 30-Year Cost-Effectiveness Summary Per Dwelling Unit – New Construction – 5-Story Prototype Building – QII

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$328.78	$78.80	4.2
2	$329.63	$87.20	3.8
3	$293.78	$89.31	3.3
4	$255.74	$90.20	2.8
5	$295.92	$73.92	4.0
6	$295.38	$75.68	3.9
7	N/A	N/A	N/A
8	$207.65	$74.39	2.8
9	$222.50	$75.56	2.9
10	$242.20	$74.39	3.3
11	$256.41	$77.27	3.3
12	$323.38	$78.15	4.1
13	$320.87	$76.03	4.2
14	$247.62	$73.10	3.4
15	$224.06	$73.63	3.0
16	$285.85	$77.33	3.7

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 PV maintenance cost savings if PV of proposed maintenance costs is less than 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 and if PV of proposed maintenance costs is greater than 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.

5.1.5.4 Submeasure D: Envelope – Fenestration Properties

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

Results of the per-unit cost-effectiveness analyses are presented in Table 96 through Table 101 for new construction and for alterations. The proposed measure saves money over the 30-year period of analysis relative to the existing conditions.

The code change only results in increased stringency for buildings four habitable stories and greater. Therefore, cost-effectiveness results are included only for the 5-story and 10-story prototypes.

Table 96: 30-Year Cost-Effectiveness Summary Per Dwelling Unit – New Construction –Curtainwall/Storefronts, 5-Story Prototype Building

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$214.48	$105.80	2.03
2	N/A	N/A	N/A
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	N/A	N/A	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	N/A	N/A	N/A
12	N/A	N/A	N/A
13	N/A	N/A	N/A
14	N/A	N/A	N/A
15	N/A	N/A	N/A
16	$172.11	$105.80	1.63

Table 97: 30-Year Cost-Effectiveness Summary Per Dwelling Unit – New Construction –Category Curtainwall/Storefronts, 10-Story Prototype Building

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$214.62	$161.92	1.33
2	N/A	N/A	N/A
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	N/A	N/A	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	N/A	N/A	N/A
12	N/A	N/A	N/A
13	N/A	N/A	N/A
14	N/A	N/A	N/A
15	N/A	N/A	N/A
16	$215.33	$161.92	1.33

Table 98: 30-Year Cost-Effectiveness Summary Per Dwelling Unit – New Construction – *Performance Class AW*, 5-Story Prototype Building

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$281.35	$115.32	2.44
2	N/A	N/A	N/A
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	N/A	N/A	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	N/A	N/A	N/A
12	N/A	N/A	N/A
13	N/A	N/A	N/A
14	N/A	N/A	N/A
15	N/A	N/A	N/A
16	$144.16	$115.32	1.25

Table 99: 30-Year Cost-Effectiveness Summary Per Dwelling Unit – New Construction – *Performance Class AW*, 10-Story Prototype Building

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$264.00	$176.49	1.50
2	N/A	N/A	N/A
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	N/A	N/A	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	N/A	N/A	N/A
12	N/A	N/A	N/A
13	N/A	N/A	N/A
14	N/A	N/A	N/A
15	N/A	N/A	N/A
16	$188.78	$176.49	1.07

Table 100: 30-Year Cost-Effectiveness Summary Per Dwelling Unit – New Construction – Combined Category *All Others*, 5-Story Prototype Building

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$639.45	$38.09	16.79
2	$294.29	$38.09	7.73
3	$158.07	$38.09	4.15
4	$166.14	$38.09	4.36
5	$103.86	$38.09	2.73
6	$18.09	$0.00	Undefined
7	($7.28)	$0.00	Undefined
8	$40.52	$38.09	1.06
9	$87.31	$38.09	2.29
10	$139.06	$38.09	3.65
11	$418.19	$38.09	10.98
12	$300.96	$38.09	7.90
13	$335.06	$38.09	8.80
14	$358.65	$38.09	9.42
15	$240.24	$38.09	6.31
16	$679.84	$38.09	17.85

Table 101: 30-Year Cost-Effectiveness Summary Per Dwelling Unit – New Construction – Combined Category *All Others*, 10-Story Prototype Building

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$706.00	$58.29	12.11
2	$405.00	$58.29	6.95
3	$199.68	$58.29	3.43
4	$210.98	$58.29	3.62
5	$102.42	$58.29	1.76
6	$14.21	$0.00	Undefined
7	($14.07)	$0.00	Undefined
8	$20.83	$58.29	0.36
9	$100.75	$58.29	1.73
10	$169.38	$58.29	2.91
11	$638.91	$58.29	10.96
12	$430.90	$58.29	7.39
13	$488.16	$58.29	8.37
14	$496.14	$58.29	8.51
15	$346.17	$58.29	5.94
16	$936.60	$58.29	16.07

Table 102: 30-Year Cost-Effectiveness Summary Per Dwelling Unit – Additions and Alterations – Curtainwall/Storefronts, High-Rise Existing Prototype Building

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$689.30	$336.79	2.05
2	$649.53	$332.87	1.95
3	$1,542.35	$673.01	2.29
4	$651.23	$332.87	1.96
5	$1,488.51	$673.01	2.21
6	$452.76	$332.87	1.36
7	$367.20	$332.87	1.10
8	$515.41	$332.87	1.55
9	$595.47	$332.87	1.79
10	$624.30	$332.87	1.88
11	$828.26	$332.87	2.49
12	$642.23	$332.87	1.93
13	$723.59	$332.87	2.17
14	$842.07	$332.87	2.53
15	$791.39	$332.87	2.38
16	$1,293.34	$652.53	1.98

Table 103: 30-Year Cost-Effectiveness Summary Per Dwelling Unit – Additions and Alterations – Class AW Fixed, High-Rise Existing Prototype Building

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$689.30	$200.78	3.43
2	$649.53	$390.38	1.66
3	$1,542.35	$866.52	1.78
4	$486.56	$390.38	1.25
5	$1,488.51	$866.52	1.72
6	$452.76	$319.92	1.42
7	$367.20	$319.92	1.15
8	$515.41	$319.92	1.61
9	$422.42	$390.38	1.08
10	$488.28	$390.38	1.25
11	$828.26	$390.38	2.12
12	$642.23	$390.38	1.65
13	$723.59	$390.38	1.85
14	$842.07	$390.38	2.16
15	$769.13	$390.38	1.97
16	$1,293.34	$516.78	2.50

Table 104: 30-Year Cost-Effectiveness Summary Per Dwelling Unit – Additions and Alterations – Class AW Operable, High-Rise Existing Prototype Building

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$270.81	$121.79	2.22
2	$480.55	$216.86	2.22
3	$1,470.75	$722.34	2.04
4	$474.45	$216.86	2.19
5	$1,455.19	$722.34	2.01
6	$415.42	$216.86	1.92
7	$356.88	$216.86	1.65
8	$468.42	$216.86	2.16
9	$521.39	$216.86	2.40
10	$534.36	$216.86	2.46
11	$605.79	$216.86	2.79
12	$513.74	$216.86	2.37
13	$575.15	$216.86	2.65
14	$652.80	$216.86	3.01
15	$749.77	$216.86	3.46
16	$826.37	$311.93	2.65

Table 105: 30-Year Cost-Effectiveness Summary Per Dwelling Unit – Additions and Alterations – Combined All Others High-Rise Existing Prototype Building

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$1,335.16	$58.29	22.91
2	$1,271.60	$58.29	21.81
3	$1,920.38	$58.29	32.94
4	$960.31	$58.29	16.47
5	$1,828.13	$58.29	31.36
6	$485.13	$4.86	99.87
7	$336.64	$4.86	69.30
8	$652.86	$58.29	11.20
9	$831.17	$58.29	14.26
10	$961.65	$58.29	16.50
11	$1,639.55	$58.29	28.13
12	$1,274.53	$58.29	21.87
13	$1,439.79	$58.29	24.70
14	$1,614.17	$58.29	27.69
15	$1,521.06	$58.29	26.09
16	$2,147.11	$58.29	36.83

5.1.5.5 Submeasure E: Envelope – Fenestration Area

The Statewide CASE Team did not perform energy or cost-effectiveness analysis because there are no anticipated energy savings associated with the submeasure.

5.2 Space Conditioning

5.2.1 Energy Cost Savings Methodology

Energy cost savings were calculated by applying the TDV energy cost factors to the energy savings estimates that were derived using the methodology described in Section 4.2. TDV is a normalized metric to calculate energy cost savings that accounts for the variable cost of electricity and natural gas for each hour of the year, along with how costs are expected to change over the period of analysis (30 years for 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 across all submeasures and multifamily building prototypes. The TDV cost impacts are presented in 2023 present value dollars and represent the energy cost savings realized over 30 years.

5.2.2 Energy Cost Savings Results

5.2.2.1 Submeasure F: Space Conditioning – Duct Insulation

This submeasure is not increasing stringency and therefore costs and cost-effectiveness analysis are not presented.

5.2.2.2 Submeasure G: Space Conditioning – Duct Leakage Testing

Per-unit energy cost savings for newly constructed buildings and alterations that are realized over the 30-year period of analysis are presented in 2023 dollars in Table 106 and Table 107 for new construction and Table 108 for alterations. Per-unit energy are presented in nominal dollars in Appendix H in Table 203 through Table 205.

The TDV methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods.

Table 106: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per 5-Story Mixed-Use Dwelling Unit – New Construction Duct Leakage

Climate Zone	30-Year TDV Electricity Cost Savings (2023 PV$)	30-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 30-Year TDV Energy Cost Savings (2023 PV$)
1	$18	$30	$47
2	$144	$18	$162
3	$84	$11	$96
4	$173	$9	$181
5	$64	$10	$74
6	$145	$3	$147
7	$124	$2	$126
8	$198	$3	$201
9	$203	$4	$207
10	$213	$7	$219
11	$255	$21	$276
12	$204	$18	$222
13	$286	$15	$302
14	$242	$17	$258
15	$399	$2	$400
16	$96	$49	$145

Table 107: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per 10-Story Mixed-Use Dwelling Unit – New Construction Duct Leakage

Climate Zone	30-Year TDV Electricity Cost Savings (2023 PV$)	30-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 30-Year TDV Energy Cost Savings (2023 PV$)
1	$19	$34	$53
2	$146	$20	$166
3	$89	$12	$101
4	$177	$9	$186
5	$69	$10	$79
6	$152	$2	$155
7	$132	$2	$134
8	$204	$2	$206
9	$211	$4	$215
10	$222	$7	$228
11	$271	$26	$297
12	$207	$20	$227
13	$294	$17	$311
14	$257	$20	$277
15	$419	$1	$421
16	$96	$62	$158

Table 108: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per 10-Story Mixed-Use Dwelling Unit – Alteration Duct Leakage

Climate Zone	30-Year TDV Electricity Cost Savings (2023 PV$)	30-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 30-Year TDV Energy Cost Savings (2023 PV$)
1	$33	$97	$131
2	$165	$82	$247
3	$114	$57	$170
4	$196	$44	$240
5	$94	$51	$145
6	$158	$16	$174
7	$129	$12	$141
8	$227	$18	$246
9	$235	$26	$260
10	$250	$35	$285
11	$298	$91	$389
12	$230	$74	$304
13	$328	$62	$390
14	$283	$77	$360
15	$484	$13	$497
16	$123	$163	$286

5.2.2.3 Submeasure H: Space Conditioning – Space Cooling Airflow Rate and Fan Efficacy

Per-unit energy cost savings for newly constructed buildings and alterations that are realized over the 30-year period of analysis are presented in 2023 dollars in Table 109 and Table 110. Per-unit energy are presented in nominal dollars in Appendix H in Table 206 and Table 207.

The TDV methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods.

Table 109: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per 5-Story Mixed-Use Dwelling Unit– New Construction (Ducted) Cooling Coil Airflow and Fan Efficacy

Climate Zone	30-Year TDV Electricity Cost Savings (2023 PV$)	30-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 30-Year TDV Energy Cost Savings (2023 PV$)
1	$135	($31)	$103
2	$626	($28)	$598
3	$460	($13)	$447
4	$750	($11)	$739
5	$380	($11)	$369
6	$688	($3)	$684
7	$632	($2)	$630
8	$851	($3)	$847
9	$842	($5)	$836
10	$891	($9)	$882
11	$927	($34)	$893
12	$856	($30)	$826
13	$1,098	($26)	$1,072
14	$863	($23)	$840
15	$1,316	($2)	$1,314
16	$528	($89)	$440

Table 110: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per 10-Story Mixed-Use Dwelling Unit– New Construction (Ducted) Cooling Coil Airflow and Fan Efficacy

Climate Zone	30-Year TDV Electricity Cost Savings (2023 PV$)	30-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 30-Year TDV Energy Cost Savings (2023 PV$)
1	$128	($26)	$101
2	$546	($22)	$524
3	$436	($9)	$427
4	$665	($8)	$657
5	$376	($7)	$368
6	$654	($2)	$653
7	$616	($1)	$614
8	$767	($2)	$765
9	$747	($4)	$743
10	$788	($7)	$781
11	$801	($32)	$769
12	$732	($25)	$707
13	$928	($20)	$908
14	$750	($20)	$730
15	$1,077	($1)	$1,076
16	$464	($72)	$392

5.2.2.4 Submeasure I: Space Conditioning – Refrigerant Charge Verification

Per-unit energy cost savings for newly constructed buildings that are realized over the 30-year period of analysis are presented in 2023 dollars in Table 111 and Table 112 for new construction and Table 113 for alterations. Per-unit energy are presented in nominal dollars in Appendix H in Table 208 through Table 210.

The TDV methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods.

Table 111: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per 5-Story Mixed-Use Dwelling Unit – New Construction Refrigerant Charge

Climate Zone	30-Year TDV Electricity Cost Savings (2023 PV$)	30-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 30-Year TDV Energy Cost Savings (2023 PV$)
1	$22	$0	$22
2	$193	$0	$193
3	$135	$0	$135
4	$235	$0	$235
5	$112	$0	$112
6	$220	$0	$220
7	$203	$0	$203
8	$275	$0	$275
9	$279	$0	$279
10	$289	$0	$289
11	$336	$0	$336
12	$269	$0	$269
13	$369	$0	$369
14	$318	$0	$318
15	$528	$0	$528
16	$116	$0	$116

Table 112: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per 10-Story Mixed-Use Dwelling Unit – New Construction Refrigerant Charge

Climate Zone	30-Year TDV Electricity Cost Savings (2023 PV$)	30-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 30-Year TDV Energy Cost Savings (2023 PV$)
1	$27	$0	$27
2	$173	$0	$173
3	$133	$0	$133
4	$211	$0	$211
5	$118	$0	$118
6	$214	$0	$214
7	$204	$0	$204
8	$252	$0	$252
9	$251	$0	$251
10	$259	$0	$259
11	$288	$0	$288
12	$233	$0	$233
13	$311	$0	$311
14	$280	$0	$280
15	$431	$0	$431
16	$113	$0	$113

Table 113: 2023 PV TDV Energy Cost Savings Over 30-Year Period of Analysis – Per 10-Story Mixed-Use Dwelling Unit – Alteration Refrigerant Charge

Climate Zone	30-Year TDV Electricity Cost Savings (2023 PV$)	30-Year TDV Natural Gas Cost Savings (2023 PV$)	Total 30-Year TDV Energy Cost Savings (2023 PV$)
1	$36	$0	$36
2	$227	$0	$227
3	$160	$0	$160
4	$273	$0	$273
5	$127	$0	$127
6	$214	$0	$214
7	$172	$0	$172
8	$312	$0	$312
9	$323	$0	$323
10	$340	$0	$340
11	$403	$0	$403
12	$315	$0	$315
13	$449	$0	$449
14	$382	$0	$382
15	$667	$0	$667
16	$136	$0	$136

5.2.3 Incremental First Cost

5.2.3.1 Submeasure F: Space Conditioning – Duct Insulation

This submeasure is not increasing stringency; therefore, costs and cost-effectiveness analysis are not presented.

5.2.3.2 Submeasure G: Space Conditioning – Duct Leakage Testing

Incremental costs for this measure reflect costs for the mechanical contractor to seal the distribution system beyond what is already required by code and conduct the leakage test. Costs are presented in Table 114. Feedback from stakeholders was split, with some indicating that most distribution systems should already meet the proposed requirements with minimal or no additional work necessary. Others indicated that to meet the 12 percent total leakage target additional sealing will be required by the mechanical contractor. It is estimated that two to four hours is necessary to properly seal all components of a duct system, from a completely un-sealed condition. Section 603.10 of the 2019 California Mechanical Code (Title 24, Part 4) requires duct system joints and seams "be made substantially airtight" and therefore code already requires a level of sealing that for some systems will be sufficient to meet the 12 percent total leakage target. Additional work that is likely required to meet the leakage target is taping the air handler and sealing around the register. The Statewide CASE Team assumed an additional quarter of an hour of labor and $10 of material per dwelling unit is required for the incremental sealing work. The Statewide CASE Team estimated 45 minutes of contractor labor to conduct the leakage test. The hourly rate of $137 is based on RS Means' hourly rate with overhead and profit for sheet metal workers and applying a population weighted average of the California City Cost Indices (Means 2020).

Table 114: First Cost Summary for Duct Leakage Testing

Cost component	Cost per Dwelling Unit
Sealing Material	$10
Sealing Labor	$34
Test and Report	$103
Total Incremental First Cost	**$147**

Costs are expected to be very similar for altered duct systems. In a typical dwelling unit with ductwork in a dropped soffit most of the ductwork will be inaccessible. The accessible areas to address are sealing at the registers, sealing the penetrations at the air handler, and taping the air handler.

5.2.3.3 Submeasure H: Space Conditioning – Space Cooling Airflow Rate and Fan Efficacy

Incremental costs for this measure reflect the cost for the mechanical contractor to conduct testing of system airflow rate and fan watt draw. Costs are presented in Table 115. Based on feedback from stakeholders most cooling systems can meet the proposed requirements with minimal or no additional work necessary; therefore, there is no material or labor incremental cost for the mechanical contractor's scope of work for this measure except for testing and documenting results in the Certificate of Installation. Measuring system airflow is typically part of system air balancing and is standard practice during installation. Measuring fan power is not typically conducted by the installer but is a straightforward test. The Statewide CASE Team estimated 45 minutes of contractor labor to conduct the tests and complete the forms. The hourly rate of $137 is based on the RS Means hourly rate with overhead and profit for sheet metal workers and applying a population weighted average of the California City Cost Indices (Means 2020).

Table 115: First Cost Summary for Cooling Coil Airflow and Fan Efficacy

Cost component	Cost per Dwelling Unit
Material	$0
Labor	$0
Test and Report	$103
Total Incremental First Cost	**$103**

Submeasure I: Space Conditioning – Refrigerant Charge Verification

Incremental costs for this measure reflect the cost for the mechanical contractor to document verification of proper refrigerant charge in the Certificate of Installation. Costs are presented in Table 116. It is the installing contractor's responsibility to ensure that the system is properly charged meeting manufacturer's installation guidelines; therefore, there is no material or labor incremental cost for the mechanical contractor's scope of work for this measure. The only additional work required is completion of the Certificate of Installation which the Statewide CASE Team estimated to be a quarter of an hour of additional labor. The hourly rate of $137 is based on RS Means' hourly rate with overhead and profit for sheet metal workers and applying a population weighted average of the California City Cost Indices (Means 2020).

Table 116: First Cost Summary for Refrigerant Charge Verification

Cost component	Cost per Dwelling Unit
Material	$0
Labor	$0
Test and Report	$34
Total Incremental First Cost	**$34**

Costs will be slightly higher for alterations because part of the testing requirement is ensuring adequate airflow. In new construction, airflow testing is proposed to be separately required and results from that test can be applied during refrigerant charge verification. For alterations, the cost for airflow testing has been included with an additional half hour of labor. The total incremental cost is $103 per dwelling unit.

5.2.4 Incremental Maintenance and Replacement Costs

Incremental maintenance cost is the incremental cost of replacing the equipment or parts of the equipment, as well as periodic maintenance required to keep the equipment operating relative to current practices over the 30-year period of analysis. The present value of equipment maintenance costs (savings) was calculated using a three percent discount rate (d), which is consistent with the discount rate used when developing the 2022 TDV. The present value of maintenance costs that occurs in the n^{th} year is calculated as follows:

$$\text{Present Value of Maintenance Cost} = \text{Maintenance Cost} \times \left\lfloor \frac{1}{1+d} \right\rfloor^{n}$$

5.2.4.1 Submeasure F: Space Conditioning – Duct Insulation

This submeasure is not increasing stringency; therefore, costs and cost-effectiveness analysis are not presented.

5.2.4.2 Submeasure G: Space Conditioning – Duct Leakage Testing

There are no incremental maintenance or replacement costs for this submeasure. It is expected that the useful life of a duct system when located in conditioned space is 30 years and it would not need to be replaced over the 30-year period of analysis. There is no difference in regular maintenance between the two system types.

5.2.4.3 Submeasure H: Space Conditioning – Space Cooling Airflow Rate and Fan Efficacy

It is expected that the HVAC system will need to be replaced over the 30-year period of analysis at year 20. The present value of the replacement cost at year 20 is calculated. At the end of the 30-year period of analysis, there are 10 years of useful life remaining for the HVAC system. The value of this is calculated and subtracted from the total present value of the cost of the system. The total present value of the incremental cost for this code change proposal are presented in Table 117. There is no difference in regular maintenance between the base case and the proposed case.

Table 117: Cooling Coil Airflow and Fan Efficacy Summary of Replacement Cost

	Cost per Dwelling Unit
Incremental First Cost	$103
Present Value of Replacement Cost at Year 20	$57
Present Value of Remaining Useful Life at Year 30	($21)
Total Present Value of Incremental Cost	**$138**

5.2.4.4 Submeasure I: Space Conditioning – Refrigerant Charge Verification

It is expected that the HVAC system will need to be replaced over the 30-year period of analysis at year 20. The present value of the replacement cost at year 20 is calculated. At the end of the 30-year period of analysis, there are 10 years of useful life remaining for the HVAC system. The value of this is calculated and subtracted from the total present value of the cost of the system. The total present value of the incremental cost for this code change proposal are presented in Table 117. There is no difference in regular maintenance between the base case and the proposed case.

Table 118: Refrigerant Charge Verification Summary of Replacement Cost

	Cost per Dwelling Unit
Incremental First Cost	$34
Present Value of Replacement Cost at Year 20	$19
Present Value of Remaining Useful Life at Year 30	($7)
Total Present Value of Incremental Cost	**$46**

For alterations, the same approach is applied to the incremental first cost of $103 for a total present value of incremental cost of $138.

5.2.5 Cost Effectiveness

The space conditioning submeasures propose either a mandatory or prescriptive requirement. As such, a 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 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. The 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 were the incremental costs of code compliance verification.

According to the Energy Commission's definitions, a measure is cost effective if the B/C ratio is 1.0 or greater. The B/C ratio is calculated by dividing the cost benefits realized over 30 years by the total incremental costs, which includes maintenance costs for 30 years. The B/C ratio was calculated using 2023 PV costs and cost savings.

5.2.5.1 Submeasure F: Space Conditioning – Duct Insulation

This submeasure is not increasing stringency; therefore, costs and cost-effectiveness analysis are not presented.

5.2.5.2 Submeasure G: Space Conditioning – Duct Leakage Testing

Results of the per-unit cost-effectiveness analyses are presented in Table 119 through Table 120 for new construction. The proposed submeasure is cost effective for new construction over the 30-year period of analysis relative to the existing conditions in Climate Zones 2, 4, 6, and 8 through 15. See Section 5.2.5.5 for cost effectiveness when packaged with other space conditioning submeasures.

The proposed new construction requirements impact alterations when an entirely new or complete replacement space-conditioning or duct system is installed. For the purposes of this analysis energy cost savings and incremental costs for these alterations are assumed to be the same as for new construction. Older, less insulated buildings will have higher cooling and heating loads and subsequently will experience higher energy savings and improved cost effectiveness.

Results of the per-unit cost-effectiveness analyses are presented in Table 121 for altered duct systems and space-conditioning systems in alterations and additions. The proposed submeasure is cost effective for alterations over the 30-year period of analysis in Climate Zones 2 through 4, 6, and 8 through 16.

Table 119: 30-Year Cost-Effectiveness Summary Per 5-Story Mixed-Use Dwelling Unit – New Construction Duct Leakage

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$47	$147	0.32
2	$162	$147	1.10
3	$96	$147	0.65
4	$181	$147	1.23
5	$74	$147	0.50
6	$147	$147	1.00
7	$126	$147	0.86
8	$201	$147	1.37
9	$207	$147	1.41
10	$219	$147	1.49
11	$276	$147	1.88
12	$222	$147	1.51
13	$302	$147	2.05
14	$258	$147	1.76
15	$400	$147	2.72
16	$145	$147	0.99

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 PV maintenance cost savings if PV of proposed maintenance costs is less than 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 and if PV of proposed maintenance costs is greater than 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 120: 30-Year Cost-Effectiveness Summary Per 10-Story Mixed-Use Dwelling Unit – New Construction Duct Leakage

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$53	$147	0.36
2	$166	$147	1.13
3	$101	$147	0.68
4	$186	$147	1.27
5	$79	$147	0.54
6	$155	$147	1.05
7	$134	$147	0.91
8	$206	$147	1.40
9	$215	$147	1.46
10	$228	$147	1.55
11	$297	$147	2.02
12	$227	$147	1.55
13	$311	$147	2.12
14	$277	$147	1.89
15	$421	$147	2.86
16	$158	$147	1.08

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 PV maintenance cost savings if PV of proposed maintenance costs is less than 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 and if PV of proposed maintenance costs is greater than 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 121: 30-Year Cost-Effectiveness Summary Per 10-Story Mixed-Use Dwelling Unit – Alterations Duct Leakage

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$131	$147	0.89
2	$247	$147	1.68
3	$170	$147	1.16
4	$240	$147	1.63
5	$145	$147	0.98
6	$174	$147	1.19
7	$141	$147	0.96
8	$246	$147	1.67
9	$260	$147	1.77
10	$285	$147	1.94
11	$389	$147	2.65
12	$304	$147	2.07
13	$390	$147	2.65
14	$360	$147	2.45
15	$497	$147	3.38
16	$286	$147	1.94

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 PV maintenance cost savings if PV of proposed maintenance costs is less than 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 and if PV of proposed maintenance costs is greater than 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.

5.2.5.3 Submeasure H: Space Conditioning – Space Cooling Airflow Rate and Fan Efficacy

Results of the per-unit cost-effectiveness analyses are presented in Table 122 through Table 123 for new construction. The proposed measure is cost effective and saves money over the 30-year period of analysis relative to the existing conditions in all climate zones except Climate Zone 1.

The proposed new construction requirements impact alterations when an entirely new or complete replacement space-conditioning system is installed. For the purposes of this analysis, energy cost savings and incremental costs for alterations are assumed to be the same as for new construction. Older, less insulated buildings will have higher cooling loads and will experience higher energy savings and improved cost effectiveness.

Table 122: 30-Year Cost-Effectiveness Summary Per 5-Story Mixed-Use Dwelling Unit – New Construction Cooling Coil Airflow and Fan Efficacy

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$103	$138	0.75
2	$598	$138	4.32
3	$447	$138	3.23
4	$739	$138	5.33
5	$369	$138	2.67
6	$684	$138	4.94
7	$630	$138	4.55
8	$847	$138	6.12
9	$836	$138	6.04
10	$882	$138	6.37
11	$893	$138	6.45
12	$826	$138	5.96
13	$1,072	$138	7.74
14	$840	$138	6.07
15	$1,314	$138	9.49
16	$440	$138	3.17

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 PV maintenance cost savings if PV of proposed maintenance costs is less than 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 and if PV of proposed maintenance costs is greater than 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 123: 30-Year Cost-Effectiveness Summary Per 10-Story Mixed-Use Dwelling Unit – New Construction Cooling Coil Airflow and Fan Efficacy

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$101	$138	0.73
2	$524	$138	3.79
3	$427	$138	3.08
4	$657	$138	4.75
5	$368	$138	2.66
6	$653	$138	4.71
7	$614	$138	4.44
8	$765	$138	5.52
9	$743	$138	5.37
10	$781	$138	5.64
11	$769	$138	5.56
12	$707	$138	5.11
13	$908	$138	6.56
14	$730	$138	5.27
15	$1,076	$138	7.77
16	$392	$138	2.83

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 PV maintenance cost savings if PV of proposed maintenance costs is less than 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 and if PV of proposed maintenance costs is greater than 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.

5.2.5.4 Submeasure I: Space Conditioning – Refrigerant Charge Verification

Results of the per-unit cost-effectiveness analyses are presented in Table 124 through Table 125 for new construction. The proposed measure is cost effective and saves money over the 30-year period of analysis relative to the existing conditions in all climate zones except Climate Zone 1. The proposed code change only applies to Climate Zones 2 and 8 through 15.

The proposed new construction requirements impact alterations when an entirely new or complete replacement space-conditioning system is installed or when a refrigerant-containing system component is altered. For the purposes of this analysis energy cost savings and incremental costs for alterations are assumed to be the same as for new construction. Older, less insulated buildings will have higher cooling loads and will experience higher energy savings and improved cost effectiveness.

Results of the per-unit cost-effectiveness analyses are presented in Table 126 for altered space-conditioning systems with mechanical cooling in alterations and additions. The proposed measure is cost effective and saves money over the 30-year period of analysis relative to the existing conditions in all climate zones except Climate Zone 1, 5, and 16. The proposed code change only applies to Climate Zones 2 and 8 through 15.

Table 124: 30-Year Cost-Effectiveness Summary Per 5-Story Mixed-Use Dwelling Unit – New Construction Refrigerant Charge

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$22	$46	0.49
2	$193	$46	4.18
3	$135	$46	2.92
4	$235	$46	5.09
5	$112	$46	2.42
6	$220	$46	4.78
7	$203	$46	4.39
8	$275	$46	5.96
9	$279	$46	6.05
10	$289	$46	6.27
11	$336	$46	7.27
12	$269	$46	5.84
13	$369	$46	8.00
14	$318	$46	6.90
15	$528	$46	11.44
16	$116	$46	2.51

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 PV maintenance cost savings if PV of proposed maintenance costs is less than 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 and if PV of proposed maintenance costs is greater than 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 125: 30-Year Cost-Effectiveness Summary Per 10-Story Mixed-Use Dwelling Unit – New Construction Refrigerant Charge

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$27	$46	0.59
2	$173	$46	3.74
3	$133	$46	2.89
4	$211	$46	4.58
5	$118	$46	2.55
6	$214	$46	4.64
7	$204	$46	4.42
8	$252	$46	5.46
9	$251	$46	5.44
10	$259	$46	5.62
11	$288	$46	6.24
12	$233	$46	5.04
13	$311	$46	6.75
14	$280	$46	6.07
15	$431	$46	9.33
16	$113	$46	2.46

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 PV maintenance cost savings if PV of proposed maintenance costs is less than 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 and if PV of proposed maintenance costs is greater than 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 126: 30-Year Cost-Effectiveness Summary Per 10-Story Mixed-Use Dwelling Unit – Alterations Refrigerant Charge

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$36	$138	0.26
2	$227	$138	1.64
3	$160	$138	1.15
4	$273	$138	1.97
5	$127	$138	0.92
6	$214	$138	1.54
7	$172	$138	1.24
8	$312	$138	2.26
9	$323	$138	2.33
10	$340	$138	2.46
11	$403	$138	2.91
12	$315	$138	2.28
13	$449	$138	3.25
14	$382	$138	2.76
15	$667	$138	4.81
16	$136	$138	0.98

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 PV maintenance cost savings if PV of proposed maintenance costs is less than 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 and if PV of proposed maintenance costs is greater than 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.

5.2.5.5 Combination G-I: Space Conditioning – New Construction Test Package

The three new construction verification measures, duct leakage testing, airflow rate and fan efficacy, and refrigerant charge verification, were evaluated as a package. Results of the per-unit cost-effectiveness analyses are presented in Table 127 through Table 128 for new construction. The proposed package of measures is cost effective and saves money over the 30-year period of analysis relative to the existing conditions in all climate zones except 1.

Table 127: 30-Year Cost-Effectiveness Summary Per 5-Story Mixed-Use Dwelling Unit – New Construction Test Package

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$122	$285	0.43
2	$940	$332	2.83
3	$450	$285	1.57
4	$885	$285	3.10
5	$343	$285	1.20
6	$731	$285	2.56
7	$629	$285	2.20
8	$1,302	$332	3.93
9	$1,320	$332	3.98
10	$1,394	$332	4.20
11	$1,575	$332	4.75
12	$1,341	$332	4.04
13	$1,859	$332	5.61
14	$1,470	$332	4.43
15	$2,407	$332	7.26
16	$549	$285	1.92

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 PV maintenance cost savings if PV of proposed maintenance costs is less than 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 and if PV of proposed maintenance costs is greater than 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 128: 30-Year Cost-Effectiveness Summary Per 10-Story Mixed-Use Dwelling Unit – New Construction Test Package

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$130	$285	0.45
2	$952	$332	2.87
3	$469	$285	1.64
4	$903	$285	3.16
5	$362	$285	1.27
6	$763	$285	2.67
7	$659	$285	2.31
8	$1,333	$332	4.02
9	$1,361	$332	4.10
10	$1,441	$332	4.35
11	$1,664	$332	5.02
12	$1,356	$332	4.09
13	$1,905	$332	5.74
14	$1,558	$332	4.70
15	$2,522	$332	7.61
16	$547	$285	1.92

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 PV maintenance cost savings if PV of proposed maintenance costs is less than 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 and if PV of proposed maintenance costs is greater than 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.

6. First-Year Statewide Impacts

6.1 Building Envelope

6.1.1 Statewide Energy and 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 assumptions about the percentage of newly constructed buildings that will be impacted by the proposed code. The statewide new construction forecast for 2023 is presented in Appendix A as are the Statewide CASE Team's assumptions about the percentage of new construction that will be impacted by the proposal (by climate zone and building type).

The first-year energy impacts represent the first-year annual savings from all buildings that were completed in 2023. The 30-year energy cost savings represent the energy cost savings over the entire 30-year analysis period. The statewide savings estimates do not take naturally occurring market adoption or compliance rates into account.

6.1.1.1 Submeasure A: Envelope – Roof Assemblies

Table 129 presents the first-year statewide energy and energy cost savings from newly constructed buildings by climate zone. Table 130 presents first-year statewide savings from new construction.

Table 129: Statewide Energy and Energy Cost Impacts – New Construction – 2-Story, 3-Story, 5-Story and 10-Story Prototype Buildings

Climate Zone	Statewide New Construction Impacted by Proposed Change in 2023 (dwelling units)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (MMTherms)	30-Year Present Valued Energy Cost Savings (million 2023 PV$)
1	66	(0.00)	0.00	(0.00)	($0.02)
2	391	0.00	0.00	(0.00)	($0.01)
3	1,895	(0.01)	(0.00)	(0.00)	($0.17)
4	987	0.00	(0.00)	(0.00)	($0.08)
5	175	(0.00)	(0.00)	(0.00)	($0.02)
6	837	(0.01)	(0.01)	(0.00)	($0.07)
7	900	(0.01)	(0.02)	(0.00)	($0.11)
8	1,177	0.02	0.00	(0.00)	$0.21
9	9,771	0.25	0.13	(0.00)	$1.48
10	3,452	0.10	0.05	(0.00)	$0.48
11	986	0.02	0.01	(0.00)	$0.11
12	1,573	0.02	0.00	(0.00)	($0.03)
13	1,624	(0.00)	(0.01)	(0.00)	($0.12)
14	738	0.01	0.01	(0.00)	$0.04
15	480	(0.00)	(0.00)	(0.00)	($0.04)
16	84	(0.00)	(0.00)	(0.00)	($0.03)
TOTAL	**25,136**	**0.39**	**0.15**	**(0.02)**	**$1.64**

a. First-year savings from all buildings completed statewide in 2023.

Table 130: Statewide Energy and Energy Cost Impacts – New Construction, Alterations, and Additions – 2-Story, 3-Story, 5-Story and 10-Story Prototype Buildings

Construction Type	First-Year Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First -Year Natural Gas Savings (MMTherms)	First-Year TDV Energy Savings (million TDV kBtu)
New Construction	0.39	0.15	(0.02)	9.48
Additions and Alterations	N/A	N/A	N/A	N/A
TOTAL	**0.39**	**0.15**	**(0.02)**	**9.48**

6.1.1.2 Submeasure B: Envelope – Wall U-Factor

Table 131 and Table 133 present the first-year statewide energy and energy cost savings from newly constructed buildings by climate zone.

Table 134 presents first-year statewide savings from new construction.

Table 131: Statewide Energy and Energy Cost Impacts – New Construction – Framed, High Fire Rating (2- and 3-hr), 3-Story

Climate Zone	Statewide New Construction Impacted by Proposed Change in 2023 (dwelling units)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (MMTherms)	30-Year Present Valued Energy Cost Savings (million 2023 PV$)
1	3	(0.00)	(0.00)	(0.00)	($0.00)
2	17	(0.00)	0.00	(0.00)	($0.00)
3	83	(0.00)	0.00	(0.00)	($0.00)
4	43	(0.00)	0.00	(0.00)	($0.00)
5	8	(0.00)	0.00	(0.00)	($0.00)
6	N/A	N/A	N/A	N/A	$0.00
7	N/A	N/A	N/A	N/A	$0.00
8	52	(0.00)	(0.00)	(0.00)	($0.00)
9	121	(0.00)	(0.00)	(0.00)	($0.00)
10	43	(0.00)	(0.00)	(0.00)	($0.00)
11	N/A	N/A	N/A	N/A	$0.00
12	69	(0.00)	0.00	(0.00)	($0.01)
13	20	(0.000133)	(0.00)	(0.00)	($0.00)
14	N/A	N/A	N/A	N/A	$0.00
15	N/A	N/A	N/A	N/A	$0.00
16	N/A	N/A	N/A	N/A	$0.00
TOTAL	**459**	**(0.00)**	**(0.00)**	**(0.00)**	**($0.02)**

a. First-year savings from all buildings completed statewide in 2023.

Table 132: Statewide Energy and Energy Cost Impacts – New Construction – Framed, Low Fire Rating ≤1 hr, 5-Story Prototype Buildings

Climate Zone	Statewide New Construction Impacted by Proposed Change in 2023 (dwelling units)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (MMTherms)	30-Year Present Valued Energy Cost Savings (million 2023 PV$)
1	60	0.00	(0.00)	0.00	$0.01
2	354	0.00	(0.00)	0.00	$0.04
3	1,717	0.01	(0.00)	0.00	$0.09
4	895	0.00	(0.00)	0.00	$0.06
5	159	0.00	(0.00)	0.00	$0.01
6	N/A	N/A	N/A	N/A	N/A
7	N/A	N/A	N/A	N/A	N/A
8	1,066	0.01	(0.00)	0.00	$0.05
9	2,503	0.01	0.00	0.00	$0.13
10	884	0.01	0.00	0.00	$0.05
11	N/A	N/A	N/A	N/A	N/A
12	1,426	0.01	0.00	0.00	$0.21
13	416	0.005036	0.00	0.00	$0.05
14	N/A	N/A	N/A	N/A	N/A
15	N/A	N/A	N/A	N/A	N/A
16	N/A	N/A	N/A	N/A	N/A
TOTAL	**9,480**	**0.06**	**0.00**	**0.01**	**$0.69**

a. First-year savings from all buildings completed statewide in 2023.

Table 133: Statewide Energy and Energy Cost Impacts – New Construction – Framed, High and Low Fire Ratings), 5-Story and 10-Story Prototype Buildings

Climate Zone	Statewide New Construction Impacted by Proposed Change in 2023 (dwelling units)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (MMTherms)	30-Year Present Valued Energy Cost Savings (million 2023 PV$)
1	N/A	N/A	N/A	N/A	$0.00
2	N/A	N/A	N/A	N/A	$0.00
3	N/A	N/A	N/A	N/A	$0.00
4	N/A	N/A	N/A	N/A	$0.00
5	N/A	N/A	N/A	N/A	$0.00
6	1,868	0.00	(0.00)	(0.00)	($0.08)
7	2,009	0.00	(0.00)	(0.00)	($0.06)
8	N/A	N/A	N/A	N/A	$0.00
9	N/A	N/A	N/A	N/A	$0.00
10	N/A	N/A	N/A	N/A	$0.00
11	622	(0.01)	(0.00)	(0.00)	($0.20)
12	N/A	N/A	N/A	N/A	$0.00
13	N/A	N/A	N/A	N/A	$0.00
14	466	(0.01)	(0.00)	(0.00)	($0.15)
15	303	(0.01)	(0.00)	(0.00)	($0.07)
16	188	(0.00)	(0.00)	(0.00)	($0.07)
TOTAL	**5,456**	**(0.02)**	**(0.02)**	**(0.00)**	**($0.63)**

a. First-year savings from all buildings completed statewide in 2023.

Table 134: Statewide Energy and Energy Cost Impacts – New Construction, Alterations, and Additions – 3-Story, 5-Story, and 10-Story Prototype Buildings

Construction Type	First-Year Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First -Year Natural Gas Savings (MMTherms)	First-Year TDV Energy Savings (million TDV kBtu)
New Construction	0.04	(0.02)	0.00	0.20
Additions and Alterations	N/A	N/A	N/A	N/A
TOTAL	0.04	(0.02)	0.00	0.20

6.1.1.3 Submeasure C: Envelope – Quality Insulation Installation

Table 135 present the first-year statewide energy and energy cost savings from newly constructed buildings by climate zone.

Table 135: Statewide Energy and Energy Cost Impacts – New Construction, QII

Climate Zone	Statewide New Construction Impacted by Proposed Change in 2023 (dwelling units)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (MM Therms)	30-Year Present Valued Energy Cost Savings (PV$ million in 2023)
1	39	0.00	0.00	0.00	$0.01
2	233	0.00	0.00	0.00	$0.04
3	1,129	0.01	0.00	0.00	$0.16
4	588	0.00	0.00	0.00	$0.07
5	104	0.00	0.00	0.00	$0.02
6	499	0.01	0.00	0.00	$0.07
7	N/A	N/A	N/A	N/A	N/A
8	701	0.01	0.00	0.00	$0.07
9	1,646	0.01	0.00	0.00	$0.17
10	582	0.01	0.00	0.00	$0.07
11	166	0.00	0.00	0.00	$0.02
12	938	0.01	0.00	0.00	$0.14
13	274	0.00	0.00	0.00	$0.04
14	124	0.00	0.00	0.00	$0.01
15	81	0.00	0.00	0.00	$0.01
16	50	0.00	0.00	0.00	$0.01
TOTAL	**7,155**	**0.07**	**0.02**	**0.01**	**$0.93**

a. First-year savings from all buildings completed statewide in 2023.

6.1.1.4 Submeasure D: Envelope – Fenestration Properties

Table 136 presents the first-year statewide energy and energy cost savings from newly constructed buildings by climate zone. Table 138 presents first-year statewide savings from new construction.

Table 136: Statewide Energy and Energy Cost Impacts – New Construction – Combined Category for Fixed, Operable Fenestrations, and Glazed Doors, 2-Story, 3-Story, 5-Story and 10-Story Prototype Buildings

Climate Zone	Statewide New Construction Impacted by Proposed Change in 2023 (dwelling units)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (MMTherms)	30-Year Present Valued Energy Cost Savings (million 2023 PV$)
1	167	(0.01)	(0.00)	0.00	$0.19
2	770	(0.00)	(0.00)	0.00	$0.23
3	3,733	(0.04)	(0.03)	0.01	$0.59
4	1,945	(0.01)	(0.00)	0.00	$0.32
5	345	(0.00)	(0.00)	0.00	$0.04
6	2,896	(0.10)	0.01	(0.03)	$0.04
7	3,113	(0.08)	0.01	(0.02)	$0.04
8	2,318	(0.03)	(0.00)	0.00	$0.09
9	5,442	(0.05)	0.01	0.01	$0.48
10	1,923	(0.01)	0.01	0.00	$0.27
11	549	0.01	0.00	0.00	$0.23
12	3,099	0.00	0.01	0.01	$0.94
13	905	0.01	0.01	0.00	$0.30
14	411	0.00	0.00	0.00	$0.15
15	268	0.01	0.00	0.00	$0.06
16	214	0.00	(0.00)	0.00	$0.12
TOTAL	**28,095**	**(0.29)**	**0.01**	**0.00**	**$4.10**

a. First-year savings from all buildings completed statewide in 2023.

Table 137: Statewide Energy and Energy Cost Impacts – Existing – Combined Category for Fixed, Operable Fenestrations, and Glazed Doors, 2-Story, 3-Story, 5-Story and 10-Story Prototype Buildings

Climate Zone	Statewide Alterations Impacted by Proposed Change in 2023 (dwelling units)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (MMTherms)	30-Year Present Valued Energy Cost Savings (million 2023 PV$)
1	225	0.02	0.00	0.00	$0.21
2	1,337	0.06	0.01	0.01	$1.21
3	6,965	1.87	0.27	0.05	$11.83
4	3,660	0.18	0.05	0.02	$2.44
5	589	0.18	0.02	0.00	$0.96
6	10,255	0.27	0.08	(0.00)	$1.44
7	9,476	0.22	0.06	0.00	$1.17
8	6,430	0.35	0.09	0.01	$3.25
9	14,279	0.88	0.27	0.04	$8.59
10	4,157	0.32	0.10	0.01	$2.83
11	1,075	0.09	0.04	0.01	$1.25
12	5,982	0.33	0.14	0.04	$5.41
13	2,024	0.17	0.08	0.01	$2.06
14	1,040	0.10	0.03	0.01	$1.21
15	526	0.09	0.03	0.00	$0.55
16	361	0.12	0.02	0.00	$0.59
TOTAL	**68,382**	**5.25**	**1.30**	**0.22**	**$45.00**

a. First-year savings from all buildings completed statewide in 2023.

Table 138: Statewide Energy and Energy Cost Impacts – New Construction, Alterations, and Additions – 2-Story, 3-Story, 5-Story, and 10-Story Prototype Buildings

Construction Type	First-Year Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First -Year Natural Gas Savings (MMTherms)	First-Year TDV Energy Savings (million TDV kBtu)
New Construction	(0.3)	0.0	0.0	24
Additions and Alterations	5.3	1.3	0.2	267
TOTAL	5.1	1.3	0.2	291

6.1.1.5 Submeasure E: Envelope – Fenestration Area

The Statewide CASE Team did not calculate statewide savings because there are no energy savings associated with the submeasure.

6.1.2 Statewide Greenhouse Gas (GHG) Emissions Reductions

The Statewide CASE Team calculated avoided GHG emissions assuming the emissions factors specified in the United States Environmental Protection Agency (U.S. EPA) Emissions & Generation Resource Integrated Database (eGRID) for the Western Electricity Coordination Council California (WECC CAMX) subregion. Avoided GHG emissions from natural gas savings attributable to sources other than utility-scale electrical power generation are calculated using emissions factors specified in U.S. EPA's Compilation of Air Pollutant Emissions Factors (AP-42). See Appendix C for additional details on the methodology used to calculate GHG emissions.

Table 139 presents the estimated first-year avoided GHG emissions of the proposed code change. During the first year, there would be a decrease in GHG emissions of 2,547 metric tons of carbon dioxide equivalents (metric tons CO2e). In short, this analysis assumes an average electricity emission factor of 240.4 metric tons CO2e per GWh based on the average emission factors for the CACX EGRID subregion.

Table 139: First-Year Statewide GHG Emissions Impacts

Measure	Electricity Savings[a] (GWh/yr)	Reduced GHG Emissions from Electricity Savings[a] (Metrc Tons CO2e)	Natural Gas Savings[a] (MMTherms/yr)	Reduced GHG Emissions from Natural Gas Savings[a] (Metric Tons CO2e)	Total Reduced CO_2e Emissions[a,b] (Metric Tons CO2e)
Roof Assemblies	0.39	94	(0.02)	(84)	10
Wall U-Factor	0.04	10	0.00	24	34
QII	0.03	0	0.01	0.00	0.00
Fenestration Properties	5.06	1,215	0.24	1,287	2,503
TOTAL	5.52	1,319	0.23	1,227	2,547

a. First-year savings from all buildings completed statewide in 2023.

b. Assumes the following emission factors: 240.4 MTCO2e/GWh and 5,454.4 MTCO2e/MMTherms.

6.1.3 Statewide Water Use Impacts

The proposed code change will not result in water savings.

6.1.4 Statewide Material Impacts

The Statewide CASE Team does not anticipate a material impact as a result of the proposed code change.

6.1.5 Other Non-Energy Impacts

The envelope submeasures will improve resident comfort where there is an increase in stringency.

6.2 Space Conditioning

6.2.1 Statewide Energy and 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 assumptions about the percentage of newly constructed buildings that will be impacted by the proposed code. The statewide new construction forecast for 2023 is presented in Appendix A as are the Statewide CASE Team's assumptions about the percentage of new construction that will be impacted by the proposal (by climate zone and building type).

The proposed new construction requirements impact alterations when a new duct system or space-conditioning system is installed or when one is altered. The percent of existing multifamily dwelling units impacted is based on the same factors as for new construction and the assumption that existing HVAC systems have a lifetime of 20 years and duct systems a lifetime of 30 years. Therefore, five percent of affected existing buildings in any year undergo equipment replacement and 3.3 percent undergo a duct system replacement and would be subject to some portion of the proposed requirements.

6.2.1.1 Submeasure F: Space Conditioning – Duct Insulation

This submeasure is not increasing stringency but does result in reduced stringency in certain situations.

The change to duct insulation for ducts in unconditioned space impacts multifamily buildings four habitable stories and greater; however, based on market data available to the Statewide CASE Team this building type does not have ducts serving residential spaces that are located in unconditioned space. There is no statewide impact for this submeasure.

For the change to duct insulation for ducts in conditioned space the first-year energy impacts represent the first-year annual increase from all buildings that were completed in 2023. The 30-year energy cost savings represent the energy cost savings over the entire 30-year analysis period. The statewide savings estimates do not take naturally occurring market adoption or compliance rates into account.

Table 140 presents the first-year statewide energy and energy cost impact from newly constructed buildings by climate zone.

Table 141 presents first-year statewide impact from new construction, additions, and alterations.

Table 140: Statewide Energy and Energy Cost Impacts – New Construction – Duct Insulation

Climate Zone	Statewide New Construction Impacted by Proposed Change in 2023 (dwelling units)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (MMTherms)	30-Year Present Valued Energy Cost Savings (million 2023 PV$)
1	16	0.00	0.00	(0.00)	(0.00)
2	93	0.00	(0.00)	(0.00)	(0.01)
3	451	(0.00)	0.00	(0.00)	(0.02)
4	235	(0.00)	(0.00)	(0.00)	(0.02)
5	42	0.00	0.00	(0.00)	(0.00)
6	199	(0.00)	(0.00)	(0.00)	(0.01)
7	214	(0.00)	(0.00)	(0.00)	(0.01)
8	280	(0.00)	(0.00)	(0.00)	(0.01)
9	657	(0.00)	(0.00)	(0.00)	(0.03)
10	232	(0.00)	(0.00)	(0.00)	(0.01)
11	66	(0.00)	(0.00)	(0.00)	(0.01)
12	374	(0.00)	(0.00)	(0.00)	(0.02)
13	109	(0.00)	(0.00)	(0.00)	(0.01)
14	50	(0.00)	(0.00)	(0.00)	(0.00)
15	32	(0.00)	(0.00)	(0.00)	(0.00)
16	20	0.00	(0.00)	(0.00)	(0.00)
TOTAL	3,071	(0.01)	(0.00)	(0.00)	(0.14)

a. First-year savings from all new buildings completed statewide in 2023.

Table 141: Statewide Energy and Energy Cost Impacts – New Construction, Alterations, and Additions – Duct Insulation

Construction Type	First-Year Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First -Year Natural Gas Savings (MMTherms)	30-Year Present Valued Energy Cost Savings (PV$ million)
New Construction	(0.01)	(0.00)	(0.00)	($0.14)
Additions and Alterations	(0.03)	(0.00)	(0.00)	($0.54)
TOTAL	(0.03)	(0.00)	(0.00)	($0.69)

a. First-year savings from all new construction and alterations completed statewide in 2023.

6.2.1.2 Submeasure G: Space Conditioning – Duct Leakage Testing

Statewide results for duct leakage testing are presented in this section. Savings for new construction are presented for Climate Zones 2 through 16 based on cost effective results for the new construction test package (see Section 5.2.5.5). The Statewide CASE Team recommends that this submeasure be required where found to be cost effective as a package for multifamily building four habitable stories and greater, even though the duct leakage testing alone is not cost effective in Climate Zones 3, 5, 7, and 16. Savings for alterations are presented for Climate Zones 2 through 4, 6, and 8 through 16 based on results for standalone duct leakage testing in existing buildings.

The first-year energy impacts represent the first-year annual savings from all buildings that will be completed in 2023. The 30-year energy cost savings represent the energy cost savings over the entire 30-year analysis period. The statewide savings estimates do not take naturally occurring market adoption or compliance rates into account.

Table 142 presents the first-year statewide energy and energy cost impact from newly constructed buildings by climate zone.

Table 143 presents first-year statewide impact from new construction, additions, and alterations.

Table 142: Statewide Energy and Energy Cost Impacts – Duct Leakage

Climate Zone	Statewide New Construction Impacted by Proposed Change in 2023 (dwelling units)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (MMTherms)	30-Year Present Valued Energy Cost Savings (million 2023 PV$)
1	N/A	N/A	N/A	N/A	N/A
2	368	0.01	0.00	0.00	$0.06
3	1,786	0.03	0.01	0.00	$0.17
4	930	0.03	0.01	0.00	$0.17
5	165	0.00	0.00	0.00	$0.01
6	789	0.03	0.01	0.00	$0.12
7	848	0.03	0.01	0.00	$0.11
8	1,109	0.05	0.01	0.00	$0.22
9	2,604	0.11	0.03	0.00	$0.54
10	920	0.04	0.01	0.00	$0.20
11	263	0.01	0.00	0.00	$0.07
12	1,483	0.05	0.02	0.00	$0.33
13	433	0.02	0.01	0.00	$0.13
14	197	0.01	0.00	0.00	$0.05
15	128	0.01	0.00	0.00	$0.05
16	79	0.00	0.00	0.00	$0.01
TOTAL	**12,102**	**0.43**	**0.12**	**0.00**	**$2.25**

a. First-year savings from all new buildings completed statewide in 2023.

Table 143: Statewide Energy and Energy Cost Impacts – New Construction, Alterations, and Additions – Duct Leakage

Construction Type	First-Year Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First -Year Natural Gas Savings (MMTherms)	30-Year Present Valued Energy Cost Savings (PV$ million)
New Construction	0.43	0.12	0.00	$2.25
Additions and Alterations	0.50	0.14	0.01	$3.28
TOTAL	0.93	0.26	0.01	$5.53

a. First-year savings from all new construction and alterations completed statewide in 2023.

6.2.1.3 Submeasure H: Space Conditioning – Space Cooling Airflow Rate and Fan Efficacy

Statewide results for airflow and fan efficacy testing are presented in this section. Savings are presented for Climate Zones 2 through 16 based on cost effective results (see Section 5.2.5.3).

The first-year energy impacts represent the first-year annual savings from all buildings that will be completed in 2023. The 30-year energy cost savings represent the energy cost savings over the entire 30-year analysis period. The statewide savings estimates do not take naturally occurring market adoption or compliance rates into account.

Table 144 presents the first-year statewide energy and energy cost impact from newly constructed buildings by climate zone.

Table 145 presents first-year statewide impact from new construction, additions, and alterations.

Table 144: Statewide Energy and Energy Cost Impacts – Cooling Coil Airflow and Fan Efficacy

Climate Zone	Statewide New Construction Impacted by Proposed Change in 2023 (dwelling units)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (MMTherms)	30-Year Present Valued Energy Cost Savings (million 2023 PV$)
1	N/A	N/A	N/A	N/A	N/A
2	327	0.03	0.01	(0.00)	$0.19
3	1,585	0.13	0.04	(0.00)	$0.71
4	826	0.11	0.04	(0.00)	$0.61
5	147	0.01	0.00	(0.00)	$0.05
6	700	0.10	0.03	(0.00)	$0.48
7	753	0.11	0.03	(0.00)	$0.47
8	984	0.17	0.05	(0.00)	$0.83
9	2,311	0.39	0.12	(0.00)	$1.92
10	817	0.15	0.05	(0.00)	$0.72
11	233	0.04	0.01	(0.00)	$0.21
12	1,316	0.20	0.07	(0.00)	$1.08
13	384	0.08	0.03	(0.00)	$0.41
14	175	0.03	0.01	(0.00)	$0.15
15	114	0.03	0.01	(0.00)	$0.15
16	70	0.01	0.00	(0.00)	$0.03
TOTAL	**10,743**	**1.59**	**0.50**	**(0.00)**	**$8.00**

a. First-year savings from all new buildings completed statewide in 2023.

Table 145: Statewide Energy and Energy Cost Impacts – New Construction, Alterations, and Additions – Cooling Coil Airflow and Fan Efficacy

Construction Type	First-Year Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First -Year Natural Gas Savings (MMTherms)	30-Year Present Valued Energy Cost Savings (PV$ million)
New Construction	1.59	0.50	(0.00)	$8.00
Additions and Alterations	3.65	1.12	(0.01)	$18.05
TOTAL	5.25	1.62	(0.01)	$26.05

a. First-year savings from all new construction and alterations completed statewide in 2023.

6.2.1.4 Submeasure I: Space Conditioning – Refrigerant Charge Verification

Statewide results for refrigerant charge verification are presented in this section. Savings are presented for Climate Zones 2 and 8 through 15.

The first-year energy impacts represent the first-year annual savings from all buildings that will be completed in 2023. The 30-year energy cost savings represent the energy cost savings over the entire 30-year analysis period. The statewide savings estimates do not take naturally occurring market adoption or compliance rates into account.

Table 146 presents the first-year statewide energy and energy cost impact from newly constructed buildings by climate zone.

Table 147 presents first-year statewide impact from new construction, additions, and alterations.

Table 146: Statewide Energy and Energy Cost Impacts – Refrigerant Charge

Climate Zone	Statewide New Construction Impacted by Proposed Change in 2023 (dwelling units)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (MMTherms)	30-Year Present Valued Energy Cost Savings (million 2023 PV$)
1	N/A	N/A	N/A	N/A	N/A
2	875	0.03	0.01	0.00	$0.17
3	N/A	N/A	N/A	N/A	N/A
4	N/A	N/A	N/A	N/A	N/A
5	N/A	N/A	N/A	N/A	N/A
6	N/A	N/A	N/A	N/A	N/A
7	N/A	N/A	N/A	N/A	N/A
8	2,634	0.15	0.04	0.00	$0.72
9	6,185	0.34	0.11	0.00	$1.71
10	2,185	0.13	0.04	0.00	$0.63
11	624	0.04	0.01	0.00	$0.21
12	3,522	0.16	0.06	0.00	$0.94
13	1,028	0.07	0.02	0.00	$0.37
14	467	0.03	0.01	0.00	$0.15
15	304	0.03	0.01	0.00	$0.16
16	N/A	N/A	N/A	N/A	N/A
TOTAL	**17,825**	**0.96**	**0.32**	**0.00**	**$5.05**

a. First-year savings from all new buildings completed statewide in 2023.

Table 147: Statewide Energy and Energy Cost Impacts – New Construction, Alterations, and Additions – Refrigerant Charge

Construction Type	First-Year Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First -Year Natural Gas Savings (MMTherms)	30-Year Present Valued Energy Cost Savings (PV$ million)
New Construction	0.96	0.32	0.00	$5.05
Additions and Alterations	3.17	1.10	0.00	$17.86
TOTAL	4.13	1.42	0.00	$22.91

a. First-year savings from all new construction and alterations completed statewide in 2023.

6.2.1.5 Combination G-I: Space Conditioning – New Construction Test Verification Package

Statewide results for the three verification measures, duct leakage testing, airflow rate and fan efficacy, and refrigerant charge verification, are presented in this section as a package. This analysis represents impacts for ducted cooling systems serving individual dwelling units in multifamily buildings four habitable stories and greater.

The refrigerant charge verification submeasure also impacts non-ducted cooling systems, of which there are many represented by ductless mini-split heat pumps and packaged terminal heat pumps and air conditioners. Savings as a result of refrigerant charge verification for this portion of the building stock in Climate Zones 2 and 8 through 15 are not accounted for here but are included in the individual measures statewide results (see Section 6.2.1.4).

The duct leakage testing submeasure also impacts ducted heating-only systems; however, this is a very small percentage of the building stock and shrinking as it becomes more common to install air conditioning with warming temperatures in climates where in the past cooling has not been common. Heating only systems are also often non-ducted. This small portion of the building stock are not accounted for in the statewide results.

The Statewide CASE Team recommends that the three contractor test and report measure be required where found to be cost effective as a package for multifamily building four habitable stories and greater, even though the duct leakage testing alone is not cost effective.

The first-year energy impacts represent the first-year annual savings from all buildings that will be completed in 2023. The 30-year energy cost savings represent the energy cost savings over the entire 30-year analysis period. The statewide savings estimates do not take naturally occurring market adoption or compliance rates into account.

Table 148 presents the first-year statewide energy and energy cost savings from newly constructed buildings by climate zone. Since these results are for the new construction test package there are no savings for alterations.

Table 148: Statewide Energy and Energy Cost Impacts – New Construction Test Package

Climate Zone	Statewide New Construction Impacted by Proposed Change in 2023 (dwelling units)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (MMTherms)	30-Year Present Valued Energy Cost Savings (million 2023 PV$)
1	N/A	N/A	N/A	N/A	N/A
2	327	0.05	0.02	(0.00)	$0.31
3	1,585	0.12	0.04	(0.00)	$0.71
4	826	0.12	0.04	(0.00)	$0.73
5	147	0.01	0.00	(0.00)	$0.05
6	700	0.11	0.03	(0.00)	$0.51
7	753	0.11	0.03	(0.00)	$0.47
8	984	0.25	0.08	(0.00)	$1.28
9	2,311	0.57	0.19	(0.00)	$3.06
10	817	0.23	0.08	(0.00)	$1.14
11	233	0.07	0.03	(0.00)	$0.37
12	1,316	0.30	0.12	(0.00)	$1.77
13	384	0.13	0.05	(0.00)	$0.72
14	175	0.05	0.02	(0.00)	$0.26
15	114	0.06	0.02	(0.00)	$0.27
16	70	0.01	0.00	(0.00)	$0.04
TOTAL	**10,743**	**2.16**	**0.74**	**(0.00)**	**$11.69**

a. First-year savings from all new buildings completed statewide in 2023.

6.2.2 Statewide Greenhouse Gas (GHG) Emissions Reductions

The Statewide CASE Team calculated avoided GHG emissions assuming the emissions factors specified in the U.S. EPA eGRID for the WECC CAMX subregion. The electricity emission factor represents savings from avoided electricity generation and accounts for the GHG impacts if the state meets the renewable portfolio standard goal of 33 percent renewable electricity generation by 2020.[10] Avoided GHG emissions from natural gas savings attributable to sources other than utility-scale electrical power generation are calculated using emissions factors specified in U.S. EPA's Compilation

[10] When evaluating the impact of increasing the Renewable Portfolio Standard from 20 percent renewables by 2020 to 33 percent renewables by 2020, the California Air Resources Board (CARB) published data on expected air pollution emissions for various future electricity generation scenarios (CARB 2010). The incremental emissions were calculated by dividing the difference between California emissions in the CARB high and low generation forecasts by the difference between total electricity generated in those two scenarios.

of Air Pollutant Emissions Factors (AP-42). See Appendix C for additional details on the methodology used to calculate GHG emissions.

Table 149 presents the estimated first-year avoided GHG emissions of the proposed code change. During the first year, GHG emissions of 2,471 metric tons of carbon dioxide equivalents (metric tons CO2e) would be avoided.

Table 149: First-Year Statewide GHG Emissions Impacts – Space Conditioning Measures

Measure	Electricity Savings[a] (GWh/yr)	Reduced GHG Emissions from Electricity Savings[a] (Metric Tons CO2e)	Natural Gas Savings[a] (MMTherms /yr)	Reduced GHG Emissions from Natural Gas Savings[a] (Metric Tons CO2e)	Total Reduced CO_2e Emissions[a,b] (Metric Tons CO2e)
Duct Insulation	(0.03)	(8)	(0.00)	(27)	(35)
Duct Leakage Testing	0.93	224	0.01	72	295
Airflow and Fan Efficacy	5.25	1,261	(0.01)	(44)	1,217
Refrigerant Charge	4.13	994	0.00	0.00	994
TOTAL	**10.28**	**2471**	**0**	**1**	**2,471**

a. First-year savings from all buildings completed statewide in 2023.

b. Assumes the following emission factors: 240.4 MTCO2e/GWh and 5,454.4 MTCO2e/MMTherms.

6.2.3 Statewide Water Use Impacts

The proposed code changes will not result in water savings.

6.2.4 Statewide Material Impacts

The proposed code changes will not result in impacts on the use of toxic or energy intensive materials.

6.2.5 Other Non-Energy Impacts

Ensuring the systems are designed and installed properly with the proposed verification measures improves HVAC system capacity and decreases system run times, which should result in longer equipment life and reduced maintenance cost. Increased capacity also improves occupant comfort. Ensuring adequate refrigerant charge at time of installation will reduce the number of times the systems a technician may need to connect a gauge to the system and re-charge it over its lifetime. Each time a gauge is connects to a refrigerant system small amounts of refrigerant is leaked.

7. Proposed Revisions to Code Language

7.1 Guide to Markup Language

The proposed changes to the standards, Reference Appendices, and the ACM Reference Manuals are provided below. Changes to the 2019 language is marked with red underlining (new language) and ~~strikethroughs~~ (deletions).

7.2 Standards

See Appendix I for the full multifamily chapter language, with mark-up to show where language differs from the 2019 residential and nonresidential chapter language. The addition of these three chapters would result in additional language clean-up throughout Title 24, Part 6, to change mention of low- and high-rise residential buildings to multifamily buildings, update references to multifamily requirements, and remove multifamily-specific requirements from the residential and nonresidential chapters.

7.3 Reference Appendices

The Statewide CASE Team recommends reference to the Residential Appendices for field verification measures for envelope and individual system HVAC systems (HERS measures). For field verification and/or commissioning of common use area or central systems, the Statewide CASE Team recommends retaining reference to the Nonresidential Appendices. This Draft CASE Report does not address additional changes to the Reference Appendices, such as reference updates, that may result from creation of the multifamily chapters and consequential revisions to the low-rise residential and nonresidential chapters.

7.4 ACM Reference Manual

The Statewide CASE Team recommends mark-up of Standard Proposed and Proposed Design for multifamily buildings, aligned with the proposed multifamily chapters, following Energy Commission decision about which software will be used for multifamily buildings. This content may be captured within the existing Residential or Nonresidential ACM Manual, or in a new Multifamily ACM Manual, dependent on Energy Commission software decisions.

7.5 Compliance Manuals

The Statewide CASE Team recommends creation of a Multifamily Compliance Manual, which will stand alone as a new, separate document dedicated to multifamily buildings, and it will incorporate all multifamily requirements that are currently discussed in either the Nonresidential or Residential Compliance Manuals. Compliance Documents

The Compliance Improvement Subprogram Team supported the CASE Team by conducting an analysis on compliance documents to support these chapters. The purpose was to determine a practicable strategy for the Energy Commission to enable multifamily building teams to document compliance, and authorities having jurisdiction to verify compliance. The current situation where permit applicants must use a combination of nonresidential and residential compliance documents results in inaccurate documentation and creates confusing permit applications for plans examiners to review.

The effort to update compliance documents includes updating and performing quality control of XML schemas, utilizing the State's report generator, and working with registry providers to update their systems, in addition to updating the documents themselves. Creating a new set of multifamily only compliance documents would result in significant duplication of existing compliance documents and would add more content to update in the period between code adoption and implementation.

The team recommends multifamily projects use the nonresidential compliance documents. Proposed common area requirements generally follow existing nonresidential requirements and could be documented using the existing tables in the nonresidential certificates of compliance (NRCC). Dwelling unit subtables could be added to the NRCCs to document compliance with requirements separate from common areas, but within the same form. Both the 2019 NRCC-MCH-E (Table J) and the 2019 NRCC-PLB-E (Table F) have dwelling unit subtables, setting this precedence. Nonresidential forms such as the NRCC-ELC-E, NRCC-PRC-E, NRCC-LTI-E, NRCC-LTO-E and NRCC-LTS-E, which document electrical, parking garage exhaust, and lighting requirements would need no or minor updates to support the multifamily requirements in these chapters.

It should also be noted a significant benefit of this strategy is the ability to document mixed-use buildings within the same form, which are not addressed directly by the multifamily chapters, but still need a reasonable solution for compliance documentation.

In addition, the analysis considered how project data would flow through the compliance process to support HERS and ATT field verifications and integrate with data registries. The Energy Commission is considering a redesign of the NRCI for the 2022 code cycle to improve documenting and verifying compliance in the field by installers and inspectors. Supporting multifamily requirements could easily be considered as part of this effort and therefore would not require updates to installation certificates. The chapters also reference a combination of HERS verifications and acceptance tests. The nonresidential documentation process already includes both nonresidential certificates of acceptance (NRCA) to document acceptance tests and NRCV to document HERS verifications. Because the general approach in the multifamily chapters is to use existing acceptance tests, there would not be updates to NRCA documents. The chapters do propose several HERS verifications that are not currently documented with NRCV forms, and therefore existing CF3R forms would need to be converted to NRCVs so that projects do not use a combination of nonresidential and residential forms to document compliance.

Advantages of this strategy noted during the analysis include:

- Less schema and report generator updates for the Energy Commission, software vendors and registry providers.
- Eliminating duplicative updates for tables documenting common areas.
- Supporting documentation of mixed-use buildings.
- Following current practices of utilizing dwelling unit subtables and NRCV documents for HERS verifications.
- The ability to utilize NRCA documents without a combination of residential and nonresidential forms.

The primary disadvantage is that the NRCC documents already implement very complex logic to document existing requirements and adding dwelling unit requirements would increase the complexity. However, the advantages for both the Energy Commission and the market actors outweigh this disadvantage; therefore, using the nonresidential documents is the recommended solution.

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Appendix A: Statewide Savings Methodology

The Statewide CASE Team estimated statewide impacts for the first year by multiplying per-unit savings estimates by statewide construction forecasts that the Energy Commission provided (California Energy Commission 2019). The Statewide CASE Team made assumptions about the percentage of buildings in each climate zone that will be impacted by the proposed code change. Table 150 through Table 173 present the number of dwelling units by prototype building, both newly constructed and existing, that the Statewide CASE Team assumed will be impacted by the proposed code change during the first year the 2022 code is in effect.

Building Envelope

Submeasure A: Envelope – Roof Assemblies

Prescriptive requirements vary dependent on roof slope; steep sloped, defined as >2:12 and low sloped, defined as ≤ 2:12. The estimated statewide impact varies across these definitions by prototype. The Statewide CASE Team referenced an Evergreen Economics survey representing 805 multifamily buildings and 14,673 dwelling units in California (Evergreen Economics 2020). In order to meet the needs of a statewide impact, Statewide CASE Team authors conducted the following recategorizations of the survey data based on market expertise.

- Evergreen's data listed roof type(s) by building but reported dwelling unit count by project.
- Buildings with two roof types (2.5 percent of listed buildings) were assumed to have half their dwelling units under each roof type).
- Project sites with multiple buildings were assumed to have their dwelling units equally split across each building.
- Evergreen's data allowed for three roof type categories: attic, roof deck, and sloped/vaulted (no attic). The Statewide CASE Team aligned roof deck with a low-sloped non-attic roof and sloped/vaulted with a steep-sloped non-attic roof.
- The Statewide CASE Team matched surveyed buildings to CASE prototypes based on a combination of the building's number of habitable stories and roof type. For example, one- and two-story buildings with attics were assigned 90 percent as the garden prototype, and 10 percent as the low-rise loaded corridor prototype.

Table 150 presents the estimates of percentage of newly constructed dwelling units under attic and non-attic roofs with low-sloped and steep-sloped roofs by prototype. It also lists the climate zones with proposed code changes for each combination.

Table 150: Estimated Dwelling Unit Ratios of Roof Type by Prototype

Prototype	Attic Roof	Low slope; ≤2:12 Non-Attic Roof	Climate Zones impacted	Steep slope; >2:12 Non-Attic Roof	Climate Zones impacted
2-Story Garden Style	67%	15%	All	18%	All
3-Story Loaded Corridor	28%	56%	All	15%	All
5-Story Mixed Use	0%	93%	9-11,13-15 (ASR only)	7%	No change
10-Story Mixed Use	0%	100%	9-11,13-15 (ASR only)	0%	No change

Table 151 presents the estimated impacted number of multifamily dwelling units for proposed non-attic roof Option A.

Table 151: Estimated New Construction and Existing Building Stock for Multifamily Buildings by Climate Zone for Buildings with Non-Attic Roofs

Building Climate Zone	New Construction in 2023 (dwelling units)			Existing Building Stock in 2023 (dwelling units)		
	Total Dwelling Units Completed in 2023 [A]	Percent of New Dwelling Units Impacted by Proposal [B]	Dwelling Units Impacted by Proposal in 2023 C = A x B	Total Existing Dwelling Units in 2023 [D]	Percent of New Dwelling Units Impacted by Proposal [E]	Dwelling Units Impacted by Proposal in 2023 F = D x E
1	265	25%		17,126		
2	1,573	25%	18	101,721	N/A	N/A
3	7,630	25%	89	530,089	N/A	N/A
4	3,975	25%	46	278,535	N/A	N/A
5	706	25%	8	44,816	N/A	N/A
6	3,370	25%	39	315,784	N/A	N/A
7	3,623	25%	42	291,804	N/A	N/A
8	4,738	25%	55	489,337	N/A	N/A
9	11,124	88%	129	1,086,699	N/A	N/A
10	3,930	88%	N/A	316,384	N/A	N/A
11	1,122	88%	N/A	81,820	N/A	N/A
12	6,335	25%	N/A	455,265	N/A	N/A
13	1,849	88%	N/A	154,048	N/A	N/A
14	840	88%	N/A	79,142	N/A	N/A
15	547	88%	N/A	40,033	N/A	N/A
16	339	25%	N/A	27,505	N/A	N/A
TOTAL	51,966		426	4,310,108	N/A	N/A

For low sloped roofs, the proposed code update will increase stringency on high rise buildings in Climate Zones 9 through 11 and 13 through 15.

Submeasure B: Envelope – Wall U-Factor

The proposed code change leads to a statewide savings impact due to the new prescriptive categories based on construction assembly and fire rating rather than number of habitable stories. The Statewide CASE Team estimated the following impacts, some of which lead to increased savings, other in reduced savings.

To estimate statewide savings impact, the Statewide CASE Team referenced an Evergreen Economics survey representing 805 multifamily buildings and 14,673 dwelling units in California (Evergreen Economics 2020). This data did not explicitly include information regarding each building's fire-code construction type. The Statewide CASE Team reviewed fire code definitions, interview California's Fire Marshall, and consulted with multifamily building design experts to determine the ratio of buildings and dwelling units in buildings with 0 or 1-hour fire-rated walls vs 2 or 3-hour rated walls by each buildings number of habitable stories. The resultant estimated ratio of dwelling units, by prototype, with low fire rated, high fire rated, and curtain wall systems are presented in Table 152.

Table 152: Estimated Ratio of Dwelling Units by Prototype and Prescriptive Wall Category

Prototype	**Low Fire Rating** (0 or 1-hour) Framed Construction	**High Fire Rating** (2 or 3-hour) Framed Construction	Curtainwall
2-Story Garden Style	100%	0%	0%
3-Story Loaded Corridor	97%	3%	0%
5-Story Mixed Use	39%	55%	7%
10-Story Mixed Use	0%	30%	70%

Low-rise buildings that have high fire rated walls due to use of masonry/steel (Type III) and timber-frame (Type IV) construction methods will result in loss of savings in Climate Zones 1-5, 8-10, 12 and 13 – estimated at 0.9 percent of low-rise construction. Table 153 presents the estimated impacted number of multifamily dwelling units for these buildings.

High-rise buildings that have low fire rated walls due to use of non-combustible (Type II) and wood framed (Type V) buildings will result in increased savings in Climate Zones 1-5, 8-10, 12 and 13– estimated at 18 percent of high-rise construction.

Table 154 presents the estimated impacted number of multifamily dwelling units for these buildings.

High-rise buildings, of both high-fire and low-fire rated framed walls, in climate zones receiving an adjusted prescriptive limit that aligns to low-rise standards will result in a loss of savings in Climate Zones 6, 7, 11, and 14-16, which are estimated at 10 percent of high-rise construction. Table 155 presents the estimated impacted number of multifamily dwelling units for these buildings.

The Statewide CASE Team did not estimate savings from high-rise metal-framed buildings, estimated at less than one percent of all multifamily new construction, that do not have their own prescriptive category in the proposed code.

The removal of the metal-framed construction category, which has been the basis of the Standard model for all high-rise multifamily construction regardless of the building's Proposed walls, and the proposal to use the Proposed wall construction type/fire-rating as the basis for the Standard model's U-factor will force performance tradeoffs or improved wall assemblies in the majority of high-rise construction. This will result in estimable real-world energy savings this code cycle by forcing performance tradeoffs or improved wall assemblies in all but Climate Zone 6. Nearly all multifamily new construction projects use the performance approach. However, these savings were already claimed during previous code-cycles that presumed prescriptive compliance as the norm and did not account for the impact of the performance modeling alternative calculation methodology. Therefore, the Statewide CASE Team did not estimate the statewide impact or include such savings in our savings claim.

The proposed code change would not be triggered in an alteration nor for any estimably significant number of additions; therefore, there is no estimated impact from existing buildings.

Table 153: Estimated New Construction and Existing Building Stock for Multifamily Buildings by Climate Zone for Low Rise Buildings with High Fire Ratings in Impacted Climate Zones

Building Climate Zone	New Construction in 2023 (dwelling units)			Existing Building Stock in 2023 (dwelling units)		
	Total Dwelling Units Completed in 2023 [A]	Percent of New Dwelling Units Impacted by Proposal [B]	Dwelling Units Impacted by Proposal in 2023 C = A x B	Total Existing Dwelling Units in 2023 [D]	Percent of New Dwelling Units Impacted by Proposal [E]	Dwelling Units Impacted by Proposal in 2023 F = D x E
1	265	1%	3	17,126	N/A	N/A
2	1,573	1%	17	101,721	N/A	N/A
3	7,630	1%	83	530,089	N/A	N/A
4	3,975	1%	43	278,535	N/A	N/A
5	706	1%	8	44,816	N/A	N/A
6	3,370	1%	37	315,784	N/A	N/A
7	3,623	N/A	N/A	291,804	N/A	N/A
8	4,738	N/A	N/A	489,337	N/A	N/A
9	11,124	1%	121	1,086,699	N/A	N/A
10	3,930	1%	43	316,384	N/A	N/A

11	1,122	N/A	N/A	81,820	N/A	N/A
12	6,335	1%	69	455,265	N/A	N/A
13	1,849	1%	20	154,048	N/A	N/A
14	840	N/A	N/A	79,142	N/A	N/A
15	547	N/A	N/A	40,033	N/A	N/A
16	339	N/A	N/A	27,505	N/A	N/A
TOTAL	51,966		444	4,310,108		0

Table 154: Estimated New Construction and Existing Building Stock for Multifamily Buildings by Climate Zone for High Rise Buildings with Low Fire Ratings in Impacted Climate Zones

Building Climate Zone	New Construction in 2023 (dwelling units)			Existing Building Stock in 2023 (dwelling units)		
	Total Dwelling Units Completed in 2023 [A]	Percent of New Dwelling Units Impacted by Proposal [B]	Dwelling Units Impacted by Proposal in 2023 C = A x B	Total Existing Dwelling Units in 2023 [D]	Percent of New Dwelling Units Impacted by Proposal [E]	Dwelling Units Impacted by Proposal in 2023 F = D x E
1	265	23%	60	17,126		
2	1,573	23%	354	101,721	N/A	N/A
3	7,630	23%	1,717	530,089	N/A	N/A
4	3,975	23%	895	278,535	N/A	N/A
5	706	23%	159	44,816	N/A	N/A
6	3,370	N/A	N/A	315,784	N/A	N/A
7	3,623	N/A	N/A	291,804	N/A	N/A
8	4,738	23%	1,066	489,337	N/A	N/A
9	11,124	23%	2,503	1,086,699	N/A	N/A
10	3,930	23%	884	316,384	N/A	N/A
11	1,122	N/A	N/A	81,820	N/A	N/A
12	6,335	23%	1,426	455,265	N/A	N/A
13	1,849	23%	416	154,048	N/A	N/A
14	840	N/A	N/A	79,142	N/A	N/A
15	547	N/A	N/A	40,033	N/A	N/A
16	339	N/A	N/A	27,505	N/A	N/A
TOTAL	51,966		9,480	4,310,108		0

Table 155: Estimated New Construction and Existing Building Stock for Multifamily Buildings by Climate Zone for High Rise Buildings with High Fire Ratings in Impacted Climate Zones

Building Climate Zone	New Construction in 2023 (dwelling units)			Existing Building Stock in 2023 (dwelling units)		
	Total Dwelling Units Completed in 2023 [A]	Percent of New Dwelling Units Impacted by Proposal [B]	Dwelling Units Impacted by Proposal in 2023 C = A x B	Total Existing Dwelling Units in 2023 [D]	Percent of New Dwelling Units Impacted by Proposal [E]	Dwelling Units Impacted by Proposal in 2023 F = D x E
1	265	N/A	N/A	17,126	N/A	N/A
2	1,573	N/A	N/A	101,721	N/A	N/A
3	7,630	N/A	N/A	530,089	N/A	N/A
4	3,975	N/A	N/A	278,535	N/A	N/A
5	706	N/A	N/A	44,816	N/A	N/A
6	3,370	55%	1,868	315,784	N/A	N/A
7	3,623	55%	2,009	291,804	N/A	N/A
8	4,738	N/A	N/A	489,337	N/A	N/A
9	11,124	N/A	N/A	1,086,699	N/A	N/A
10	3,930	N/A	N/A	316,384	N/A	N/A
11	1,122	55%	622	81,820	N/A	N/A
12	6,335	N/A	N/A	455,265	N/A	N/A
13	1,849	N/A	N/A	154,048	N/A	N/A
14	840	55%	466	79,142	N/A	N/A
15	547	55%	303	40,033	N/A	N/A
16	339	55%	188	27,505	N/A	N/A
TOTAL	51,966		5,456	4,310,108		0

Submeasure C: Envelope – Quality Insulation Installation

The Statewide CASE Team considered three data sources to determine the statewide distribution of new construction dwelling units impacted the proposed QII measure: CoStar project data set, the CMFNH program, and energy consultant project data sets.

The CMFNH data set contains 128 projects representing 646 buildings built or scheduled to be built during the 2016 or 2019 code cycles. The projects all voluntarily took part in PG&E’s above-code, multifamily new construction program and are therefore all above-code projects. The data points from these projects are highly reliable—they were screened for accuracy and program eligibility, and TRC reviewed the plans as part of our role as program implementors.

The consultant project data set contains 39 projects representing 58 buildings. The project-available project data categories and details do not easily align with or provide complete details to categorize relative to CASE prototypes.

The CoStar data include self-reported building data from all multifamily buildings constructed or scheduled to complete construction between 2014 and 2022. It contains data from 2,180 projects representing 6,771 buildings. It is the most comprehensive set of data available with the fewest inherent biases, and it was the primary source of information for statewide distribution of building type for this savings assessment. However, review of the data shows clearly inaccurate data within some project records, and the available data categories do not cleanly align with or provide complete detail to categorize relative to CASE prototypes and the proposed QII threshold of 40,000 ft^2 of conditioned space. Therefore, the Statewide CASE Team made multiple subjective decisions on how to filter, sort, interpret, and analyze the data to determine representation of multifamily building type in the California market for the statewide savings claim. The Statewide CASE Team relied on SME guidance and market knowledge, plus insight from the other two data sources, to develop the final distribution estimations by prototype and building size.

Table 156 shows each prototype, the number of stories each prototype represents for the variety of real construction expectations, as well as the percentage of dwelling units represented in the data for each prototype both above and below the 40,000 ft^2 threshold. Two story buildings are represented either by the low-rise garden style prototype or the low-rise loaded corridor prototype, depending on other aspects of their construction methodology and building layout.

Table 156: Classification of Project Data into CASE Prototypes

Prototype	Number of Stories	Percent of prototype's dwelling units in buildings <40,000 CFA	Percent of prototype's dwelling units in buildings ≥40,000 CFA	Percent of prototype's dwelling units in buildings using curtain wall construction assemblies
2-Story Garden Style	1-2	100%	0%	0%
3-Story Loaded Corridor	2-3	78%	22%	0%
5-Story Mixed Use	4-6	13%	72%	15%
10-Story Mixed Use	7+	0%	7%	93%

Table 157: Estimated New Construction for Multifamily Buildings QII Requirement

Building Type	Total Statewide New Construction Permitted in 2023 (dwelling units)	Percent of Statewide New Construction Impacted by Proposal		New Construction Permitted in 2023 (dwelling units)
3-Story Loaded Corridor	17,149	QII	78%	13,639
		No Requirement (except CZ 7)	22%	3,510 (263 in CZ 7)
		Not Applicable	0%	0
5-Story Mixed Use	30,140	QII (except CZ7)	13%	3,645 (273 in CZ 7)
		No Requirement	72%	21,701
		Not Applicable	15%	4,521

Table 158 and Table 159 present the number of dwelling units for the 5-Story Mixed Use prototype the Statewide CASE Team determined would be impacted by the proposed code change during the first year the 2022 code is in effect.

Table 158: Estimated New Construction Building Stock for Multifamily Buildings by Climate Zone for 5-Story Prototype Building, QII

Building Climate Zone	New Construction in 2023 (dwelling units)			Existing Building Stock in 2023 (dwelling units)		
	Total Dwelling Units Completed in 2023 [A]	Percent of New Dwelling Units Impacted by Proposal [B]	Dwelling Units Impacted by Proposal in 2023 C = A x B	Total Existing Dwelling Units in 2023 [D]	Percent of Dwelling Units Impacted by Proposal [E]	Dwelling Units Impacted by Proposal in 2023 F = D x E
1	154	13%	20	3,083	N/A	N/A
2	912	13%	119	18,310	N/A	N/A
3	4,425	13%	575	95,416	N/A	N/A
4	2,305	13%	300	50,136	N/A	N/A
5	409	13%	53	8,067	N/A	N/A
6	1,955	13%	254	56,841	N/A	N/A
7	2,101	N/A	N/A	52,525	N/A	N/A
8	2,748	13%	357	88,081	N/A	N/A
9	6,452	13%	839	195,606	N/A	N/A
10	2,279	13%	296	56,949	N/A	N/A
11	651	13%	85	14,728	N/A	N/A
12	3,674	13%	478	81,948	N/A	N/A
13	1,072	13%	139	27,729	N/A	N/A
14	487	13%	63	14,246	N/A	N/A
15	317	13%	41	7,206	N/A	N/A
16	197	13%	26	4,951	N/A	N/A
TOTAL	30,140		3,645	775,819		0

Table 159: Estimated New Construction Building Stock for Multifamily Buildings by Climate Zone for 3-Story Prototype Building, QII

Building Climate Zone	New Construction in 2023 (dwelling units)			Existing Building Stock in 2023 (dwelling units)		
	Total Dwelling Units Completed in 2023 [A]	Percent of New Dwelling Units Impacted by Proposal [B]	Dwelling Units Impacted by Proposal in 2023 C = A x B	Total Existing Dwelling Units in 2023 [D]	Percent of Dwelling Units Impacted by Proposal [E]	Dwelling Units Impacted by Proposal in 2023 F = D x E
1	87	22%	19	3,083	N/A	N/A
2	519	22%	114	18,310	N/A	N/A
3	2,518	22%	554	95,416	N/A	N/A
4	1,312	22%	289	50,136	N/A	N/A
5	233	22%	51	8,067	N/A	N/A
6	1,112	22%	245	56,841	N/A	N/A
7	1,196	N/A	N/A	52,525	N/A	N/A
8	1,564	22%	344	88,081	N/A	N/A
9	3,671	22%	808	195,606	N/A	N/A
10	1,297	22%	285	56,949	N/A	N/A
11	370	22%	81	14,728	N/A	N/A
12	2,091	22%	460	81,948	N/A	N/A
13	610	22%	134	27,729	N/A	N/A
14	277	22%	61	14,246	N/A	N/A
15	181	22%	40	7,206	N/A	N/A
16	112	22%	25	4,951	N/A	N/A
TOTAL	17,149		3,510	775,819		0

Submeasure D: Envelope – Fenestration Properties

The proposed code change establishes three categories of window requirements applicable to all multifamily buildings: (1) curtain wall and storefront, (2) NAFS Performance Class AW, and (3) all other windows.

The Statewide CASE Team reviewed an Evergreen Economics survey representing 805 multifamily buildings and 14,673 dwelling units in California. From the data, the Statewide CASE Team estimated that 7 percent of mid-rise and 70 percent of high rise the multifamily dwelling units are in buildings with curtain wall glazing methods. The remainder are in buildings that use a combination of fixed and operable punched windows.

Data is not available to determine the percentage of buildings that use Performance Class AW windows. The Statewide CASE Team therefore estimated their prominence based on subject matter expert opinion as applicable to the prototype buildings. Of the 93 percent of 5-story mixed-use buildings that use non curtainwall glazing, experts estimated that 10 percent would use Performance Class AW windows. Of the 30 percent of 10-story mixed-use buildings that use non-curtain wall glazing, experts estimated 75 percent would also use Performance Class AW windows.

Performance Class AW windows are not required for low-rise construction and are seldom specified due to their significantly higher cost. Therefore, 100 percent of 2-story and 3-story multifamily buildings fall under the proposed *all-other* window category. Table 160 shows these breakdowns accordingly.

Table 160: Estimated Ratio of Dwelling Units by Prototype and Prescriptive Window Category

Prototype	Curtainwall and Storefront	Performance Class AW	All Others
2-Story Garden Style	0%	0%	100%
3-Story Loaded Corridor	0%	0%	100%
5-Story Mixed Use	7%	9.3%	83.7%
10-Story Mixed Use	70%	22.5%	7.5%

For existing buildings, the proposed code change would trigger the new requirements on window replacement. Using useful product life estimates from Fannie Mae, The Statewide CASE Team assumed that curtainwall glazing is replaced every 35 years and Class AW windows and punched windows are replaced every 30 years.

Table 161 presents the estimated impacted number of multifamily dwelling units for proposed changes to prescriptive curtain wall requirements, and curtain wall alterations. Only high-rise buildings are impacted.

Table 161: Estimated New Construction and Existing Building Stock for Multifamily Buildings by Climate Zone for Buildings using the Curtainwall and Storefront Window Category

Building Climate Zone	New Construction in 2023 (dwelling units)			Existing Building Stock in 2023 (dwelling units)		
	Total Dwelling Units Completed in 2023 [A]	Percent of New Dwelling Units Impacted by Proposal [B]	Dwelling Units Impacted by Proposal in 2023 C = A x B	Total Existing Dwelling Units in 2023 [D]	Percent of Dwelling Units Impacted by Proposal [E]	Dwelling Units Impacted by Proposal in 2023 F = D x E
1	265	8%	20	17,126	0.5%	88
2	1,573	N/A	N/A	101,721	0.5%	525
3	7,630	N/A	N/A	530,089	0.5%	2,735
4	3,975	N/A	N/A	278,535	0.5%	1,437
5	706	N/A	N/A	44,816	0.5%	231
6	3,370	N/A	N/A	315,784	0.5%	1,629
7	3,623	N/A	N/A	291,804	0.5%	1,506
8	4,738	N/A	N/A	489,337	0.5%	2,525
9	11,124	N/A	N/A	1,086,699	0.5%	5,607
10	3,930	N/A	N/A	316,384	0.5%	1,633
11	1,122	N/A	N/A	81,820	0.5%	422
12	6,335	N/A	N/A	455,265	0.5%	2,349
13	1,849	N/A	N/A	154,048	0.5%	795
14	840	N/A	N/A	79,142	0.5%	408
15	547	N/A	N/A	40,033	0.5%	207
16	339	8%	26	27,505	0.5%	142
TOTAL	51,966		46	4,310,108		22,240

Table 162 presents the estimated impacted number of multifamily dwelling units for proposed changes to prescriptive Class AW requirements, and Class AW alterations. Only high-rise buildings are impacted.

Table 162: Estimated New Construction and Existing Building Stock for Multifamily Buildings by Climate Zone for Buildings using the Class AW Window Category

Building Climate Zone	New Construction in 2023 (dwelling units)			Existing Building Stock in 2023 (dwelling units)		
	Total Dwelling Units Completed in 2023 [A]	Percent of New Dwelling Units Impacted by Proposal [B]	Dwelling Units Impacted by Proposal in 2023 C = A x B	Total Existing Dwelling Units in 2023 [D]	Percent of Dwelling Units Impacted by Proposal [E]	Dwelling Units Impacted by Proposal in 2023 F = D x E
1	265	7%	17	17,126	0.2%	40
2	1,573	N/A	N/A	101,721	0.2%	240
3	7,630	N/A	N/A	530,089	0.2%	1,250
4	3,975	N/A	N/A	278,535	0.2%	657
5	706	N/A	N/A	44,816	0.2%	106
6	3,370	N/A	N/A	315,784	0.2%	745
7	3,623	N/A	N/A	291,804	0.2%	688
8	4,738	N/A	N/A	489,337	0.2%	1,154
9	11,124	N/A	N/A	1,086,699	0.2%	2,562
10	3,930	N/A	N/A	316,384	0.2%	746
11	1,122	N/A	N/A	81,820	0.2%	193
12	6,335	N/A	N/A	455,265	0.2%	1,074
13	1,849	N/A	N/A	154,048	0.2%	363
14	840	N/A	N/A	79,142	0.2%	187
15	547	N/A	N/A	40,033	0.2%	94
16	339	7%	22	27,505	0.2%	65
TOTAL	51,966		39	4,310,108		10,163

Table 163 presents the estimated impacted number of multifamily dwelling units in high-rise buildings with glazing adhering to the proposed prescriptive and alterations code changes for the all-others window category.

Table 163: Estimated New Construction and Existing Building Stock for Multifamily Buildings by Climate Zone for High Rise Buildings using the All-Others Window Category

Building Climate Zone	New Construction in 2023 (dwelling units)			Existing Building Stock in 2023 (dwelling units)		
	Total Dwelling Units Completed in 2023 [A]	Percent of New Dwelling Units Impacted by Proposal [B]	Dwelling Units Impacted by Proposal in 2023 C = A x B	Total Existing Dwelling Units in 2023 [D]	Percent of Dwelling Units Impacted by Proposal [E]	Dwelling Units Impacted by Proposal in 2023 F = D x E
1	265	49%	130	17,126	0.6%	96
2	1,573	49%	770	101,721	0.6%	572
3	7,630	49%	3,733	530,089	0.6%	2,980
4	3,975	49%	1,945	278,535	0.6%	1,566
5	706	49%	345	44,816	0.6%	252
6	3,370	49%	1,649	315,784	0.6%	1,775
7	3,623	49%	1,772	291,804	0.6%	1,641
8	4,738	49%	2,318	489,337	0.6%	2,751
9	11,124	49%	5,442	1,086,699	0.6%	6,109
10	3,930	49%	1,923	316,384	0.6%	1,779
11	1,122	49%	549	81,820	0.6%	460
12	6,335	49%	3,099	455,265	0.6%	2,559
13	1,849	49%	905	154,048	0.6%	866
14	840	49%	411	79,142	0.6%	445
15	547	49%	268	40,033	0.6%	225
16	339	49%	166	27,505	0.6%	155
TOTAL	51,966		25,422	4,310,108		24,231

Table 164 presents the estimated impacted number of dwelling units in low-rise buildings that will see a less stringent prescriptive requirement for the proposed all-others window category

Table 164: Estimated New Construction and Existing Building Stock for Multifamily Buildings by Climate Zone for Low Rise Buildings Impacted by the All-Others Windows Category Slide Back

Building Climate Zone	New Construction in 2023 (dwelling units)			Existing Building Stock in 2023 (dwelling units)		
	Total Dwelling Units Completed in 2023 [A]	Percent of New Dwelling Units Impacted by Proposal [B]	Dwelling Units Impacted by Proposal in 2023 C = A x B	Total Existing Dwelling Units in 2023 [D]	Percent of Dwelling Units Impacted by Proposal [E]	Dwelling Units Impacted by Proposal in 2023 F = D x E
1	265	N/A	N/A	17,126	N/A	N/A
2	1,573	N/A	N/A	101,721	N/A	N/A
3	7,630	N/A	N/A	530,089	N/A	N/A
4	3,975	N/A	N/A	278,535	N/A	N/A
5	706	N/A	N/A	44,816	N/A	N/A
6	3,370	37%	1,247	315,784	1.9%	6,105
7	3,623	37%	1,341	291,804	1.9%	5,642
8	4,738	N/A	N/A	489,337	N/A	N/A
9	11,124	N/A	N/A	1,086,699	N/A	N/A
10	3,930	N/A	N/A	316,384	N/A	N/A
11	1,122	N/A	N/A	81,820	N/A	N/A
12	6,335	N/A	N/A	455,265	N/A	N/A
13	1,849	N/A	N/A	154,048	N/A	N/A
14	840	N/A	N/A	79,142	N/A	N/A
15	547	N/A	N/A	40,033	N/A	N/A
16	339	N/A	N/A	27,505	N/A	N/A
TOTAL	51,966		2,587	4,310,108		11,747

Submeasure E: Envelope – Fenestration Area

The proposed code change has no statewide savings impact. The Statewide CASE Team reviewed data from Evergreen Economics, the CalCERTS HERS registry, and PG&E’s CMFNH program and did not find instances where the proposed code would newly force either changes to window design or performance offsets.

Space Conditioning

The estimated percent of multifamily dwelling units impacted by each of the space conditioning submeasures is based on data collected by Evergreen Economics. Evergreen Economics surveyed 90 multifamily projects across California in 2020 covering 14,673 dwelling units in total. 127 individual units were surveyed within the 90 projects. Data collected used for this analysis was building characteristics, type of HVAC system, and duct characteristics. Each site surveyed was categorized according to the four multifamily prototypes based on number of habitable stories and, for the low-rise prototypes, the presence of interior or exterior enclosed corridors.

The proposed new construction requirements impact alterations when an entirely new or complete replacement duct system or space-conditioning system is installed. The percent of existing multifamily dwelling units impacted is based on the same factors as for new construction and the assumption that existing HVAC and duct systems have a lifetime of 20 years; therefore, five percent of affected existing buildings in any year undergo a system replacement and would be subject to the proposed requirements.

Submeasure F: Space Conditioning – Duct Insulation

Table 165 presents results from the Evergreen Economics survey representing the duct condition and location as a proportion of total projects surveyed.

Table 165: Distribution of Duct Characteristics by Prototype

Prototype	Ductless	In-Unit Ducts in Unconditioned Space	In-Unit Ducts in Conditioned Space
2-Story Garden Style	57.4%	6.4%	36.2%
3-Story Loaded Corridor	55.8%	0.0%	44.2%
5-Story Mixed Use	61.6%	0.0%	38.4%
10-Story Mixed Use	77.0%	0.0%	23.0%

Source: Evergreen Economics

Table 166 presents the estimated impacted number of multifamily dwelling units for the duct insulation submeasure for ducts in unconditioned space. The results are based on the percentage of total projects for the 5-story mixed use (0 percent) and 10-story mixed use (0 percent) prototypes with in-unit duct systems with the ductwork in unconditioned space. There is no statewide impacts for this measure.

Table 166: Estimated New Construction and Existing Building Stock for Multifamily Buildings by Climate Zone for the Duct Insulation in Unconditioned Space Submeasure

Building Climate Zone	New Construction in 2023 (dwelling units)			Existing Building Stock in 2023 (dwelling units)		
	Total Dwelling Units Completed in 2023 [A]	Percent of New Dwelling Units Impacted by Proposal [B]	Dwelling Units Impacted by Proposal in 2023 C = A x B	Total Existing Dwelling Units in 2023 [D]	Percent of New Dwelling Units Impacted by Proposal [E]	Dwelling Units Impacted by Proposal in 2023 F = D x E
1	265	0.0%	0	17,126	0.0%	0
2	1,573	0.0%	0	101,721	0.0%	0
3	7,630	0.0%	0	530,089	0.0%	0
4	3,975	0.0%	0	278,535	0.0%	0
5	706	0.0%	0	44,816	0.0%	0
6	3,370	0.0%	0	315,784	0.0%	0
7	3,623	0.0%	0	291,804	0.0%	0
8	4,738	0.0%	0	489,337	0.0%	0
9	11,124	0.0%	0	1,086,699	0.0%	0
10	3,930	0.0%	0	316,384	0.0%	0
11	1,122	0.0%	0	81,820	0.0%	0
12	6,335	0.0%	0	455,265	0.0%	0
13	1,849	0.0%	0	154,048	0.0%	0
14	840	0.0%	0	79,142	0.0%	0
15	547	0.0%	0	40,033	0.0%	0
16	339	0.0%	0	27,505	0.0%	0
TOTAL	51,966		0	4,310,108		0

Table 167 presents CalCERTS CF-2R data from 5,121 low-rise multifamily registered dwelling units. The data represents projects with ducts in conditioned space without the verified low leakage duct test credit. Even though the current mandatory code requires that ducts in conditioned space install R-6 minimum insulation, it appears this is not always done. Duct insulation is not input into CBECC-Res if ducts are in conditioned space so there is no direct verification of this requirement in the modeling software.

Table 167: R-Value of Ductwork in Conditioned Space from CalCERTS CF-2R Data for Low-Rise Multifamily Buildings

	Percent of Total Projects with Ducts in Conditioned Space (without verified low leakage testing)
Supply ducts in conditioned space ≤R-4.2	63%
Supply ducts in conditioned space ≥R-6	37%

Source: CalCERTS

Table 168 presents the estimated impacted number of multifamily dwelling units for the duct insulation submeasures for ducts in unconditioned space and in conditioned space, respectively. The results are based on the percentage of total projects for the 2-story garden style (36.2 percent) and 3-story loaded corridor (44.2 percent) prototypes with in-unit duct systems with the ductwork in conditioned space. These values were reduced to account for the estimated percentage of projects that currently are only meeting the R-4.2 requirement (63 percent).

Table 168: Estimated New Construction and Existing Building Stock for Multifamily Buildings by Climate Zone for the Duct Insulation in Conditioned Space Submeasure

Building Climate Zone	New Construction in 2023 (dwelling units)			Existing Building Stock in 2023 (dwelling units)		
	Total Dwelling Units Completed in 2023 [A]	Percent of New Dwelling Units Impacted by Proposal [B]	Dwelling Units Impacted by Proposal in 2023 C = A x B	Total Existing Dwelling Units in 2023 [D]	Percent of New Dwelling Units Impacted by Proposal [E]	Dwelling Units Impacted by Proposal in 2023 F = D x E
1	265	5.91%	16	17,126	0.41%	71
2	1,573	5.91%	93	101,721	0.41%	421
3	7,630	5.91%	451	530,089	0.41%	2,193
4	3,975	5.91%	235	278,535	0.41%	1,152
5	706	5.91%	42	44,816	0.41%	185
6	3,370	5.91%	199	315,784	0.41%	1,306
7	3,623	5.91%	214	291,804	0.41%	1,207
8	4,738	5.91%	280	489,337	0.41%	2,024
9	11,124	5.91%	657	1,086,699	0.41%	4,495
10	3,930	5.91%	232	316,384	0.41%	1,309
11	1,122	5.91%	66	81,820	0.41%	338
12	6,335	5.91%	374	455,265	0.41%	1,883
13	1,849	5.91%	109	154,048	0.41%	637
14	840	5.91%	50	79,142	0.41%	327
15	547	5.91%	32	40,033	0.41%	166
16	339	5.91%	20	27,505	0.41%	114
TOTAL	51,966		3,071	4,310,108		17,830

Submeasure G: Space Conditioning – Duct Leakage Testing

Table 169 presents results from the Evergreen Economics survey representing the duct condition and location as a proportion of total projects surveyed.

Table 169: Distribution of Duct Characteristics by Prototype

Prototype	Ductless	In-Unit Ducts in Unconditioned Space	In-Unit Ducts in Conditioned Space
2-Story Garden Style	57.4%	6.4%	36.2%
3-Story Loaded Corridor	55.8%	0.0%	44.2%
5-Story Mixed Use	61.6%	0.0%	38.4%
10-Story Mixed Use	77.0%	0.0%	23.0%

Source: Evergreen Economics

Table 170 presents the estimated impacted number of multifamily dwelling units for the duct leakage testing submeasure. The results are based on the percentage of total projects for the 5-story mixed use (38.4 percent) and 10-story mixed use (23.0 percent) prototypes with in-unit duct systems with the ductwork in conditioned space.

Table 170: Estimated New Construction and Existing Building Stock for Multifamily Buildings by Climate Zone for the Duct Leakage Testing Submeasure

Building Climate Zone	New Construction in 2023 (dwelling units)			Existing Building Stock in 2023 (dwelling units)		
	Total Dwelling Units Completed in 2023 [A]	Percent of New Dwelling Units Impacted by Proposal [B]	Dwelling Units Impacted by Proposal in 2023 C = A x B	Total Existing Dwelling Units in 2023 [D]	Percent of New Dwelling Units Impacted by Proposal [E]	Dwelling Units Impacted by Proposal in 2023 F = D x E
1	265	23.4%	62	17,126	0.62%	107
2	1,573	23.4%	368	101,721	0.62%	633
3	7,630	23.4%	1,786	530,089	0.62%	3,297
4	3,975	23.4%	930	278,535	0.62%	1,732
5	706	23.4%	165	44,816	0.62%	279
6	3,370	23.4%	789	315,784	0.62%	1,964
7	3,623	23.4%	848	291,804	0.62%	1,815
8	4,738	23.4%	1,109	489,337	0.62%	3,043
9	11,124	23.4%	2,604	1,086,699	0.62%	6,758
10	3,930	23.4%	920	316,384	0.62%	1,968
11	1,122	23.4%	263	81,820	0.62%	509
12	6,335	23.4%	1,483	455,265	0.62%	2,831
13	1,849	23.4%	433	154,048	0.62%	958
14	840	23.4%	197	79,142	0.62%	492
15	547	23.4%	128	40,033	0.62%	249
16	339	23.4%	79	27,505	0.62%	171
TOTAL	51,966		12,164	4,310,108		26,804

Submeasure H: Space Conditioning – Space Cooling Airflow Rate and Fan Efficacy

Table 171 presents results from the Evergreen Economics survey representing the presence of mechanical cooling and ducted mechanical cooling as a proportion of total projects surveyed.

Table 171: Distribution of Projects with Mechanical Cooling both Ducted and Ductless by Prototype

Prototype	In-Unit Cooling System	In-Unit Ducted Cooling System
2-Story Garden **Style**	72.5%	40.9%
3-Story Loaded Corridor	97.5%	48.2%
5-Story Mixed Use	88.0%	33.8%
10-Story Mixed Use	90.8%	23.0%

Source: Evergreen Economics

Table 172 presents the estimated impacted number of multifamily dwelling units for the space cooling airflow rate and fan efficacy submeasure. The results are based on the percentage of total projects for the 5-story mixed use (33.8 percent) and 10-story mixed use (23 percent) prototypes with in-unit duct systems and individual mechanical cooling.

Table 172: Estimated New Construction and Existing Building Stock for Multifamily Buildings by Climate Zone for the Airflow Rate and Fan Efficacy Submeasure

Building Climate Zone	New Construction in 2023 (dwelling units)			Existing Building Stock in 2023 (dwelling units)		
	Total Dwelling Units Completed in 2023 [A]	Percent of New Dwelling Units Impacted by Proposal [B]	Dwelling Units Impacted by Proposal in 2023 C = A x B	Total Existing Dwelling Units in 2023 [D]	Percent of New Dwelling Units Impacted by Proposal [E]	Dwelling Units Impacted by Proposal in 2023 F = D x E
1	265	20.8%	55	17,126	0.58%	100
2	1,573	20.8%	327	101,721	0.58%	591
3	7,630	20.8%	1,585	530,089	0.58%	3,080
4	3,975	20.8%	826	278,535	0.58%	1,618
5	706	20.8%	147	44,816	0.58%	260
6	3,370	20.8%	700	315,784	0.58%	1,835
7	3,623	20.8%	753	291,804	0.58%	1,696
8	4,738	20.8%	984	489,337	0.58%	2,843
9	11,124	20.8%	2,311	1,086,699	0.58%	6,315
10	3,930	20.8%	817	316,384	0.58%	1,838
11	1,122	20.8%	233	81,820	0.58%	475
12	6,335	20.8%	1,316	455,265	0.58%	2,645
13	1,849	20.8%	384	154,048	0.58%	895
14	840	20.8%	175	79,142	0.58%	460
15	547	20.8%	114	40,033	0.58%	233
16	339	20.8%	70	27,505	0.58%	160
TOTAL	51,966		10,798	4,310,108		25,045

Submeasure I: Space Conditioning – Refrigerant Charge Verification

Table 173 presents the estimated impacted number of multifamily dwelling units for the space cooling refrigerant charge verification submeasure. The results are based on the percentage of total projects for the 5-story mixed use (88 percent) and 10-story mixed use (90.8 percent) prototypes with individual mechanical cooling systems (see Table 171).

Table 173: Estimated New Construction and Existing Building Stock for Multifamily Buildings by Climate Zone for the Refrigerant Charge Verification Submeasure

Building Climate Zone	New Construction in 2023 (dwelling units)			Existing Building Stock in 2023 (dwelling units)		
	Total Dwelling Units Completed in 2023 [A]	Percent of New Dwelling Units Impacted by Proposal [B]	Dwelling Units Impacted by Proposal in 2023 C = A x B	Total Existing Dwelling Units in 2023 [D]	Percent of New Dwelling Units Impacted by Proposal [E]	Dwelling Units Impacted by Proposal in 2023 F = D x E
1	265	0.0%	0	17,126	0.00%	0
2	1,573	55.6%	875	101,721	1.88%	1,914
3	7,630	0.0%	0	530,089	0.00%	0
4	3,975	0.0%	0	278,535	0.00%	0
5	706	0.0%	0	44,816	0.00%	0
6	3,370	0.0%	0	315,784	0.00%	0
7	3,623	0.0%	0	291,804	0.00%	0
8	4,738	55.6%	2,634	489,337	1.88%	9,207
9	11,124	55.6%	6,185	1,086,699	1.88%	20,447
10	3,930	55.6%	2,185	316,384	1.88%	5,953
11	1,122	55.6%	624	81,820	1.88%	1,539
12	6,335	55.6%	3,522	455,265	1.88%	8,566
13	1,849	55.6%	1,028	154,048	1.88%	2,898
14	840	55.6%	467	79,142	1.88%	1,489
15	547	55.6%	304	40,033	1.88%	753
16	339	0.0%	0	27,505	0.00%	0
TOTAL	51,966		17,825	4,310,108		52,766

Appendix B: Embedded Electricity in Water Methodology

There are no on-site water savings associated with the proposed code change.

Appendix C: Environmental Impacts Methodology

Greenhouse Gas (GHG) Emissions Factors

As directed by Energy Commission staff, GHG emissions were calculated making use of the average emissions factors specified in the U.S. EPA eGRID for the WECC CAMX subregion (United States Environmental Protection Agency 2018). This ensures consistency between state and federal estimations of potential environmental impacts. The electricity emissions factor calculated from the eGRID data is 240.4 metric tons CO2e per GWh. The summary table from eGrid 2016 reports an average emission rate of 529.9 pounds CO2e/MWh for the WECC CAMX subregion. This value was converted to metric tons/GWh.

Avoided GHG emissions from natural gas savings attributable to sources other than utility-scale electrical power generation are calculated using emissions factors specified in Chapter 1.4 of the U.S. EPA's Compilation of Air Pollutant Emissions Factors (AP-42) (United States Environmental Protection Agency 1995). The U.S. EPA's estimates of GHG pollutants that are emitted during combustion of one million standard cubic feet of natural gas are: 120,000 pounds of CO_2 (Carbon Dioxide), 0.64 pounds of N_2O (Nitrous Oxide), and 2.3 pounds of CH_4 (Methane). The emission value for N_2O assumed that low NOx burners are used in accordance with California air pollution control requirements. The carbon equivalent values of N_2O and CH_4 were calculated by multiplying by the global warming potentials (GWP) that the California Air Resources Board used for the 2000-2016 GHG emission inventory, which are consistent with the 100-year GWPs that the Intergovernmental Panel on Climate Change used in the fourth assessment report (AR4). The GWP for N_2O and CH_4 are 298 and 25, respectively. Using a nominal value of 1,000 Btu per standard cubic foot of natural gas, the carbon equivalent emission factor for natural gas consumption is 5,454.4 metric tons per MMTherms.

GHG Emissions Monetization Methodology

The 2022 TDV energy cost factors used in the lifecycle cost-effectiveness analysis include the monetary value of avoided GHG emissions based on a proxy for permit costs (not social costs). To demonstrate the cost savings of avoided GHG emissions, the Statewide CASE Team disaggregated the value of avoided GHG emissions from the other economic impacts. The authors used the same monetary values that are used in the TDV factors – $106/metric tons CO_2e.

Water Use and Water Quality Impacts Methodology

There are no impacts to water quality or water use.

Appendix D: CBECC Software Specification

Introduction

The purpose of this appendix is to present proposed revisions to CBECC for multifamily buildings (CBECC- Com/Res) along with the supporting documentation that the Energy Commission staff, and the technical support contractors would need to approve and implement the software revisions.

Technical Basis for Software Change

Currently, code compliance analysis for multifamily buildings is fragmented into two software tools, CBECC-Res and CBECC-Com, based on whether the building is considered low-rise or high-rise and whether there are any nonresidential spaces within the building. This approach is problematic for building designers, energy modelers and building officials because it:

1. Negatively impacts compliance verification.
   a. Separate residential and nonresidential software encourage separation of residential and nonresidential spaces, creating a more complex compliance verification pathway. This makes it hard to develop a whole building model for the multifamily building.
   b. Authorities having jurisdiction must review compliance documents from both software tools for most multifamily buildings.
2. Places a burden on energy modelers.
   a. Energy modelers need to be fluent in two software programs that are based on different simulation engines, have differing capabilities, and use different rulesets. Mixed-use buildings are increasingly common in urban/suburban developments, and this duopoly creates extra complexity for modelers to ensure that proper efficiency features are implemented correctly. Additional billable hours spent increases the cost to the customer.
   b. The input requirements, quality control procedures, and output verification processes are different between CBECC-Res and CBECC-Com, resulting in lost productivity.
3. Creates inconsistent results.
   a. The underlying simulation engines and rulesets differ between CBECC-Res and CBECC-Com, allowing identical building features to have different compliance results from one software to the other. For example, for a mixed-use low-rise multifamily building, the modeler currently needs to analyze the

residential portions using CBECC-Res while the nonresidential portions need to be modeled in CBECC-Com or other commercial building compliance software. The same set of measures if installed in a mid-rise multifamily or high-rise multifamily can be analyzed using CBECC-Com for both the residential and nonresidential portions but the energy results for the residential portion may not match those for the low-rise CBECC-Res model.

These issues create an unequitable situation specifically for multifamily buildings which are an increasing share of residential new construction in the state. Over the past four years, the Statewide CASE Team has conducted several symposia[11] related to improvements needed to the compliance software that have identified the need for streamlined energy modeling that addresses the needs of energy efficiency programs, rating entities, designers, regulatory entities, and software developers.

Description of Software Change

To achieve equitable treatment across all multifamily building types as well as whole-building compliance, the Statewide CASE Team requests movement away from a two-software system whereby low-rise multifamily buildings are modeled in CBECC-Res and high-rise multifamily buildings are modeled in CBECC-Com. An equitable and lasting solution is to develop a single software solution for all multifamily buildings whereby all building features and systems are modeled in one tool regardless of whether the building is considered low-rise, mid-rise, or high-rise and regardless of whether there are residential and nonresidential occupancies within the same building.

Summary of Proposed Revisions to CBECC Com and/or CBECC-Res

The Statewide CASE Team recommends that the multifamily compliance modeling tool achieve at a minimum the following:

- Model dwelling unit, common area, and nonresidential spaces accurately to their code requirement(s).
- **Produce a single compliance output** with whole building energy results including dwelling unit, common area, and nonresidential spaces combined. Whole building compliance will allow trade-offs between residential, common area, and nonresidential spaces to maximize flexibility that accommodates for the high variability across multifamily buildings. Additionally, a single compliance document where the results are documented will assist in ease of compliance.
- **Incorporate HERS measures and pair with the HERS registry**. This includes

[11] https://calbem.ibpsa.us/archive/

application of HERS measures to high-rise buildings.

- Include PV and battery storage.
- **Include an Energy Design Rating** for single family and low-rise multifamily code compliance as well as above-code incentive programs.
- **Model individual and central ventilation systems** serving multiple dwelling units and/or common area and nonresidential spaces.
- **Model individual and central space conditioning systems** serving multiple dwelling units and/or common area and nonresidential spaces.
- **Model individual duct distribution systems** including the impacts of duct insulation and duct leakage.
- **Model individual and central water heating systems** serving dwelling units and common area and/or nonresidential spaces.
- **Model central heat pump water heating** for domestic hot water and space conditioning.
- **Address attics, crawlspaces,** and other special features modeled currently within CBECC-Res only.
- **Model heat recovery systems** including drain water heat recovery, heat recovery chillers, and water loop heat pumps**.**
- Incorporate parking garages, including fans.
- **Address unconditioned and partially conditioned spaces** and their impact on load gains/losses to conditioned spaces.
- **Model lighting** for residential, common area, and nonresidential spaces.

Appendix E: Impacts of Compliance Process on Market Actors

This appendix discusses how the recommended compliance process, which is described in Section 2.5, could impact various market actors. Table 174 and Table 175 identify 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. The information contained are summaries of key feedback the Statewide CASE Team received when speaking to market actors about the compliance implications of the proposed multifamily restructuring. Appendix F summarizes the stakeholder engagement that the Statewide CASE Team conducted when developing and refining the code change proposal, including gathering information on the compliance process.

The proposed multifamily restructuring measure would simplify understanding and enforcement of requirements for multifamily buildings. Generally speaking, the workflow and tasks of market actors would remain the same, as well as coordination between market actors. Because the proposed multifamily chapters include residential and nonresidential requirements that already apply to multifamily buildings, market actors will not require new skills, training, or resources. The proposed restructuring would result in consolidated documentation that will be familiar but different from current documentation.

Table 174: Roles of Market Actors in the Proposed Compliance Process – Envelope Submeasures

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
Energy Consultant	• Identify relevant requirements and/or compliance path options. • Coordinate with other team members on requirements. • Complete compliance documents for permit application.	• Ensure energy code is met by clients. • Streamline coordination with other team members. • Provide proper documentation.	Additional communication required with design team to ensure they are aware of requirements.	Availability of training for architects and designers on importance of accurate and available thermal envelope details being on construction plans.
Architect/ Designer	• Be aware of energy code requirements, particularly mandatory minimums, NAFS Performance Class, and exterior wall fire-rating. • Specify products and construction assemblies that meet energy code. • Coordinate with other team members, especially the Energy Consultant, on requirements. • Document energy efficiency specifications, and related details such as use of Performance Class AW windows, exterior wall fire ratings, on building plans and schedules.	• Provide accurate documentation of code compliance. • Streamline coordination with other team members. • Clearly communicate required energy efficiency requirement details for construction assemblies. • Ensure procurement team has the information necessary to fulfill energy requirements.	Additional time to document and communicate NAFS Performance Class (when AW) and exterior wall fire-rating.	• Availability of training on importance of accurate and available thermal envelope details being on construction plans. • Availability of NAFS Performance Class ratings listed within NFRC database.

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
Plans Examiner	• Be aware of differentiation within energy code for Performance Class AW windows and exterior wall fire-rating. • Locate Performance Class AW and exterior wall fire ratings on plans and confirm accurate representation in compliance documentation.	• Quickly and easily determine requirements based on scope. • Quickly and easily determine if plans/specs match documents. • Quickly and easily determine if Compliance documents meet requirements. • Quickly and easily provide correction comments that would resolve issue.	Additional time to verify Performance Class AW windows and exterior wall fire ratings are addressed in design documents and compliance documents.	• Availability of training materials on Performance Class AW windows and exterior wall fire-ratings. • Availability of training materials on locating Performance Class AW windows and exterior wall fire-rating indicators on building plans and specification sheets.
Building Inspector	• Be aware of differentiation within energy code for Performance Class AW windows and exterior wall fire-rating.	• Quickly and easily determine if installed products and construction assemblies match compliance documents.	Additional time to verify Performance Class AW windows and exterior wall fire-rating.	Availability of training materials on how to fine and interpret Performance Class AW window indicators and determine a building's exterior wall fire-rating.

Table 175: Roles of Market Actors in the Proposed Compliance Process – Space Conditioning Submeasures

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
Energy Consultant	• Identify relevant requirements and/or compliance path options. • Coordinate with other team members on requirements. • Complete compliance documents for permit application.	Meet compliance requirements easily for Client.	Additional communication required with design team to ensure they are aware of requirements.	Availability of training for HVAC designers and contractors to educate them on the new requirements.

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
HVAC Designer	• Coordinate with the energy consultant. • Select equipment and design system to meet requirements. • Incorporate relevant requirements into design documents.	• Quickly and easily determine requirements based on scope and meet schedule. • Demonstrate compliance with code requirements. • Minimize costs for Client • Streamline coordination with other team members.	Additional code requirements to verify are met during design development.	Easy reference document that describe what requirements apply based on scope of work.
HVAC Contractors	• Review design documents and understand relevant requirements. • Install HVAC systems to meet requirements. • Coordination with project team.	• Quickly and easily determine requirements based on scope and meet schedule. • Demonstrate compliance with code requirements. • Streamline coordination with other team members. • Clearly communicate system requirements to installation crew. • Complete compliance documents required for permit sign-off.	May need to spend additional time during installation to ensure systems meet requirements.	• Easy reference document that describe what requirements apply based on scope of work • Proposal applies existing requirements and compliance documents as for low-rise multifamily buildings and therefore many contractors will already be familiar with the process.
HERS Rater (for multifamily building three stories and fewer)	• Perform required testing to confirm compliance. • Verify performance meets code requirements. • Coordinate with HVAC contractor.	• Demonstrate compliance by ensuring calculations on compliance documents meet testing requirements in code. • Recommend potential fixes in case requirements are not met.	Impact is expanded portfolio of projects.	N/A

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/ Plans Examiners	• Understand code requirement and confirm data on documents is compliant. • Confirm Certificates of Installation and Certificates of Verification confirm compliance. • Provide correction comments as necessary.	• Quickly and easily determine requirements based on scope. • Quickly and easily determine if plans/specs match documents. • Quickly and easily determine if Compliance documents meet requirements. • Quickly and easily provide correction comments that would resolve issue.	Additional time to verify new requirements are addressed in design documents and compliance documents.	Proposal applies existing requirements and compliance documents as for low-rise multifamily buildings and therefore building department staff will already be familiar with the process.

Appendix F: Summary of Stakeholder Engagement

Collaborating with stakeholders that might be impacted by proposed changes is a critical aspect of the Statewide CASE Team's efforts. The Statewide CASE Team aims to work with interested parties to identify and address issues associated with the proposed code changes so that the proposals presented to the Energy Commission in this Draft CASE Report are generally supported. Public stakeholders provide valuable feedback on draft analyses and help identify and address challenges to adoption including cost effectiveness; market barriers; technical barriers; compliance and enforcement challenges; or potential impacts on human health or the environment. Some stakeholders also provide data that the Statewide CASE Team uses to support analyses.

This appendix summarizes the stakeholder engagement that the Statewide CASE Team conducted when developing and refining the recommendations presented in this report.

Utility-Sponsored Stakeholder Meetings

Utility-sponsored stakeholder meetings provide an opportunity to learn about the Statewide CASE Team's role in the advocacy effort and to hear about specific code change proposals that the Statewide CASE Team is pursuing for the 2022 code cycle. The goal of stakeholder meetings is to solicit input on proposals from stakeholders early enough to ensure the proposals and the supporting analyses are vetted and have as few outstanding issues as possible. To provide transparency in what the Statewide CASE Team is considering for code change proposals, during these meetings the Statewide CASE Team asks for feedback on:

- Proposed code changes
- Draft code language
- Draft assumptions and results for analyses
- Data to support assumptions
- Compliance and enforcement
- Technical and market feasibility

The Statewide CASE Team hosted five stakeholder meetings, via webinar, touching on topics included in the Multifamily Restructuring CASE Report. Please see below for dates and links to event pages on Title24Stakeholders.com. Materials from each meeting. Such as slide presentations, proposal summaries with code language, and meeting notes, are included in the bibliography section of this report. (Statewide Utility Codes and Standards Team 2020)

Meeting Name	Meeting Date	Event Page from Title24stakeholders.com
Utility-Sponsored Stakeholder Meeting on Multifamily Topics – 1st Occurrence	February 8, 2019	https://title24stakeholders.com/event/utility-sponsored-stakeholder-meeting-on-multifamily-topics/
Utility-Sponsored Stakeholder Meeting on Multifamily Topics – 2nd Occurrence	February 25, 2019	https://title24stakeholders.com/event/utility-sponsored-stakeholder-meeting-on-multifamily-topics-2/
First Round of Multifamily HVAC and Envelope Utility-Sponsored Stakeholder Meeting	August 22, 2019	https://title24stakeholders.com/event/multifamily-hvac-and-envelope-utility-sponsored-stakeholder-meeting/
Second Round of Multifamily HVAC and Envelope Utility-Sponsored Stakeholder Meeting	March 25, 2020	https://title24stakeholders.com/event/multifamily-hvac-and-envelope-utility-sponsored-stakeholder-meeting-2/
Multifamily Chapter Restructuring Utility-Sponsored Stakeholder Meeting	May 7, 2020	https://title24stakeholders.com/event/multifamily-chapter-restructuring-utility-sponsored-stakeholder-meeting/

The first round of utility-sponsored stakeholder meetings occurred from February to November 2019, and they were important for providing transparency and an early forum for stakeholders to offer feedback on measures being pursued by the Statewide CASE Team. The objectives of the first round of stakeholder meetings were to solicit input on the scope of the 2022 code cycle proposals; request data and feedback on the specific approaches, assumptions, and methodologies for the energy impacts and cost-effectiveness analyses; and understand potential technical and market barriers. The Statewide CASE Team also presented initial draft code language for stakeholders to review.

The second round of utility-sponsored stakeholder meetings occurred from January to May 2020 and provided updated details on proposed code changes. The second round of meetings introduced early results and solicited feedback on refined draft code language.

Utility-sponsored stakeholder meetings were open to the public. For each stakeholder meeting, two promotional emails were distributed from info@title24stakeholders.com One email was sent to the entire Title 24 Stakeholders listserv, totaling over 1,900 individuals, and a second email was sent to a targeted list of individuals on the listserv depending on their subscription preferences. The Title 24 Stakeholders' website listserv is an opt-in service and includes individuals from a wide variety of industries and trades, including manufacturers, advocacy groups, local government, and building and energy professionals. Each meeting was posted on the Title 24 Stakeholders' LinkedIn page[12] (and cross-promoted on the Energy Commission LinkedIn page) two weeks before each meeting to reach out to individuals and larger organizations and channels outside of the listserv. The Statewide CASE Team conducted extensive personal outreach to stakeholders identified in initial work plans who had not yet opted into the listserv. Exported webinar meeting data captured attendance numbers and individual comments and recorded outcomes of live attendee polls to evaluate stakeholder participation and support.

Statewide CASE Team Communications

The Statewide CASE Team held personal communications over email and phone with numerous stakeholders when developing this report. These stakeholders are listed in Table 176.

Table 176: List of Stakeholders

Organization	Person	Role
1 Earth, Inc.	Stanford Rollins	Advocate
2050 Partners	Garth Torvestad	Consultant
2050 Partners	Gypsy Achong	Consultant
2050 Partners	John Bade	Consultant
AEA	Nick Young	Consultant
Amaro Construction	Allen Amaro	Contractor
Andersen Windows	Drew Pavlacky	Manufacturer
Andersen Windows	Mark Mikkelson	Manufacturer
Aronic	Chris Giovannielli	Manufacturer
Aronic	Greg McKenna	Manufacturer
Atlas Mechanical	TJ Stewart	Engineer
Beyond Efficiency	Dan Johnson	Engineer
Beyond Efficiency	Peter Grant	Engineer
Birch Point Consulting	Thomas Culp	Consultant
BJ Heating & Air Conditioning	Matt Holleron	Installer
Bright Green Energy	Patti Heath	Consultant
Bright Green Strategies	Peter Kennedy	Consultant
Bright Green Strategies	Sharon Block	Consultant
Brummit Engineering	Hans Marsman	Consultant, Designer
Building Material Distributor – Millwork Division	Matthew Delaney	Distributor
CalCERTS	Charlie Bachand	Advocate

[12] Title 24 Stakeholders' LinkedIn page can be found here: https://www.linkedin.com/showcase/title-24-stakeholders/

Organization	Person	Role
CalCERTS	Roy Eads	Advocate
CalCERTS	Russ King	Advocate
California Association of Sheet Metal and Air Conditioning Contractors National Association	Christopher J. Walker	Contractor
California Association of Sheet Metal and Air Conditioning Contractors National Association	Veronica Darrach	Contractor
California Association of Sheet Metal and Air Conditioning Contractors National Association	Eli Howard	Contractor
Chit Wood Energy	Rick Chitwood	Engineer
City of Davis	Greg Mahoney	Regulatory
Cool Machines Inc.	Dave Krendl	Manufacturer
CTCAC State Treasurer	Gina Ferguson	Regulatory
E3 California	Tommy Young	Consultant
Efficiency First California	Charley Cormany	Advocate
Enercomp, Inc.	Ken Nittler	Manufacturer
Energy 350	Meg Waltner	Consultant
Environmental Protection Agency	Rebecca Hudson	Regulatory
Environmental Protection Agency	Dean Gamble	Regulatory
Fard	Avery Colter	Consultant
Gabel Energy	Gina Rodda	Consultant
Gilleran Energy	Kevin Gilleran	Consultant
Guttmann & Blaevoet	Ted Tiffany	Consultant
Harris & Sloan	Shawn Mayer	Consultant
Harris & Sloan	Abe Cubano	Consultant
Hassler Heating	Rahsaan Whitney	Manufacturer
Knauf Insulation	David W. Ware	Manufacturer
LDI Mechanical	Edgar Flores	Contractor
LDI Mechanical	Luis Garcia	Contractor
Litzenberger Engineering	Shane Litzenberger	Engineer
Los Angeles Department of Water & Power	Jim Kemper	Regulatory
Lovazzano HVAC	Serbio Melgar	Contractor
McHugh Energy consultants Inc.	Jon McHugh, PE	Consultant
MI Windows and Doors	Ray Garries	Manufacturer
Morrison Hershfield	Patrick Roppel, P. Eng., M.A. Sc	Engineer
New Building Institute	Sean Denniston	Advocate
New York Energy Research and Development Authority (NYSERDA) Multifamily Performance Program	Gwen McLaughlin (TRC, as program administration)	Above Code Program
NORESCO	Nikhil Kapur	Contractor
North American Insulation Manufacturers Association	Rich Curt	Manufacturer
OJ Insulation LP	Griff Jenkins	Contractor

Organization	Person	Role
Pella Windows	Joe Hayden	Manufacturer
RDH Building Science Inc.	Michael Hsueh	Engineer
Red Car Analytics	Neil Bulger	Consultant
Resource Refocus	Vrushali Mendon	Consultant
Steven Winter Associates, Inc.	Gayathri Vijayakumar	Consultant
Strawn & Strawn	Steve Strawn	Manufacturer
Taylor Engineering	Steve Taylor	Consultant
Tommy Siu and Associates	Alina Carlson	Engineer
U.S. Green Building Council	Wes Sullens	Advocate
Valley Duct Testing	John Flores	HERS Rater, Consultant
VCA Green	Glen Folland	Consultant, Designer
VCA Green	Wayne Alldredge	Consultant, Designer
Villara Building Systems	Justin Sahota	Consultant
Wausau Window and Wall Systems	Steve Fronek	Manufacturer
WEST Lab	Jeff Baker	Manufacturer

Appendix G: Additional Details on Measure Analysis

Duct Insulation

The Statewide CASE Team evaluated duct insulation requirement for ducts in conditioned space and ducts in unconditioned space. The initial proposal was to create three new categories for duct insulation based on duct location leveraging current requirements in both the low-rise residential and nonresidential sections of code. This change would have required mandatory R-4.2 duct insulation for HERS verified low leakage ducts within conditioned space, R-6 insulation for all other ducts within conditioned space, and R-8 insulation for ducts in unconditioned space; prescriptive duct insulation requirements would be eliminated.

This would have separately impacted multifamily buildings up to three habitable stories and multifamily buildings four habitable stories and greater with individual duct systems serving the dwelling units. For multifamily buildings up to three habitable stories, the change would have increased mandatory duct insulation requirements from R-6 to R-8 for ducts in unconditioned space. Existing prescriptive duct requirements are already R-8 in all climate zones except 3 and 5 through 7. For multifamily building four habitable stories and greater, the change would have increased mandatory duct insulation requirements from R-4.2 to R-6 for ducts in conditioned space, unless verified as low leakage by a HERS Rater.

The cost effectiveness analysis did not justify the proposed changes described above and therefore the recommendation presented in this Draft CASE Report were altered. This section presents the results of the initial energy savings and cost-effectiveness analysis.

Energy Savings Methodology

There is an existing Title 24, Part 6 requirement that covers ductwork installed in all multifamily buildings and applies to both new construction and alterations, so the Standard Design is minimally compliant with the 2019 Title 24, Part 6 requirements. For ductwork in unconditioned space for multifamily buildings up to three habitable stories, the current mandatory and prescriptive requirement is R-6 duct insulation in Climate Zones 3 and 5 through 7. The prescriptive requirement in all other climate zones is R-8 duct insulation; therefore, there are no energy savings to evaluate.

For ductwork in conditioned space for multifamily buildings four habitable stories and greater the current mandatory requirement is R-4.2 duct insulation in all climate zones; there is no prescriptive requirement in the nonresidential code.

Table 177 presents precisely which parameters were modified and what values were used in the Standard Design and Proposed Design. Specifically, for the component of this submeasure that impacts ducts in unconditioned space the proposed conditions assume R-8 ductwork in a vented attic. For the component of this submeasure that impacts ducts in conditioned space, the energy impacts cannot be modeled in CBECC-Com using the 5-story and 10-story prototypes, because CBECC-Com does not currently include a duct model and neither thermal nor leakage impacts of ducts are considered.

CBECC-Res has a detailed duct system model; however, it does not evaluate thermal losses of ductwork within conditioned space. To simulate the conditions of an indirectly conditioned dropped soffit, where ducts are typically located in multifamily buildings, the unvented attic model was used. To isolate the unvented attic from exterior conditions high levels of insulation were added at the roof level, insulation was removed at the ceiling level, and the roof was modeled with perfect solar reflectance and emissivity. Temperature conditions within the unvented attic were reviewed for the base model in Climate Zone 12. It was found that the maximum temperature difference between the unvented attic and the zone below was 6°F and the average temperature difference was less than 1°F. Based on these results, the Statewide CASE Team concluded this was a reasonable approach to modeling this scenario.

Results from the loaded 3-story loaded corridor prototype were calculated on a per dwelling unit basis and applied to the 5-story and 10-story prototypes.

Table 177: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change for Duct Insulation Based on Initial Proposal

Prototype ID	Climate Zone	Software	Parameter Name	Standard Design Parameter Value	Proposed Design Parameter Value
2-story garden style & 3-story loaded corridor (with vented attic)	3, 5-7	CBECC-Res	2nd Floor - Distribution System - Type	Ducts located in attic (Ventilated)	Ducts located in attic (Ventilated)
			2nd Floor - Distribution System - Duct Insulation R-value	R-6	R-8
3-story loaded corridor as proxy for 5-story & 10-story mixed-use	All	CBECC-Res	Distribution System - Type	Ducts located in attic (Unventilated)	Ducts located in attic (Unventilated)
			Distribution System - Duct Insulation R-value	R-4.2	R-6
			Attic – Sol. Reflectance	1	1
			Attic – IR Emittance	1	1
			Attic Roof Cons. U-factor (cavity R-value)	0.029 (R-60)	0.029 (R-60)

Incremental First Cost and Replacement Costs

Incremental costs for this measure reflect the incremental cost for material for additional duct insulation. Costs are presented in Table 178. There are no incremental labor costs associated with this measure.

Duct insulation costs were collected from online product research and are based on average costs for four-inch, six-inch, and eight-inch flexible duct. A cost of $0.33 and $0.71 per linear foot of ductwork is estimated for the conditioned duct measure (R-6 versus R-4.2) and the unconditioned duct measure (R-8 versus R-6), respectively.

Table 178: First Cost Summary for Duct Insulation

Cost component	Cost per Linear Foot of Duct – R-6 vs. R-4.2	Cost per Linear Foot of Duct – R-8 vs. R-6
Material	$0.33	$0.71
Labor	$0.00	$0.00
Total Incremental First Cost	$0.33	$0.71

It is expected that the duct system would need to be replaced over the 30-year period of analysis at year 20. The present value of the replacement cost at year 20 is calculated and based on the incremental first cost. At the end of the 30-year period of analysis, there are 10 years of useful life remaining for the duct system. The value of this is calculated and subtracted from the total present value of the cost of the system. The total present value of the incremental cost for this code change proposal are presented in Table 179. There is no difference in regular maintenance between the two system types.

Table 179: Duct Insulation Summary of Replacement Cost

	Cost per Linear Foot of Duct – R-6 vs. R-4.2	Cost per Linear Foot of Duct – R-8 vs. R-6
Incremental First Cost	$0.33	$0.71
Present Value of Replacement Cost at Year 20	$0.18	$0.39
Present Value of Remaining Useful Life at Year 30	($0.07)	($0.15)
Total Present Value of Incremental Cost	$0.44	$0.96

Cost Effectiveness

Results of the per-unit cost-effectiveness analyses are presented in Table 180 through Table 183 for new construction.

Table 180: 30-Year Cost-Effectiveness Summary Per 2-Story Garden Dwelling Unit – New Construction Duct Insulation

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savingsa (2023 PV$)	Costs Total Incremental PV Costsb (2023 PV$)	Benefit-to-Cost Ratio
1	N/A	N/A	N/A
2	N/A	N/A	N/A
3	$25	$62	0.40
4	N/A	N/A	N/A
5	$14	$62	0.22
6	$26	$62	0.42
7	$26	$62	0.42
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	N/A	N/A	N/A
12	N/A	N/A	N/A
13	N/A	N/A	N/A
14	N/A	N/A	N/A
15	N/A	N/A	N/A
16	N/A	N/A	N/A

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 PV maintenance cost savings if PV of proposed maintenance costs is less than 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 and if PV of proposed maintenance costs is greater than 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 181: 30-Year Cost-Effectiveness Summary Per 3-Story Loaded Corridor Dwelling Unit – New Construction Duct Insulation

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	N/A	N/A	N/A
2	N/A	N/A	N/A
3	$21	$43	0.49
4	N/A	N/A	N/A
5	$12	$43	0.27
6	$33	$43	0.75
7	$34	$43	0.80
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	N/A	N/A	N/A
12	N/A	N/A	N/A
13	N/A	N/A	N/A
14	N/A	N/A	N/A
15	N/A	N/A	N/A
16	N/A	N/A	N/A

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 PV maintenance cost savings if PV of proposed maintenance costs is less than 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 and if PV of proposed maintenance costs is greater than 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 182: 30-Year Cost-Effectiveness Summary Per 5-Story Mixed-Use Dwelling Unit – New Construction Duct Insulation

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$75	$74	1.00
2	$51	$74	0.69
3	$32	$74	0.42
4	$60	$74	0.80
5	$28	$74	0.38
6	$27	$74	0.36
7	$23	$74	0.31
8	$28	$74	0.38
9	$35	$74	0.47
10	$43	$74	0.58
11	$70	$74	0.94
12	$58	$74	0.78
13	$63	$74	0.85
14	$73	$74	0.98
15	$48	$74	0.65
16	$71	$74	0.96

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 PV maintenance cost savings if PV of proposed maintenance costs is less than 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 and if PV of proposed maintenance costs is greater than 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 183: 30-Year Cost-Effectiveness Summary Per 10-Story Mixed-Use Dwelling Unit – New Construction Duct Insulation

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$71	$71	1.00
2	$49	$71	0.69
3	$30	$71	0.42
4	$57	$71	0.80
5	$27	$71	0.38
6	$25	$71	0.36
7	$22	$71	0.31
8	$27	$71	0.38
9	$33	$71	0.47
10	$41	$71	0.58
11	$66	$71	0.94
12	$55	$71	0.78
13	$60	$71	0.85
14	$69	$71	0.98
15	$46	$71	0.65
16	$68	$71	0.96

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 PV maintenance cost savings if PV of proposed maintenance costs is less than 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 and if PV of proposed maintenance costs is greater than 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.

Appendix H: Nominal Savings Tables

Building Envelope

Submeasure A: Envelope – Roof Assemblies

Table 184: Nominal TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit– New Construction – Roof Assembly Change, 2-Story Prototype Building

Climate Zone	30-Year TDV Electricity Cost Savings (Nominal PV$)	30-Year TDV Natural Gas Cost Savings (Nominal PV$)	Total 30-Year TDV Energy Cost Savings (Nominal PV$)
1	($3)	($78)	($81)
2	$7	$3	$10
3	($116)	($24)	($139)
4	($170)	$61	($109)
5	($44)	($41)	($85)
6	($201)	($7)	($208)
7	($238)	($27)	($265)
8	$191	$7	$197
9	$1,038	($146)	$893
10	$1,001	($186)	$815
11	$1,280	($373)	$907
12	$102	($98)	$4
13	($259)	($119)	($377)
14	$936	($478)	$459
15	($541)	($17)	($558)
16	$10	($88)	($78)

Table 185: Nominal TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit– New Construction – Roof Assembly Change, 3-Story Prototype Building

Climate Zone	30-Year TDV Electricity Cost Savings (Nominal PV$)	30-Year TDV Natural Gas Cost Savings (Nominal PV$)	Total 30-Year TDV Energy Cost Savings (Nominal PV$)
1	($71)	($467)	($538)
2	$205	($274)	($70)
3	($55)	($129)	($185)
4	($71)	($98)	($169)
5	($67)	($137)	($204)
6	($142)	($24)	($165)
7	($232)	($12)	($244)
8	$398	($16)	$382
9	$981	($90)	$891
10	$981	($161)	$820
11	$1,092	($431)	$660
12	$256	($302)	($46)
13	($402)	($302)	($704)
14	$745	($478)	$266
15	($828)	($16)	($843)
16	($51)	($596)	($647)

Table 186: Nominal TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit– New Construction – Low-Slope Increase to 0.63 ASR, 5-Story Prototype Building

Climate Zone	30-Year TDV Electricity Cost Savings (Nominal PV$)	30-Year TDV Natural Gas Cost Savings (Nominal PV$)	Total 30-Year TDV Energy Cost Savings (Nominal PV$)
1	N/A	N/A	N/A
2	N/A	N/A	N/A
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	N/A	N/A	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	N/A	N/A	N/A
9	$93	($8)	$85
10	$90	($10)	$80
11	$79	($15)	$64
12	N/A	N/A	N/A
13	$87	($22)	$65
14	$81	($20)	$61
15	$109	($6)	$103
16	N/A	N/A	N/A

Table 187: Nominal TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit– New Construction – Low-Slope Increase to 0.63 ASR, 10-Story Prototype Building

Climate Zone	30-Year TDV Electricity Cost Savings (Nominal PV$)	30-Year TDV Natural Gas Cost Savings (Nominal PV$)	Total 30-Year TDV Energy Cost Savings (Nominal PV$)
1	N/A	N/A	N/A
2	N/A	N/A	N/A
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	N/A	N/A	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	N/A	N/A	N/A
9	$38	($3)	$35
10	$37	($4)	$33
11	$31	($5)	$25
12	N/A	N/A	N/A
13	$36	($8)	$28
14	$34	($6)	$28
15	$43	($2)	$41
16	N/A	N/A	N/A

Table 188: Nominal TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit– New Construction – Roof/Ceiling Insulation, 2-Story Prototype Building

Climate Zone	30-Year TDV Electricity Cost Savings (Nominal PV$)	30-Year TDV Natural Gas Cost Savings (Nominal PV$)	Total 30-Year TDV Energy Cost Savings (Nominal PV$)
1	$65	($2,395)	($2,331)
2	$705	($3,208)	($2,504)
3	$184	($3,361)	($3,177)
4	$667	($3,439)	($2,772)
5	$123	($3,720)	($3,597)
6	$283	($3,852)	($3,570)
7	$272	($3,608)	($3,336)
8	$1,297	($3,852)	($2,555)
9	$2,107	($4,106)	($1,999)
10	$2,193	($4,130)	($1,937)
11	$2,741	($3,625)	($884)
12	$1,226	($3,439)	($2,213)
13	$739	($3,534)	($2,795)
14	$2,404	($4,509)	($2,106)
15	$746	($4,140)	($3,395)
16	$426	($3,039)	($2,613)

Table 189: Nominal TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit– New Construction – Roof/Ceiling Insulation, 3-Story Prototype Building

Climate Zone	30-Year TDV Electricity Cost Savings (Nominal PV$)	30-Year TDV Natural Gas Cost Savings (Nominal PV$)	Total 30-Year TDV Energy Cost Savings (Nominal PV$)
1	($87)	($510)	($596)
2	$205	($274)	($70)
3	($55)	($129)	($185)
4	($71)	($98)	($169)
5	($67)	($137)	($204)
6	($142)	($24)	($165)
7	($232)	($12)	($244)
8	$398	($16)	$382
9	$981	($90)	$891
10	$981	($161)	$820
11	$1,092	($431)	$660
12	$256	($302)	($46)
13	($402)	($302)	($704)
14	$745	($478)	$266
15	($828)	($16)	($843)
16	($32)	($651)	($682)

Submeasure B: Envelope – Wall U-Factor

Table 190: Nominal TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit– New Construction – Framed (Wood or Metal) and Others, ≤ 1 hr Fire Rating, 5-Story Prototype Building

Climate Zone	30-Year TDV Electricity Cost Savings (Nominal PV$)	30-Year TDV Natural Gas Cost Savings (Nominal PV$)	Total 30-Year TDV Energy Cost Savings (Nominal PV$)
1	$39	$210	$249
2	$85	$145	$230
3	$6	$96	$102
4	$58	$85	$143
5	($9)	$97	$88
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	$52	$36	$88
9	$58	$49	$107
10	$57	$69	$127
11	N/A	N/A	N/A
12	$133	$163	$296
13	$129	$105	$234
14	N/A	N/A	N/A
15	N/A	N/A	N/A
16	N/A	N/A	N/A

Submeasure C: Envelope – Quality Insulation Installation

Table 191: Nominal TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit– New Construction – 5-Story Mixed Use – QII

Climate Zone	30-Year TDV Electricity Cost Savings (Nominal PV$)	30-Year TDV Natural Gas Cost Savings (Nominal PV$)	Total 30-Year TDV Energy Cost Savings (Nominal PV$)
1	$106	$565	$671
2	$253	$420	$674
3	$164	$436	$600
4	$227	$296	$523
5	$155	$449	$604
6	$261	$343	$604
7	$53	$138	$191
8	$237	$188	$425
9	$244	$211	$455
10	$259	$236	$495
11	$263	$261	$524
12	$299	$362	$661
13	$368	$288	$656
14	$251	$256	$506
15	$369	$90	$459
16	$144	$440	$584

Table 192: Nominal TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit– New Construction – 3-Story – QII

Climate Zone	30-Year TDV Electricity Cost Savings (Nominal PV$)	30-Year TDV Natural Gas Cost Savings (Nominal PV$)	Total 30-Year TDV Energy Cost Savings (Nominal PV$)
1	($91)	($480)	($571)
2	($241)	($320)	($561)
3	($139)	($195)	($334)
4	($212)	($199)	($411)
5	($77)	($177)	($255)
6	($106)	($51)	($157)
7	($96)	($16)	($112)
8	($291)	($32)	($322)
9	($282)	($83)	($366)
10	($335)	($132)	($467)
11	($442)	($297)	($739)
12	($331)	($271)	($602)
13	($492)	($220)	($712)
14	($399)	($307)	($706)
15	($664)	($9)	($672)
16	($147)	($608)	($756)

Submeasure D: Envelope – Fenestration Properties

Table 193: Nominal TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit – New Construction – Curtainwall/Storefronts, 5-Story Prototype Building

Climate Zone	30-Year TDV Electricity Cost Savings (Nominal PV$)	30-Year TDV Natural Gas Cost Savings (Nominal PV$)	Total 30-Year TDV Energy Cost Savings (Nominal PV$)
1	($185)	$621	$437
2	N/A	N/A	N/A
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	N/A	N/A	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	N/A	N/A	N/A
12	N/A	N/A	N/A
13	N/A	N/A	N/A
14	N/A	N/A	N/A
15	N/A	N/A	N/A
16	$1	$350	$351

Table 194: Nominal TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit – New Construction - Curtainwall/Storefronts, 10-Story Prototype Building

Climate Zone	30-Year TDV Electricity Cost Savings (Nominal PV$)	30-Year TDV Natural Gas Cost Savings (Nominal PV$)	Total 30-Year TDV Energy Cost Savings (Nominal PV$)
1	($459)	$895	$436
2	N/A	N/A	N/A
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	N/A	N/A	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	N/A	N/A	N/A
12	N/A	N/A	N/A
13	N/A	N/A	N/A
14	N/A	N/A	N/A
15	N/A	N/A	N/A
16	($81)	$520	$439

Table 195: Nominal TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit – New Construction – Combined Category *Performance* Class *AW*, 5-Story Prototype Building

Climate Zone	30-Year TDV Electricity Cost Savings (Nominal PV$)	30-Year TDV Natural Gas Cost Savings (Nominal PV$)	Total 30-Year TDV Energy Cost Savings (Nominal PV$)
1	($191)	$764	$573
2	N/A	N/A	N/A
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	N/A	N/A	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	N/A	N/A	N/A
12	N/A	N/A	N/A
13	N/A	N/A	N/A
14	N/A	N/A	N/A
15	N/A	N/A	N/A
16	$10	$284	$294

Table 196: Nominal TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit – New Construction - Combined Category *Performance* Class *AW*, 10-Story Prototype Building

Climate Zone	30-Year TDV Electricity Cost Savings (Nominal PV$)	30-Year TDV Natural Gas Cost Savings (Nominal PV$)	Total 30-Year TDV Energy Cost Savings (Nominal PV$)
1	($511)	$1,047	$536
2	N/A	N/A	N/A
3	N/A	N/A	N/A
4	N/A	N/A	N/A
5	N/A	N/A	N/A
6	N/A	N/A	N/A
7	N/A	N/A	N/A
8	N/A	N/A	N/A
9	N/A	N/A	N/A
10	N/A	N/A	N/A
11	N/A	N/A	N/A
12	N/A	N/A	N/A
13	N/A	N/A	N/A
14	N/A	N/A	N/A
15	N/A	N/A	N/A
16	($28)	$413	$385

Table 197: Nominal TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit – New Construction - Combined Category *All Others*, 5-Story Prototype Building

Climate Zone	30-Year TDV Electricity Cost Savings (Nominal PV$)	30-Year TDV Natural Gas Cost Savings (Nominal PV$)	Total 30-Year TDV Energy Cost Savings (Nominal PV$)
1	($203)	$1,507	$1,303
2	$67	$534	$601
3	($61)	$383	$322
4	$43	$296	$339
5	($115)	$326	$211
6	($26)	$63	$37
7	($63)	$48	($15)
8	($33)	$115	$83
9	$13	$166	$178
10	$56	$228	$284
11	$275	$579	$854
12	$135	$480	$615
13	$276	$409	$685
14	$219	$514	$733
15	$413	$79	$492
16	$99	$1,288	$1,387

Table 198: Nominal TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit – New Construction - Combined Category *All Others*, 10-Story Prototype Building

Climate Zone	30-Year TDV Electricity Cost Savings (Nominal PV$)	30-Year TDV Natural Gas Cost Savings (Nominal PV$)	Total 30-Year TDV Energy Cost Savings (Nominal PV$)
1	($696)	$2,133	$1,437
2	$14	$812	$826
3	($190)	$596	$406
4	($12)	$443	$430
5	($286)	$494	$208
6	($69)	$97	$29
7	($114)	$85	($29)
8	($120)	$162	$42
9	($46)	$251	$205
10	$18	$328	$346
11	$365	$940	$1,305
12	$129	$750	$880
13	$367	$631	$998
14	$254	$759	$1,013
15	$602	$107	$709
16	($21)	$1,932	$1,911

Table 199: Nominal TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit – Alterations – Curtainwall/Storefronts, High-Rise Existing Prototype Building

Climate Zone	30-Year TDV Electricity Cost Savings (Nominal PV$)	30-Year TDV Natural Gas Cost Savings (Nominal PV$)	Total 30-Year TDV Energy Cost Savings (Nominal PV$)
1	$653	$756	$1,409
2	$530	$798	$1,328
3	$2,344	$813	$3,158
4	$617	$271	$888
5	$2,258	$789	$3,048
6	$423	$136	$558
7	$308	$110	$418
8	$566	$151	$717
9	$667	$183	$850
10	$699	$228	$928
11	$923	$771	$1,694
12	$648	$666	$1,313
13	$925	$555	$1,481
14	$962	$760	$1,723
15	$1,268	$111	$1,379
16	$2,385	$266	$2,650

Table 200: Nominal TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit– Alterations – Alterations Class AW Fixed, High-Rise Existing Prototype Building

Climate Zone	30-Year TDV Electricity Cost Savings (Nominal PV$)	30-Year TDV Natural Gas Cost Savings (Nominal PV$)	Total 30-Year TDV Energy Cost Savings (Nominal PV$)
1	$653	$756	$1,409
2	$530	$798	$1,328
3	$2,344	$813	$3,158
4	$527	$469	$995
5	$2,258	$789	$3,048
6	$423	$136	$558
7	$308	$110	$418
8	$566	$151	$717
9	$554	$311	$864
10	$613	$386	$999
11	$923	$771	$1,694
12	$648	$666	$1,313
13	$925	$555	$1,481
14	$962	$760	$1,723
15	$1,394	$182	$1,576
16	$2,385	$266	$2,650

Table 201: Nominal TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit– Alterations – Class AW Operable, High-Rise Existing Prototype Building

Climate Zone	30-Year TDV Electricity Cost Savings (Nominal PV$)	30-Year TDV Natural Gas Cost Savings (Nominal PV$)	Total 30-Year TDV Energy Cost Savings (Nominal PV$)
1	$620	($64)	$555
2	$796	$188	$984
3	$2,683	$330	$3,013
4	$877	$95	$972
5	$2,643	$339	$2,981
6	$797	$55	$851
7	$688	$43	$731
8	$893	$67	$960
9	$995	$73	$1,068
10	$999	$96	$1,095
11	$1,059	$182	$1,241
12	$900	$152	$1,052
13	$1,069	$110	$1,179
14	$1,180	$157	$1,337
15	$1,486	$51	$1,537
16	$2,569	($871)	$1,698

Table 202: Nominal TDV Energy Cost Savings Over 30-Year Period of Analysis – Per Dwelling Unit– Alterations – Combined All Others, High-Rise Existing Prototype Building

Climate Zone	30-Year TDV Electricity Cost Savings (Nominal PV$)	30-Year TDV Natural Gas Cost Savings (Nominal PV$)	Total 30-Year TDV Energy Cost Savings (Nominal PV$)
1	$656	$2,071	$2,727
2	$1,073	$1,526	$2,599
3	$2,591	$1,340	$3,930
4	$1,064	$900	$1,964
5	$2,448	$1,293	$3,741
6	$684	$309	$993
7	$440	$249	$689
8	$871	$466	$1,336
9	$1,116	$585	$1,701
10	$1,239	$729	$1,968
11	$1,857	$1,496	$3,354
12	$1,325	$1,282	$2,607
13	$1,885	$1,061	$2,946
14	$1,861	$1,441	$3,302
15	$2,778	$339	$3,117
16	$2,769	$1,624	$4,394

Submeasure E: Envelope – Fenestration Area

The Statewide CASE Team did not calculate energy cost savings for this submeasure because it has no energy savings impact.

Space Conditioning

Submeasure F: Space Conditioning – Duct Insulation

The Statewide CASE Team did not calculate energy cost savings for this submeasure because there do not increase stringency.

Submeasure G: Space Conditioning – Duct Leakage Testing

Per-unit energy cost savings for newly constructed buildings and alterations that are realized over the 30-year period of analysis are presented in nominal dollars in Table 203 and Table 204.

Table 203: Nominal TDV Energy Cost Savings Over 30-Year Period of Analysis – Per 5-Story Mixed-Use Dwelling Unit – New Construction Duct Leakage

Climate Zone	30-Year TDV Electricity Cost Savings (Nominal $)	30-Year TDV Natural Gas Cost Savings (Nominal $)	Total 30-Year TDV Energy Cost Savings (Nominal $)
1	$25	$61	$86
2	$204	$38	$242
3	$120	$23	$143
4	$245	$18	$263
5	$91	$20	$111
6	$205	$5	$210
7	$177	$4	$181
8	$282	$5	$287
9	$288	$8	$297
10	$302	$13	$315
11	$363	$43	$406
12	$290	$37	$327
13	$407	$31	$438
14	$343	$34	$377
15	$566	$3	$569
16	$137	$101	$237

Table 204: Nominal TDV Energy Cost Savings Over 30-Year Period of Analysis – Per 10-Story Mixed-Use Dwelling Unit – New Construction Duct Leakage

Climate Zone	30-Year TDV Electricity Cost Savings (Nominal $)	30-Year TDV Natural Gas Cost Savings (Nominal $)	Total 30-Year TDV Energy Cost Savings (Nominal $)
1	$27	$70	$97
2	$208	$41	$248
3	$126	$24	$150
4	$252	$18	$270
5	$98	$20	$118
6	$216	$4	$221
7	$187	$4	$191
8	$290	$5	$295
9	$300	$9	$308
10	$315	$14	$329
11	$384	$54	$438
12	$294	$41	$335
13	$418	$35	$452
14	$366	$41	$407
15	$596	$3	$599
16	$136	$127	$264

Table 205: Nominal TDV Energy Cost Savings Over 30-Year Period of Analysis – Per 10-Story Mixed-Use Dwelling Unit – Alteration Duct Leakage

Climate Zone	30-Year TDV Electricity Cost Savings (Nominal $)	30-Year TDV Natural Gas Cost Savings (Nominal $)	Total 30-Year TDV Energy Cost Savings (Nominal $)
1	$47	$200	$247
2	$234	$168	$402
3	$161	$116	$278
4	$278	$90	$368
5	$133	$105	$238
6	$224	$34	$258
7	$183	$25	$208
8	$323	$38	$360
9	$333	$52	$386
10	$355	$71	$426
11	$423	$187	$610
12	$327	$151	$478
13	$465	$127	$592
14	$402	$159	$560
15	$687	$27	$714
16	$174	$335	$509

Submeasure H: Space Conditioning – Space Cooling Airflow Rate and Fan Efficacy

Per-unit energy cost savings for newly constructed buildings and alterations that are realized over the 30-year period of analysis are presented in nominal dollars in Table 206 and Table 207.

Table 206: Nominal TDV Energy Cost Savings Over 30-Year Period of Analysis – Per 5-Story Mixed-Use Dwelling Unit– New Construction Cooling Coil Airflow and Fan Efficacy

Climate Zone	30-Year TDV Electricity Cost Savings (Nominal $)	30-Year TDV Natural Gas Cost Savings (Nominal $)	Total 30-Year TDV Energy Cost Savings (Nominal $)
1	$191	($64)	$127
2	$889	($57)	$832
3	$653	($26)	$627
4	$1,065	($23)	$1,042
5	$540	($22)	$518
6	$977	($7)	$970
7	$897	($4)	$893
8	$1,208	($7)	$1,201
9	$1,195	($11)	$1,184
10	$1,265	($18)	$1,246
11	$1,317	($70)	$1,247
12	$1,216	($62)	$1,153
13	$1,559	($53)	$1,506
14	$1,225	($47)	$1,178
15	$1,868	($4)	$1,864
16	$750	($182)	$568

Table 207: Nominal TDV Energy Cost Savings Over 30-Year Period of Analysis – Per 10-Story Mixed-Use Dwelling Unit – New Construction Cooling Coil Airflow and Fan Efficacy

Climate Zone	30-Year TDV Electricity Cost Savings (Nominal $)	30-Year TDV Natural Gas Cost Savings (Nominal $)	Total 30-Year TDV Energy Cost Savings (Nominal $)
1	$181	($54)	$127
2	$776	($45)	$731
3	$620	($19)	$600
4	$945	($17)	$928
5	$534	($15)	$519
6	$929	($3)	$926
7	$874	($3)	$871
8	$1,089	($4)	$1,085
9	$1,060	($7)	$1,053
10	$1,119	($14)	$1,104
11	$1,138	($65)	$1,073
12	$1,040	($51)	$989
13	$1,318	($41)	$1,277
14	$1,064	($41)	$1,023
15	$1,529	($2)	$1,527
16	$659	($148)	$511

Submeasure I: Space Conditioning – Refrigerant Charge Verification

Per-unit energy cost savings for newly constructed buildings that are realized over the 30-year period of analysis are presented in nominal dollars in Table 208 through Table 210.

Table 208: Nominal TDV Energy Cost Savings Over 30-Year Period of Analysis – Per 5-Story Mixed-Use Dwelling Unit– New Construction Refrigerant Charge

Climate Zone	30-Year TDV Electricity Cost Savings (Nominal $)	30-Year TDV Natural Gas Cost Savings (Nominal $)	Total 30-Year TDV Energy Cost Savings (Nominal $)
1	$32	$0	$32
2	$274	$0	$274
3	$192	$0	$192
4	$333	$0	$333
5	$158	$0	$158
6	$313	$0	$313
7	$288	$0	$288
8	$390	$0	$390
9	$397	$0	$397
10	$411	$0	$411
11	$477	$0	$477
12	$383	$0	$383
13	$525	$0	$525
14	$452	$0	$452
15	$750	$0	$750
16	$165	$0	$165

Table 209: Nominal TDV Energy Cost Savings Over 30-Year Period of Analysis – Per 10-Story Mixed-Use Dwelling Unit– New Construction Refrigerant Charge

Climate Zone	30-Year TDV Electricity Cost Savings (Nominal $)	30-Year TDV Natural Gas Cost Savings (Nominal $)	Total 30-Year TDV Energy Cost Savings (Nominal $)
1	$38	$0	$38
2	$245	$0	$245
3	$189	$0	$189
4	$300	$0	$300
5	$167	$0	$167
6	$304	$0	$304
7	$289	$0	$289
8	$358	$0	$358
9	$357	$0	$357
10	$368	$0	$368
11	$409	$0	$409
12	$330	$0	$330
13	$442	$0	$442
14	$398	$0	$398
15	$612	$0	$612
16	$161	$0	$161

Table 210: Nominal TDV Energy Cost Savings Over 30-Year Period of Analysis – Per 10-Story Mixed-Use Dwelling Unit – Alteration Refrigerant Charge

Climate Zone	30-Year TDV Electricity Cost Savings (Nominal $)	30-Year TDV Natural Gas Cost Savings (Nominal $)	Total 30-Year TDV Energy Cost Savings (Nominal $)
1	$51	$0	$51
2	$322	$0	$322
3	$227	$0	$227
4	$387	$0	$387
5	$180	$0	$180
6	$303	$0	$303
7	$244	$0	$244
8	$444	$0	$444
9	$458	$0	$458
10	$483	$0	$483
11	$573	$0	$573
12	$448	$0	$448
13	$638	$0	$638
14	$542	$0	$542
15	$946	$0	$946
16	$194	$0	$194

Appendix I: Marked Up Standards